Future projections of fire danger in Brazilian savanna and shrublands in the 21^{st} century

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Fire has a fundamental role in the Earth system, as it influences global and local ecosystem patterns and processes, such as vegetation distribution and structure, the carbon cycle and climate. In the global context, Brazil is one of the regions with higher fire activity, affecting ecosystems and the global carbon cycle. An increased likelihood of extreme weather events is expected for Brazil, which may affect fire patterns. The present study relies on regional climate simulations over woody savanah in Brazil (the *cerrado* region) using outputs from the Rossby Centre Regional Climate Model (RCA4) forced with EC-Earth, and on a meteorological fire danger index to assess the sensitivity of wildfire occurrence in Brazilian *cerrado* to changes in regional climate during the 21^{st} century.

1. Data and Area of Study

The analysis in the present study is focused on the Brazilian regions of savanna, woody savanna, and open and closed shrublands, where the highest number of fire events take place (Davidson et al., 2012). Simulations were obtained from the regional downscaling of the EC-Earth climate model for the CORDEX South American domain, by the Rossby Centre Regional Climate Model (RCA4) (Jones et al., 2011, Samuelsson et al., 2011). Daily values of surface temperature, relative humidity and precipitation were extracted and selected for the study area. Our study focuses on three 30-year periods: the last 30 years of the historical period (1976-2005), and of the first (2021-2050) and the second (2071-2100) halves of the 21st century, for both RPC 4.5 and RCP 8.5.

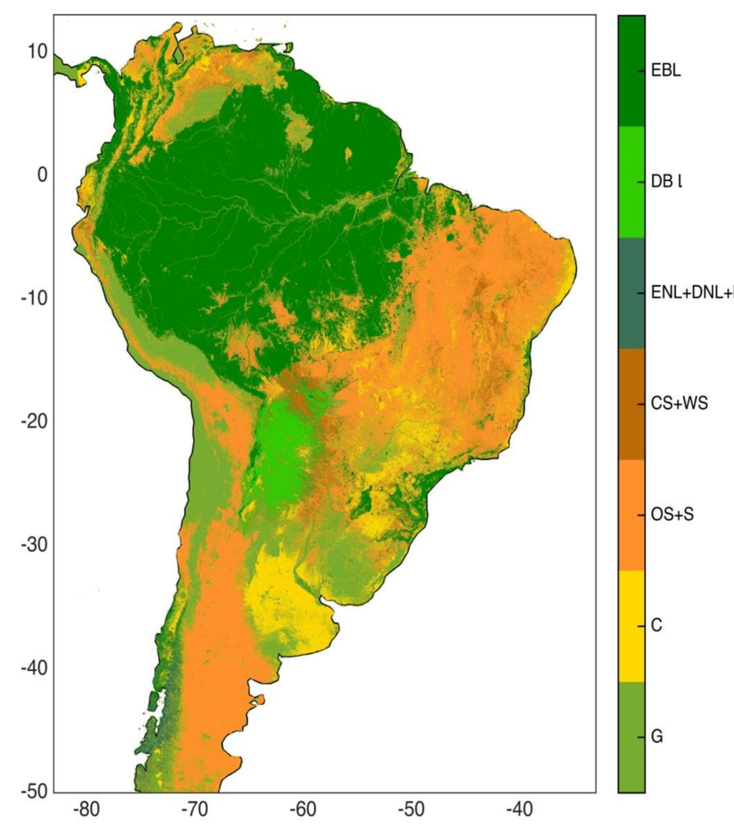

Figure 1: Types of vegetation in South America: Grasslands(G); Croplands (C); Open Shrublands and Savanas (OS+S); Closed Shrublands and Woody Savanas (CS+WS); Evergreen Needleleaf, Deciduous Needleleaf and Mixed forests (ENL+DNL+M); Deciduous Broadleaf Forest (DBL); and Evergreen Broadleaf Forest (EBL) . From IGBP's classification adapter for Brazil by INPE.

2. Fire Risk Index

The assessment of fire risk relies on the so-called Meteorological Fire Danger Index (MFDI) (Sismanoglu and Setzer, 2004). Computation of MFDI is based on information about vegetation cover and on daily values of the maximum temperature, minimum relative humidity and accumulated precipitation. The rationale is that the longer the time without rain, the higher the risk of vegetation to burn.

For each day, the value of MFDI is obtained using the so-called Drought Days (DD), Basic Danger (BD), and the Humidity (HF) and Temperature Factors (TF). MFDI is dimensionless, and varies between zero and slightly above unity. Meteorological fire danger is then stratified into five classes, from low to critical levels, as specified in Table 1.

Danger classes MFDI	
Minimum	< 0.15
Low	0.15 > 0.40
Medium	0.40 >0.70
High	0.70 > 0.95
Critical	> 0.95

Table 1: Classes of meteorological fire danger and respective ranges of the Meteorological Fire Danger Index (MFDI).

