REPORT ON PALAEOFIRES WORKSHOP
22-26 October 2007
Dartington Hall, Totnes, UK

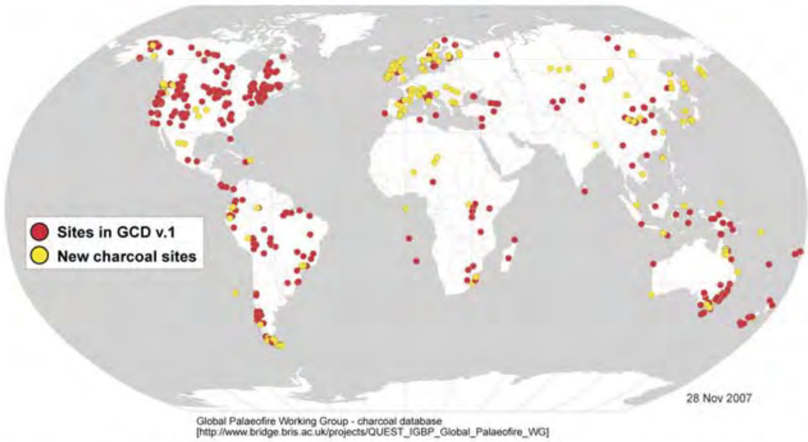
Motivation for Workshop

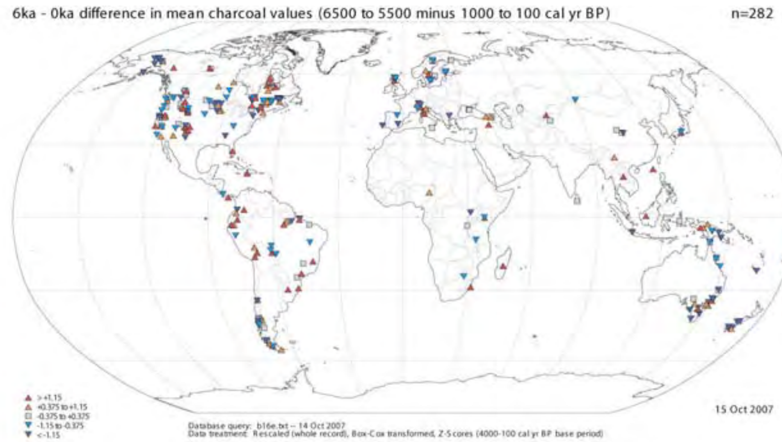
Late-Quaternary charcoal records provide a unique opportunity to evaluate the linkages among climate, vegetation and humans and to evaluate fire-related changes in the structure and functioning of ecosystems. Charcoal records also provide the opportunity to evaluate components of earth system models. Global palaeofire reconstructions combined with data on changing vegetation distribution can be used to evaluate state-of-the-art coupled vegetation-fire models. The first phase of the Global Palaeofire Working Group (GPWG), following the Dartington I workshop in October 2006, resulted in a reconstruction of global fire regimes since the Last Glacial Maximum (Power et al., in press) (figure 1). These efforts, combined with the strong scientific and organizational structure of the GPWG, have contributed to the rapid growth of the global charcoal database. Thus, as a result of this success and the growing interests by the international palaeofire community, including a palaeo-component of the new International Geosphere Biosphere Program (IGBP) cross-project FIRE activity (endorsed by the IGBP Scientific Steering Committee in March 2007) necessitated bringing together members of the GPWG and identify the state-of-the-art science in palaeofire research and to initiate four strands of the operational plan that utilize the Global Charcoal Database (GCD) as a research tool. The successful completion of our first global synthesis, reconstructing fire regimes since the Last Glacial Maximum, and the endorsement of over 90 international members of the GPWG highlighted the importance of arranging an organizational and scientific structure that will carry palaeofire science forward.

Workshop Achievements

1) The palaeofire workshop brought together 14 international experts on palaeofire science with different perspectives and investigative techniques for reconstructing late Quaternary fire histories (see Appendix A).

