Using a spectral reflectance change model to explore fire and its usage in Mato Grosso

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1. Introduction

Spaceborne sensors have revolutionised our understanding of wildfires by providing comprehensive coverage. These sensors facilitate detailed reporting on the incidence and progression of fires, as exemplified by their use in the Amazon Prevention and Control of Deforestation Plan (PPCDAm). Typically, two primary types of information are utilised: thermal anomalies or 'fire counts', and burned area products. The former relies on thermal sensors that detect the high energy released by fires as the satellite passes overhead. The latter employs either the spectral reflectance change or the post-fire reflectance to categorise pixels as either burned or unburned."

While burned area and fire counts are established and useful indicators of fire activity, other traits derived from satellite observations have been proposed to provide a more comprehensive understanding of fires Haas et al. (2022). In this paper, we introduce a novel metric to assess fire impact on vegetation and analyse fire patterns in the Brazilian state of Mato Grosso. This research is part of a broader study aimed at exploring fire usage by different landholders in the region and the factors driving pressures on protected areas and indigenous lands.

2. Data and method

2.1 Data

Our research focuses on data collected from the Brazilian state of Mato Grosso. For a broad-scale, long-term analysis, we use surface reflectance products from the MODIS archive (MOD09GA and MYD09GA, Vermote and Wolfe (2021)) and the MCD64A1 MODIS burned area product as our primary data sources. For more detailed examinations, we employ Sentinel 2 surface reflectance (L2A product, European Space Agency (2022)). Additionally, we incorporate Fire Radiative Power estimates from both VIIRS and MODIS sensors to provide benchmarks for comparison (e.g., Giglio and Justice (2021)).

2.2 Method

We analyse optical observations from MODIS and Sentinel 2 sensors using a spectral reflectance change modelling approach to determine the impact of fire on reflectance. This method assumes that post-fire reflectance can be expressed as a linear combination of burned and unburned spectral endmembers. Further, we approximate the burned endmember by the pre-fire reflectance, and also assume that the post-fire reflectance is a mixture of exposed dry soils, char, and ash. The assumption on the nature of the post-fire reflectance allows us to develop a spectral model for it, governed by two parameters. Finally, we bundle these into a model that uses pre- and post-fire reflectances to estimate the fire-affected fraction of the pixel, denoted as $0 < fcc < 1$ and to derive two parameters, a_0 and a_1, which characterise the spectral properties of the post-fire reflectance (a_0 suggesting a char/ash component, and a_1 suggesting an exposed dry soil component). More details on the method can be found in Lewis et al. (2010) and Gomez-Dans et al. (2013).

For Sentinel 2 data, we apply this model pixel-by-pixel to consecutive images, treating the earlier image as pre-fire and the subsequent one as post-fire. We also apply the model for each pre-fire image with a subsequent time series of posterior acquisitions to verify the burn's stability over time.

In the case of MODIS, we employ a burned area product to determine the burn date and fit standard linear BRDF kernel models to the reflectances before and after the fire, aiming to minimise BRDF effects. We use a 16-day temporal window for both pre- and post-fire observations, aligning with established practices. This approach provides per-pixel estimates of fcc, a_0 and a_1.

3. Preliminary results

We present some preliminary results of the Sentinel 2 processing for two sites in Mato Grosso: one in the Capoto/Jarina Indigenous Territory (Figure 1, July 2022) and a site near São Luiz (Figure 2, August 2022).

We note that in both cases, high values of fcc are consistent with burn scars (so there has been a large change in reflectance in a short time). We have masked the spectral model parameters using the rule of $fcc < 0.3$, as fcc values below this number will arise due to non-fire changes in vegetation, residual atmospheric correction issues, etc.

In Capoto (Figure 1), we see that higher values of fcc are often associated with low values of a_1, suggesting that the post fire signal is very consistent with a char/ash response rather than soil response, and indicative of post fire debris accumulation.

