The sources of dissolved black carbon in rivers draining Brazilian tropical forests

Matthew W. Jones, Timothy A. Quine, Carlos E. de Rezende, Thorsten Dittmar, Ben Johnson, Marcus Manecki, Jomar S. J. Marques and Luiz E. O. C. de Aragão

When biomass and fossil fuels burn, the majority of the organic carbon consumed by fire is released to the atmosphere as gases. In addition, a small portion of organic carbon is converted to extremely stable black carbon (BC) in the form of aerosol particles (soot; <2%) or charcoal left behind in residues (5-25%). The transport of this black carbon to the global oceans by rivers is an important process for the long-term storage of terrestrial carbon. In the oceanic pool of dissolved organic carbon (DOC), black carbon has a residence time of >10,000 years. Thus, the process of biomass burning followed by full recovery of fire-affected vegetation carbon stocks leads to an increase in the total stock of carbon held in terrestrial-marine stocks of carbon and a corresponding reduction in atmospheric carbon. This effect persists over extremely long timescales and is generally referred to as a sink in the carbon cycle. In recent years, large fluxes of dissolved black carbon (DBC) have been observed in rivers draining deforested catchments. Researchers have thus concluded that stocks of charcoal degrading in soils over centennial timescales are the source of DBC transported from land to oceans. However, previous studies have not considered the contribution of aerosols to these land-ocean fluxes.

Study Outline

In Southeast Brazil, large stocks of charcoal exist in soils due to slash-and-burn deforestation over the past three centuries. Further, emissions of BC aerosol from fossil fuel sources in the densely populated states of Rio de Janiero and Sao Paulo occurs at among the highest rates observed globally, whilst fires due to continuing deforestation, pasture maintenance, and crop waste removal add to regional aerosol emissions. Our aim was to analyse the relative contribution of historic charcoal sources and modern aerosol sources to the DBC load of the major river draining the region, the Paraíba do Sul River, which flows for ~900 km and drains a catchment area 4.5 times larger than that of the River Thames (**figure 1**).

Approach in Brief

Stocks of BC in charcoal and aerosol were quantified in tributary catchments (**figure 2**), and a spatial model for DBC concentrations resulting from mixing of these sources in river channels was developed. We assessed the ability of over 50,000 mixing scenarios to replicate concentrations of DBC (n=25) in drainage channels (**figure 1**), which were measured in four sampling campaigns (**figure 3**).

Major Findings and Implications

We observed consistent evidence for a nontrivial input of DBC from aerosol sources in the Paraíba do Sul river catchment. The contribution of aerosols in the best-fitting scenarios was 5-18% across all measurement periods. Scenarios in which charcoal was considered the only source of BC were among the worst performing mixture scenarios in 3 of the 4 time periods. Thus, we consider modern sources of DBC to make a far greater contribution to oceanic stores of DBC than previously thought. Our results suggest that aerosol deposits of BC have a shorter residence time in river catchments than charcoal BC and, therefore, contribute disproportionately (with respect to stock magnitude) towards fluvial fluxes of BC.

Grant Value and Dissemination

The British Society for Geomorphology grant enabled us to meet project collaborators in Brazil and, thereby access spatial datasets for land cover and deforestation and the time series data for dissolved black carbon in the Paraíba do Sul. This led directly to award of NERC PhD funding for Matthew Jones to further develop the modelling approach, extend the areas sampled with collaborators in Brazil and to visit Prof Dittmar (ICBM-MPI, University of Oldenburg, Germany) to undertake DBC analysis. The initial work has recently been published in the Journal of Geophysical Research: Biogeosciences (DOI: 10.1002/2017JG004126) and will be presented at the EGU conference (Vienna, April 2018). The Figures below include the highlights from that paper; if citing, please refer to the full paper:

Jones, M.W., Quine, T.A., de Rezende, C.E., Dittmar, T., Johnson, B., Manecki, M., Marques, J.S.J. and de Aragão, L.E.O.C. 2017. Do regional aerosols contribute to the riverine export of dissolved black carbon? *Journal of Geophysical Research: Biogeosciences*, DOI: 10.1002/2017JG004126.

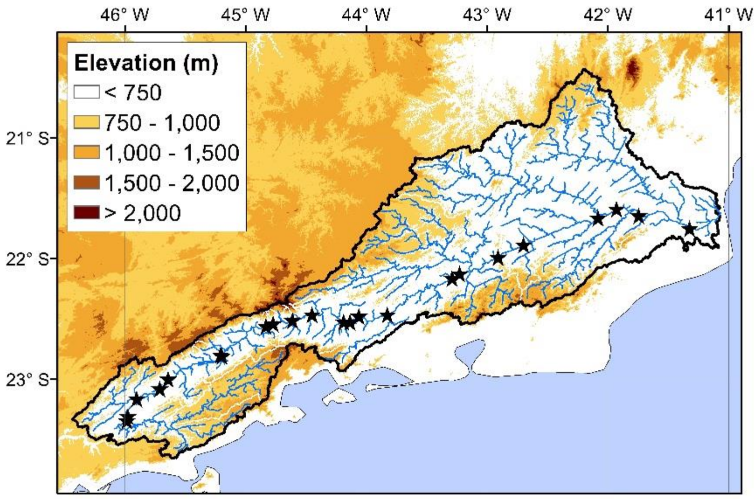

Figure 1. Drainage channels and sampling locations (black stars) in the Paraíba do Sul catchment.