2) DATA COLLECTION. Prior to the workshop, workshop participants were responsible for identifying and collecting charcoal records from areas that remained underrepresented following the first phase of data synthesis. Data collection was not the major focus of this workshop as compared to the previous workshop, however, 114 new charcoal records were identified from key "gap" areas (e.g. Europe, Russia, eastern Asia) in the GCD. Discussion and analysis during the workshop examined a variety of "gaps" in the charcoal database, including the representation the Earth's climates and biomes by sites currently within the database. The number of charcoal records increased from 532 to 646 as a result of these efforts at the workshop with most sites occurring in warm temperate, boreal, and tropical forests.





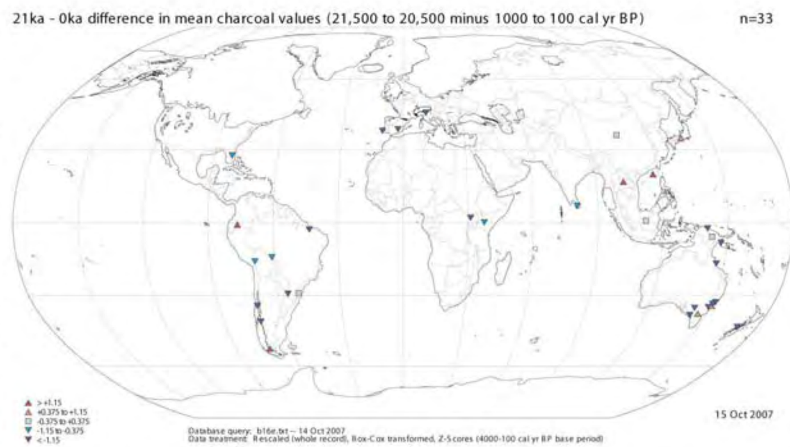


Figure 1: The global distribution of sites in the charcoal database (*above*), and 6 ka (6000 cal yr BP) minus present (0 ka) (*top right*) and 21 ka (21,000 cal yr BP) minus present (*bottom right*) charcoal abundance differences or anomalies. The number of sites has increased from 248 sites prior to the Dartington I workshop in October 2006, to 646 sites after the recent Dartington II workshop, October 2007. The distribution of red colored sites (*above*) represents the sites used in the first global synthesis (Power et al. *in press*) and yellow colored sites are those that have been added since the release of GCD v1. The number of sites shown represents a snapshot of a recent version of the database and is continuously changing as new records are contributed to the GCD.

The charcoal data used to create the charcoal anomaly maps (right) are heterogeneous, reflecting the range of laboratory and data-anaylytical methods used to describe charcoal abundance variations over time. Charcoal values contained within the GCD range over 13 orders of magnitude and required a standardization protocol for the recently published global syntheses and subsequent syntheses efforts. Individual records were analyzed by: (a) rescaling the whole record to range between 0.0 and 1.0; (b) rescaled values were then transformed using the Box-Cox transformation to approach normality where possible, where the transformation parameter estimated using maximum likelihood; (c) the transformed values were then standardized or converted to Z-Scores using the mean and standard deviation for each record over the interval from 4000 to 100 cal yr BP; (d) anomalies were calculated as the difference between the mean of Z-scores for the intervals 6500 to 5500 cal yr BP (*top*) or 21,500 to 20,500 cal yr BP (*bottom*) and those for the interval 1000 to 100 cal yr BP (not shown). The anomaly maps reveal increasing spatial heterogenity from 21 ka to 6 ka. For example, most records from 21 ka (n=33) show less-than-present charcoal abundances while at 6 ka (n=282), most records show considerable spatial heterogeneity (as expected considering the dual controls of fire by climate and vegetation). However, regional coherency occurs, for example, the mid-latitudes of South America and the temperate latitudes of northeastern North America show greater-than-present charcoal abundances at 6 ka. In comparison, the high latitudes at 6ka, including Australia, New Zealand and Alaska, show less-than-present charcoal.