3. Results

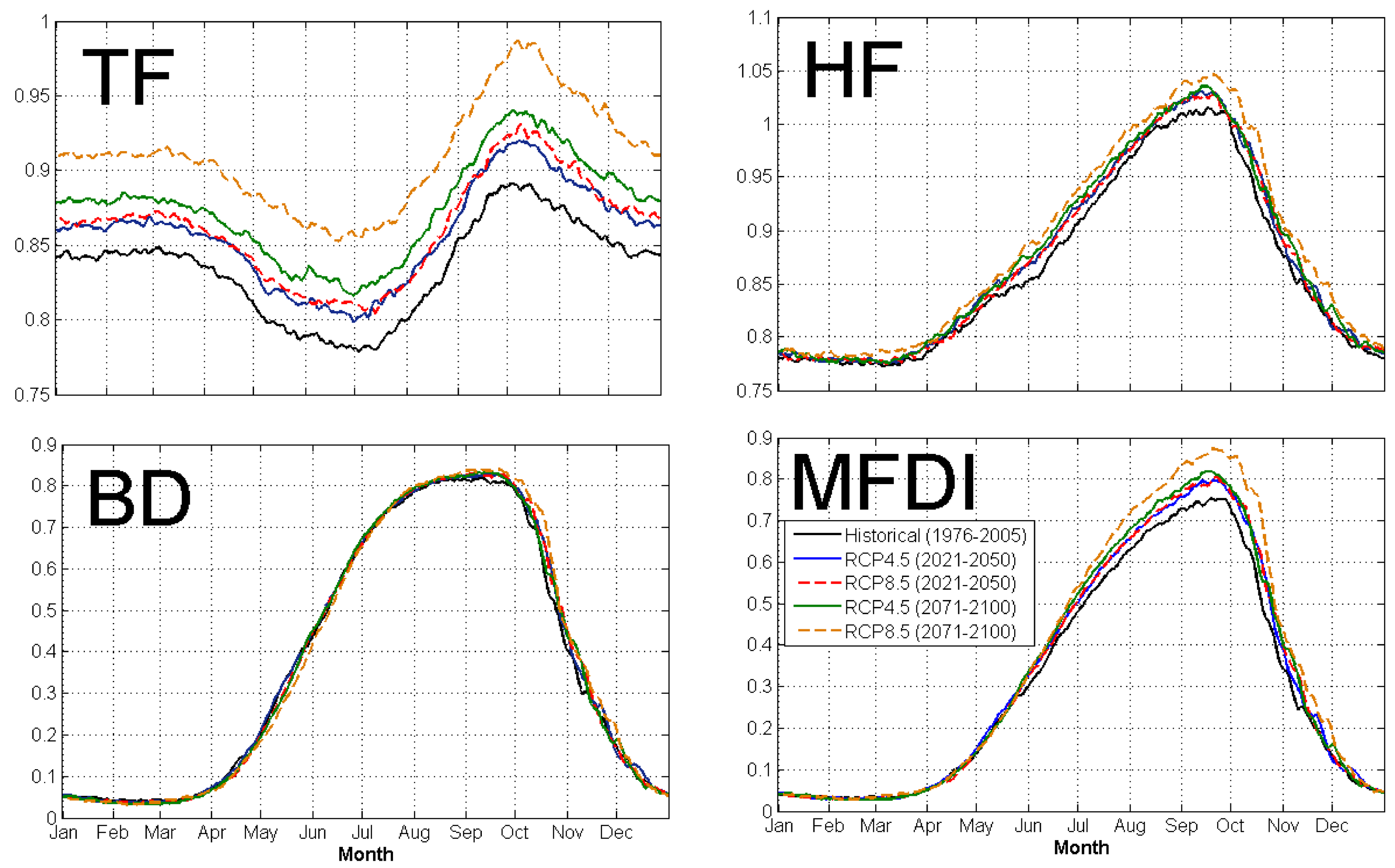

Figure 2: Average seasonal cycle over the study area of the Temperature Factor (TF, upper left panel), the Humidity Factor (HF, upper right panel), the Basic Danger (BD, bottom left panel) and the Meteorological Fire Danger Index (MFDI, bottom right panel). The five curves represent different study periods.

The seasonal dynamics of the factors that compose the index and the annual cycle of MFDI present values close to zero during the wet season (January to April), increasing until the peak in September (the fire season) and decreasing rapidly afterwards.

The response to the climate forcing is registered mainly between July and October, but it is more pronounced in the peak month, .i.e. September. This is due to the increase in both the Humidity (HF) and Temperature (TF) Factors, from the Historical period to the two future scenarios, especially in the second half of the century.