In the São Luiz area (Figure 2), we note the difference between agricultural fires towards the South of the site, and natural fires towards the North. It is interesting that the agricultural fires are characterised by a low value of fcc and a (relative) high value of a_1, suggesting that fires in agricultural land occur post harvest, and that the post-fire scene is made up mostly of exposed soil. This observation also suggests that harvesting may be a

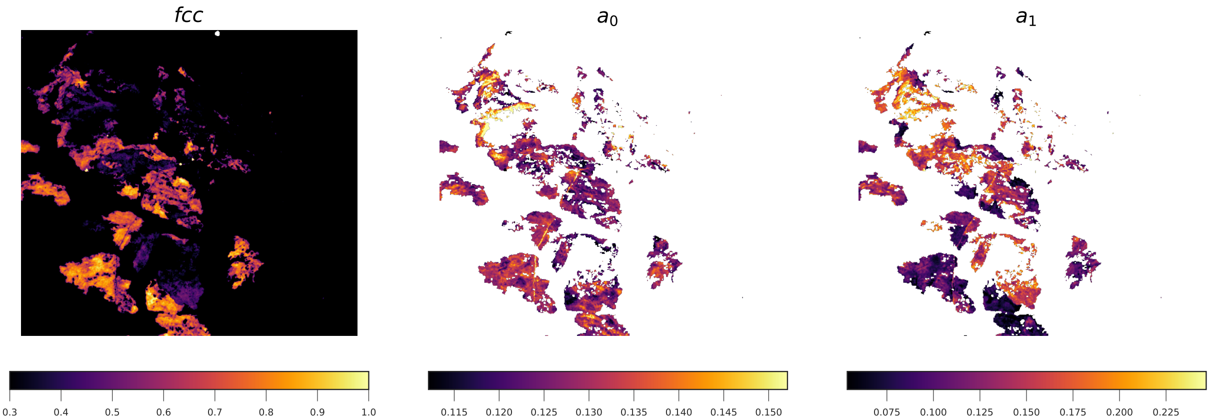

Figure 1. Retrieved model parameters fcc (left), a_0 (center) and a_1 (right) for the Capoto region. The data depict July 2022. For a_0 and a_1, pixels where $fcc < 0.3$ have been masked out

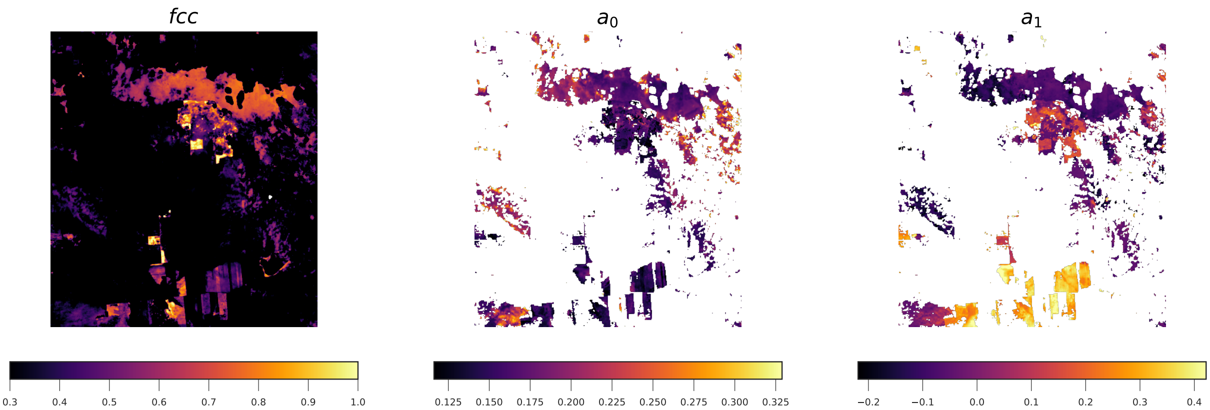

Figure 2. Retrieved model parameters fcc (left), a_0 (center) and a_1 (right) for the São Luiz region. The data depict July 2022. For a_0 and a_1, pixels where $fcc < 0.3$ have been masked out

source of confusion, which may be mitigated by using thermal anomaly data in conjunction with the optical data.

Further work currently in progress will consider the spatial scaling properties of the model parameters through comparisons between S2 and MODIS derived parameters, as well as temporal trends of e.g. fcc and its comparison with trends in Fire Radiative Power.

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