3) DATA ANALYSES TECHNIQUES. The GCD currently contains 122 methods for quantifying charcoal records from around the globe. A major focus of Dartington I was to explore data analysis techniques that allow for comparing charcoal quantities that range over 13 orders of magnitude. These initial efforts were targeted at summarizing fire regimes since the LGM (Power et al., in press), but new approaches were required to facilitate new research directions. Building on this initial synthesis, appropriate analytical techniques were identified that can be used for comparing a variety of charcoal records with differing temporal resolution. For example, the GCD contains charcoal records with both high and low sampling resolution (e.g. one sample/decade versus one sample/century) and with short and long temporal resolution (e.g. one record spanning 20,000 years versus one record spanning 1000 years). Several participants at the workshop had recently developed analytical techniques for exploring charcoal data, including a variety of charcoal software packages (e.g. *CHAPS* - P.Bartlein, *CharAnalysis* - P.Higuera, *Charster* - D.Gavin). These techniques were presented and discussed by workshop participants and appropriate analytical methodologies were identified for new research agendas.

4) PROGRESSION OF PREVIOUS ANALYSES. Simulated changes in fire regimes at the Last Glacial Maximum (LGM: ca. 21,000 cal yr BP) and during the mid-Holocene (MH: ca. 6000 cal yr BP) were presented at the workshop. These simulations were made with the LPJ-SPITFIRE model (Thonicke et al., in press), driven by an ensemble average of climate output from coupled ocean-atmosphere general circulation models participating in the Palaeoclimate Modelling Intercomparison Project. Diagnosis of the simulated fire regimes at the workshop showed that there are still some issues about dealing with changes in lightning-strikes in palaeo-mode before definitive simulations can be achieved and analysed. It is anticipated that new simulations will be available by the end of 2007, and these simulations will then be compared with the data syntheses for LGM and MH. A paper describing the results of these data-model comparisons (led by Jenn Marlon and co-authored by members of the GPWG) is expected to be completed by spring 2008.

5) NEW ANALYSES. A major part of the workshop was given over to analyzing the charcoal records over the past 2000 years in order to determine whether changes in fire regime during this period display the characteristic “hockey-stick” pattern shown by other climate and environmental variables. This work involved revisiting issues of data transformation, and investigating whether biases in the data coverage geographically and with respect to distribution in climate- and biome-space had an impact on the overall signal reconstructed for the past 2000 years. Preliminary results from these analyses appear to show that the charcoal record of fire regimes closely follows the climate signal determined by solar and volcanic forcing. A small task force was formed to carry these analyses through to

completion, in anticipation of submission of an article describing this signal in spring 2008.

6) PLANNED FUTURE ANALYSES. Workshop participants presented analyses that they plan to do making use of the global charcoal database, and group discussions refined these ideas and led to further the development of collaborative networks around key issues. A list of “Planned Analyses” was created and has been added to the GPWG webpage:[http://www.bridge.bris.ac.uk/projects/QUEST_IGBP_Global_Palaeofire_WG/related.html]. The success of the GPWG has been fostered through the participation of the global palaeofire community; there are 92 GPWG members. To ensure the continued involvement of the global palaeofire community, information on all active and planned GPWG research activities will be communicated through the “Planned Analyses” page on the GPWG website. Current research activities by GPWG members include:

- How did fire regimes (charcoal abundances) change during and after the Younger Dryas Chronozone and to what extent is the “comet theory” of an extraterrestrial impact at 12,900 years ago in North America supported or refuted by data from the global charcoal database (figure 2).
- How has the late Holocene expansion of agriculture in Europe impacted regional fire regimes?
- How did fire regimes in Amazon forests respond to increased aridity during the middle Holocene (figure 3)?
- What are the relationships between vegetation and fire in North America since the Last Glacial Maximum?
- What are the relationships between vegetation, fire and humans in Australia during the Late Quaternary?
- Using palaeofire data from the global charcoal database to evaluate the key differences between multiple coupled ocean-atmosphere models of the PMIP-II group when run offline with the coupled vegetation-fire model LPJ-SPITFIRE-V2.