	Historical (1976-2005)	First half (2021-2050)		Second half (2071-2100)	
		RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Mean	0.741	0.782	0.785	0.801	0.854
Standard Deviation	0.051	0.042	0.045	0.058	0.052

Table 2: Mean and standard deviation of MFDI for September over the study area covering the Brazilian savannas and shrublands, for the study periods defined in the historical period (1976-2005) and in scenarios RCP 4.5 and RCP 8.5 (for 2021-2050 and 2071-2100).

Changes in MFDI regime in September show an increase of the mean values from 1976-2005 to 2021-2050 in both scenarios (Table 2), and an even higher increase in 2071-2100. The differences between both scenarios in the first of the century are not significant, however in the second half of the century these differences are much higher.

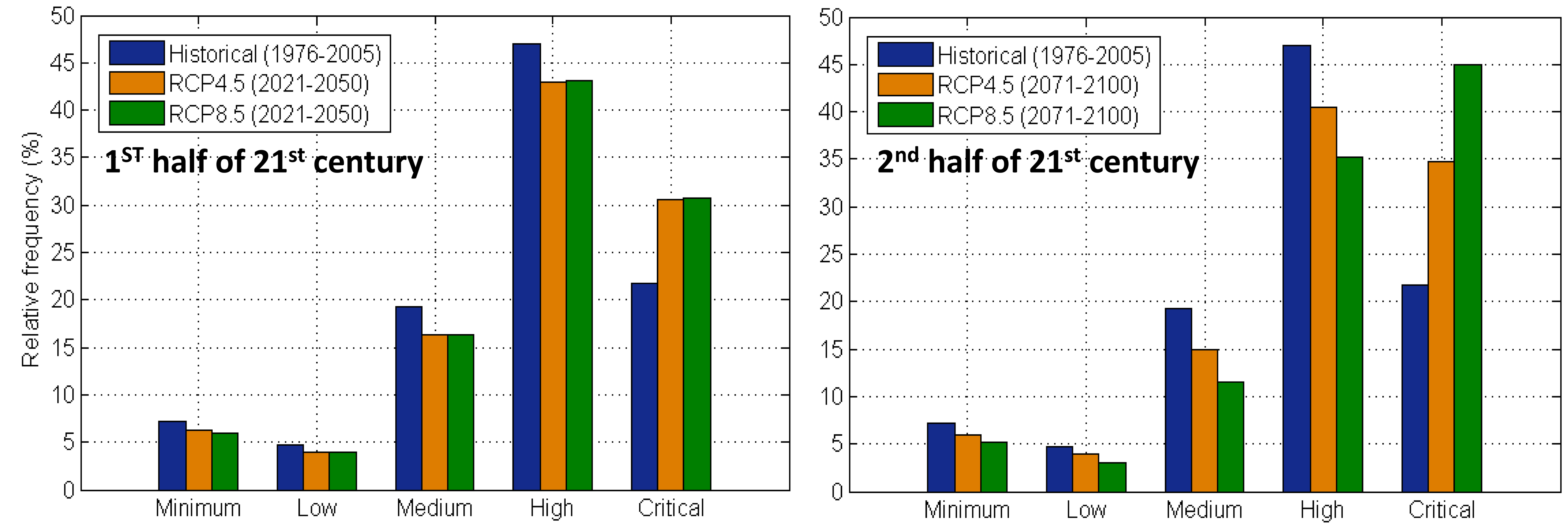

Figure 3: Relative frequency of occurrence (%) of classes of meteorological fire danger for the two RCP scenarios and the two study periods (2021-2050, left and 2071-2100, right), compared with fire danger in the historical period (blue bars).

Fire danger over the 21^{st} century is characterized by a systematic increase of days of critical fire danger (Figure 3), while the remaining classes decrease over the course of the century. In the first half of the century (2021-2050), there is a similar increase on the critical class from the present to both future scenarios. However, in the second half (2071-2100) there is an significant increase from about 20% in the present, to 35% in RCP 4.5 and 45% in RCP 8.5.

4. Conclusions

This feasibility study intended to evaluate the applicability of using outputs from a Regional Climate Model (RCM) combined with a regionally-fit fire index to evaluate meteorological fire danger patterns in the Brazilian savannas and shrublands. In this study, a systematic increase in "critical" meteorological fire danger is observed in Brazilian semi-arid biomes throughout the 21^{st} century, for an intermediate and a severe scenarios of climate change. This increase supports the likelihood of more severe fire seasons in savanna and shrubland regions in Brazil along the century.

References

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Acknowledgments

This work was developed within the framework of the Brazilian Fire-Land-Atmosphere System (BrFLAS) Project financed by the Portuguese and Brazilian science foundations, FCT and FAPESP (project references FAPESP/1389/2014 and 2015/01389-4).