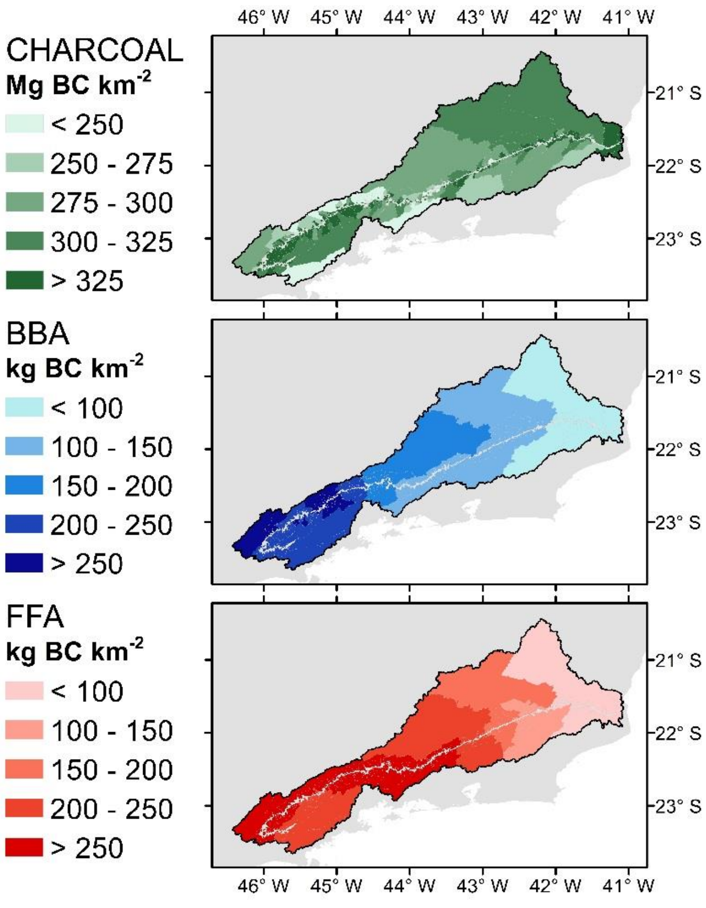

Figure 2. Spatial distributions of black carbon in charcoal, biomass burning aerosols (BBA) and fossil fuel aerosols (FFA) in sub-catchments of the Paraíba do Sul River.

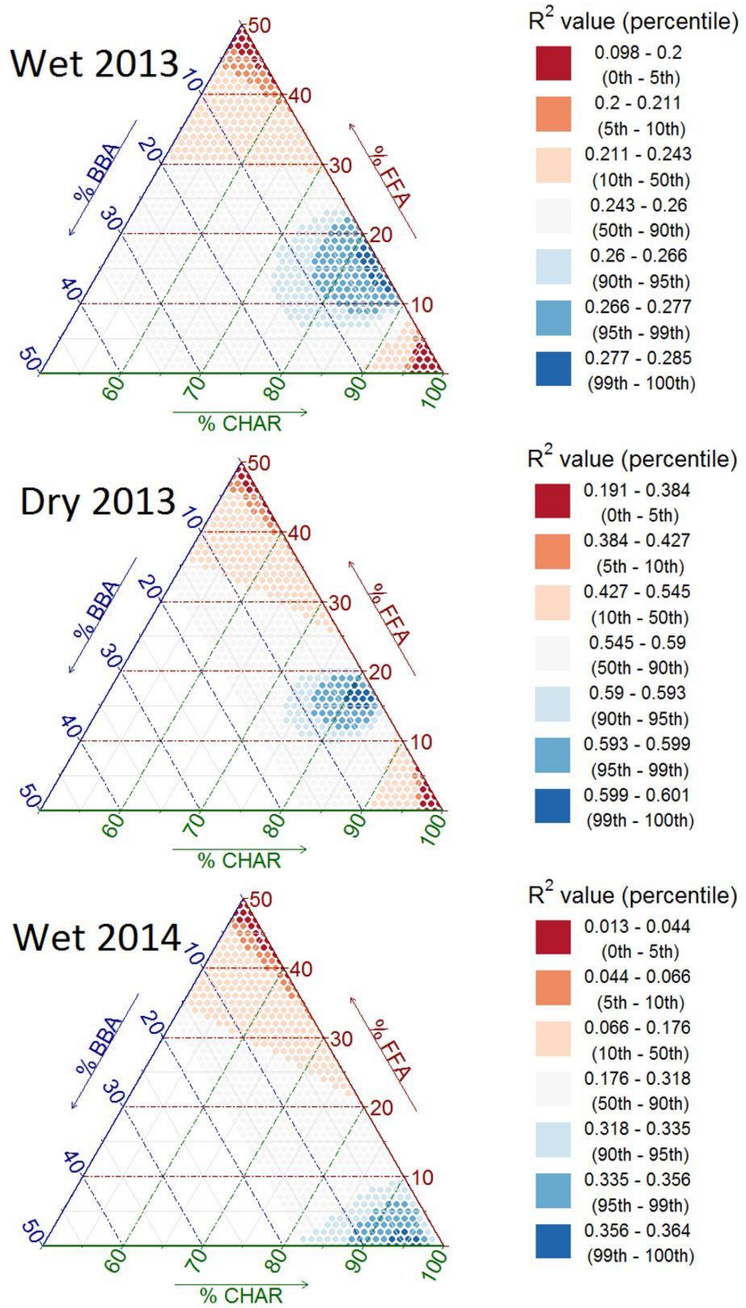

Figure 3: Goodness-of-fit between the measured and modelled concentrations of dissolved black carbon in all potential combinations of BC input from charcoal, biomass burning aerosols (BBA) and fossil fuel aerosols (FFA). The results are shown for three sampling periods. Goodness-of-fit improves with inclusion of aerosol sources.