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Fire in Australian Savannas: from leaf to landscape

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Tropical savanna ecosystems account for 11.5% of the global landscape (Scholes and Hall 1996). Up to 75% of this landscape burns annually (Hao et al. 1990) and 50% of all biomass burning in tropical regions originates from savannas (Hao and Liu 1994). The wet-dry tropics of northern Australia feature extensive tracts of savanna vegetation which occupy approximately 2 million km2. This area is equivalent to 12% of the world's tropical savanna estate, making this savanna biome of global significance. Fire is arguably the greatest natural and anthropogenic environmental disturbance in this region. Vast tracts are burnt each year by pastoralists, aboriginal landholders and conservation managers (Russell-Smith et al. 2000; Williams et al. 2002). Fire in Australian savannas, results in a scorched canopy that dramatically reduces the green Leaf Area Index (LAI) and blackens the soil. These surface changes are likely to result in altered energy partitioning (enhanced sensible heat flux) and shifts in albedo. In addition, the aerodynamic and biological properties of the ecosystem may change, affecting surface-atmosphere coupling. For example, a loss of canopy leaf area due to fire could reduce canopy photosynthesis and evapotranspiration, greatly influencing post-fire fluxes of water and carbon. We measured radiative, energy and carbon exchanges over unburned and burned open forest savanna at Howard Springs, Darwin, Australia. Fire affected the radiative balance immediately following fire through the consumption of the grass-dominated understorey and blackening of the surface. Albedo was halved following fire (0.12 to 0.06). A moderate intensity fire resulted in a comprehensive canopy scorch and almost complete leaf drop in the weeks following fire. The shutdown of most leaves within the canopy reduced transpiration and altered energy partitioning. Leaf death and shedding also resulted in a cessation of ecosystem carbon uptake and the savanna turned from a sink to a source of carbon to the atmosphere because of the continued ecosystem respiration. We present data from 2001-2005 on the Net Biome Productivity of these savannas estimated at 2.0 tCha-1 yr-1 which is much greater than previously thought. Fire subsequently increased the Bowen ratio of the landscape and generated large increases in sensible heat fluxes. These changes in surface energy exchange following fire, when applied at the landscape scale, may have impacts on larger scale climate. At the local scale, enhanced sensible heat fluxes over patches of burnt landscape could generate mesoscale circulation systems (Knowles 1993). Variations in atmospheric heating rates above burnt and unburnt savanna and associated horizontal pressure gradients will produce atmospheric motion at a range of scales. In order to examine these processes we performed a sensitivity analysis using a global climate model (CSIRO Conformal-Cubic Atmospheric Model (C-CAM)). We utilized a distributed computing approach that allowed the development of a challenging experimental design that permitted simultaneous variation of all fire attributes (intensity, spatial extent and time during the year). The experiment demonstrates that savanna burning could shape the monsoon through two mechanisms. Boundary-layer circulation and large-scale convergence is intensified monotonically through increasing fire intensity and area burned. However, thresholds of fire timing and area are evident in the consequent influence on monsoon rainfall. In the optimal band of late, high intensity fires with a somewhat limited extent, it is possible for the wet season to be significantly enhanced. As such, these results suggest that local-to-regional scale circulation changes associated with burning may modify patterns of precipitation and could potentially affect the strength of the Australian monsoon as suggested by Beringer et al. (2003).