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Temporal variability and spatial dynamics of CO_2 and CH_4 concentrations and fluxes in the Zambezi River system

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Spanning over 2900 km in length and with a catchment of approximately 1.4 million km^2, the Zambezi River is the fourth largest river in Africa and the largest flowing into the Indian Ocean from the African continent. Yet, there is surprisingly little or no information on carbon (C) cycling in this large river system. As part of a broader study on the riverine biogeochemistry in the Zambezi River basin, we present here mainstream dissolved CO_2 and CH_4 data collected during 2012 and 2013 over two climatic seasons (dry and wet) to constrain the interannual variability, seasonality and spatial heterogeneity of partial pressure of CO_2 (pCO_2) and CH_4 concentrations and fluxes along the aquatic continuum, in relation to physico-chemical parameters (temperature, conductivity, oxygen, and pH) and various carbon pools (dissolved and particulate, organic and inorganic carbon, total alkalinity, primary production, respiration and net aquatic metabolism). Both pCO_2 and CH_4 variability was high, ranging from minimal values of 150 ppm and 7 nM, respectively, mainly in the two large reservoirs (the Kariba and the Cabora Bassa characterized by high pH and oxygen and low DOC), up to maximum values of 12,500 ppm and 12,130 nM, CO_2 and CH_4, respectively, mostly below floodplains/wetlands (low pH and oxygen levels, high DOC and POC concentrations). The interannual variability was relatively large for both CO_2 and CH_4 (mean pCO_2: 2350 ppm in 2013 vs. 3180 ppm in 2013; mean CH_4: 600 nM in 2012 vs. 1000 nM in 2013) and significantly higher (up to two fold) during wet season compared to dry season closely linked to distinct seasonal hydrological characteristics. Overall, no clear pattern was observed along the longitudinal gradient as river CO_2 and CH_4 concentrations are largely influenced by the presence of floodplains/wetlands, anthropogenic reservoirs or natural barriers (waterfalls/ rapids). Following closely the concentration patterns, river CO_2 and CH_4 mean fluxes of 3440 mg C-CO_2 m^{-2} d^{-1} and 50 mg C-CH_4 m^{-2} d^{-1}, respectively, were well within the range of literature data for tropical river systems, while the two reservoirs were a sink of atmospheric CO_2 (-240 mg C-CO_2 m^{-2} d^{-1}) and a low CH_4 source (4 mg C-CH_4 m^{-2} d^{-1}).