Global Charcoal Database (v1) Anomalies of Z-Scores of Charcoal Values (1000-yr Window)

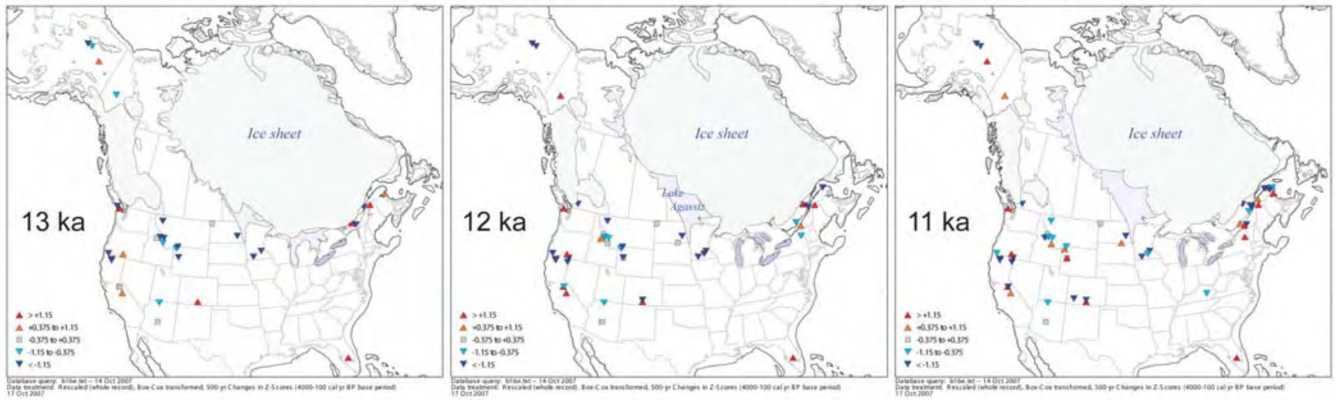


Figure 2: Three snapshots from the GCD show charcoal anomalies, or differences from present (1000 to 100 cal yr BP), at 13 ka (13,000 cal yr BP) (*above left*), 12 ka (12,000 cal yr BP) (*above center*) and at 11 ka (11,000 cal yr BP) (*above right*). These data provide an opportunity to test recent hypothesis on the causes and responses to the climate reversal during the Younger Dryas Chronozone, beginning about 13,000 years ago. The leading theory that explains this abrupt climate shift suggests a sudden draining of fresh water from Lake Agassiz along the southern edge of the Laurentide ice sheet into the North Atlantic. This cold, fresh water pulse slowed the ocean circulation system that transports heat poleward to the mid-latitudes and caused widespread cooling. However, recent research by Firestone et al. (PNAS, 2007), provides evidence for a giant comet impact 12,900 years ago, coincident with the beginning of the YD chronozone (YDC). Firestone et al. argue that the impact, which probably occurred over Canada, triggered the meltwater outflow from the proglacial lakes and melting the ice sheet.

Firestone et al. (2007) also propose that explosion-related effects, including severe continent-wide wildfires led to the extinction of the North American megafauna and the disappearance of the Clovis hunters. The GCD permits an examination of the "comet theory" and to what extent environmental effects were associated with the trigger, and how the changes were transmitted through the global climate system. Sedimentary charcoal data from lakes, bogs and soils are being used to look for evidence of widespread, severe wildfires at 12,900 cal yr BP and to examine the spatial distribution and sequence of changes in biomass burning at records spanning the YDC (Marlon et al. in prep). A poster describing this research is available at:http://www.uoregon.edu/~jmarlon/Marlon_etal_DISCCRS3.pdf. This new research by members of the GPWG illustrates the utility of the GCD as a reseach tool for testing hypotheses and evaluating changes in fire activity relative to past climate variability.

