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Climate versus carbon dioxide controls on biomass burning: a model-based analysis of the glacial-interglacial contrast

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Climate controls natural fire regimes through several mechanisms, influencing the amount of fuel present, its flammability, and the probability of lightning, the chief natural ignition source. Fire prediction is challenging, even in the absence of human impacts, because of the complexity of the interactions among vegetation, fuel load and climate effects on fire incidence and spread. Reconstructions of climate, vegetation and fire for past times have already helped to improve knowledge of the controls of fire, and drawn attention to the high sensitivity of biomass burning – as registered by sedimentary charcoal records and other indicators – to temperature variations on centennial to multi-millennial time scales. In this study the Land-surface Processes and eXchanges (LPX) dynamic global vegetation model is used in an attempt to model fire and vegetation patterns during the Last Glacial Maximum (LGM), with outputs of four general circulation models (GCMs) providing LGM climate scenarios. The use of a process-based model allows quantification of changes in fluxes, and experimentation to assess the relative importance of different controls. We examined the contribution of CO_2 concentration changes (responsible for large changes in vegetation productivity) between the LGM and pre-industrial Holocene to the global increase in biomass burning previously inferred from charcoal records. With both LGM climate and LGM CO_2 (185 ppm) effects included, modelled biomass burning fluxes were globally lower at the LGM than in pre-industrial time, and almost consistently lower (albeit with considerable variation among the four GCMs) within each of the northern and southern tropical and extratropical bands. But combining LGM climate with pre-industrial (280 ppm) CO_2 yielded qualitatively unrealistic results, with global and northern-hemisphere biomass burning fluxes even greater than in the pre-industrial climate. The artificially increased CO_2 concentration increased simulated global LGM biomass burning fluxes by 4 to 43%, depending on the GCM. We conclude that a substantial part of the increase in biomass burning after the LGM may be attributed to the effect of increasing CO_2 concentration on productivity. Not all of it can be accounted for by global warming after the LGM. Today, therefore, both rising CO_2 and global warming must be considered as risk factors for increasing biomass burning. Both effects need to be included in models to project future fire regimes.