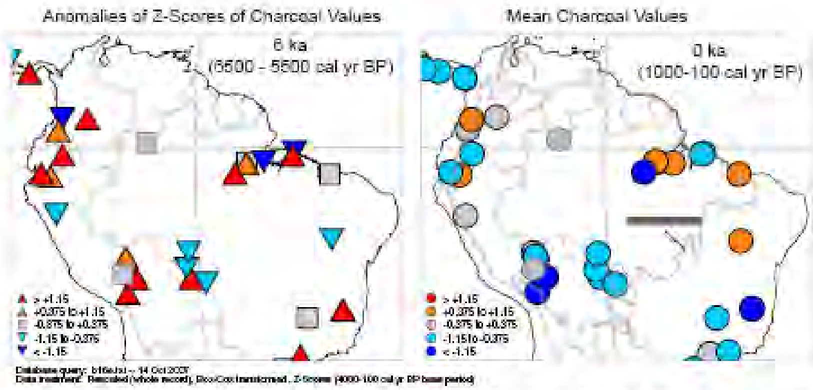


Figure 3: The impact of a drier climate during the early-mid Holocene (ca. 8,000 to 4,000 years ago) upon Amazonia's forests likely caused changes to fire regimes, as shown by the snapshot from the GCD(v1) of changes in charcoal abundances at 6 ka (6000 cal yr BP)(*above left*), expressed as anomalies or differences from present (1000 to 100 cal yr BP) (*above right*). Palaeovegetation (pollen data) and palaeofire (charcoal) records were synthesised from 20 sites within the present tropical forest biome (Mayle and Power, in press). During the early-mid Holocene fire occurrence increased as lowland ecotonal areas, which are presently covered by evergreen rainforest, were dominated by savannas and/or semi-deciduous dry forest. However, there was still considerable spatial and temporal variation in patterns of vegetation change and fire occurrence during the mid-Holocene, which likely reflects the complex heterogeneous patterns in precipitation and seasonality across the basin, and the interactions between climate change, drought- and fire susceptibility of the forests, and palaeo-indian land-use. This analysis suggests the Amazon forest biome was remarkably resilient to climatic conditions significantly drier than today.

7) ORGANIZATIONAL STRUCTURE & OPERATIONAL PLAN. The final day of the workshop was devoted to discussing the organizational structure of the GPWG and the operational plan for the next five years. Workshop participants agreed to participate in one or more strands that are designed to move palaeofire science forward across four major themes, including:

- Strand 1:Data Synthesis
- Strand 2: Analysis of the causes and consequences of changes in fire regimes over the past glacial-interglacial cycle
- Strand 3: Development of new interpretive tools for charcoal data
- Strand 4: Provision of benchmark data sets for model evaluation

The particular activities associated with each strand are outlined in a five-year plan, endorsed by the IGBP Scientific Steering Committee, and available from the GPWG webpage. In addition to partitioning the future work load of the organization, an operational plan was created and discussed that focuses on the implementation of these four major strands. The dominant mode of implementation will be through a series of workshops designed to around each theme and supported through a variety of funding agencies. The first workshop will occur October 2008 in Nairobi, Kenya and is aimed at strands 1 and 3.

8) DELIVERABLES. The GPWG will provide the following deliverables to the scientific community over the next several years:

- A comprehensive global charcoal database that spans the geologic record from modern to Eemian times.
- Creation of a web-based interface that can be easily accessed and used by a variety of global change scientists (including both palaeodata experts and modelers) to query the global charcoal database by specific region or time span.
- Benchmark data sets for use in FIRE-MIP projects associated with IGBP fire activity
- Publication of peer-reviewed manuscripts that present the palaeofire database, fire simulations, and regionally and/or thematically focused research topics.
- Publication of both palaeofire data and simulations in the IGBP Earth System Atlas for use in scientific research, to aid in policy decisions, and provide the public with access to scientific data.

To summarize, the main achievements of the workshop were:

- to identify and collect charcoal records that fill important gaps (e.g. geographical, climatological, and biological (biome)) in the global charcoal database
- to establish data analysis protocols for conducting research with the global charcoal database through a variety of software packages and analytical techniques
- to progress work on the data-model comparison paper (Marlon et al., in prep) that evaluates model simulations of fire regimes using charcoal-based reconstructions of fire regimes for 21,000 and 6000 years ago
- to initiate and make substantial progress on an analysis of changes in fire regimes over the past 2000 years, which will lead to submission of a joint-authored paper in spring 2008
- to identify several analyses that will use the charcoal database to address key scientific questions in palaeofire research
- to create a concrete plan for moving the GPWG forward over the next several years and to continue building community collaboration efforts already underway by palaeofire scientist through the communication of ongoing research activities at the GPWG

Global Palaeofire Working Group Steering Committee
November 2007

Fire Workshop
22 October – 26 October 2007

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