Modelling Current and Global Warming-Induced Fire Risk in Africa

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Abstract

Based on regional climate model simulations conducted with RegCM3, the impact of anomalous climate forcing on the environmental vulnerability to wildfire occurrence in Africa is analyzed by applying the Potential Fire Index (PFI). Three distinct vegetation distributions have been analyzed for present day (1980-2000) and for the end of the twenty-first century (2080-2100).

We demonstrated that under current conditions the PFI is able to detect the principal fire risk areas which are concentrated in the Sahelian region from December to March, and in the subtropical Africa from July to October. It was found that under greenhouse warming conditions the PFI foresees an increase of the fire risk area, particularly for the latter region. We concluded, furthermore, that changes of vegetation predicted to occur in the future lead to substantial modifications in the magnitude of the PFI, and may potentially extend the length of the fire season due to induced longer drought periods as compared to current conditions. The reliability of the PFI in reproducing the areas with high fire activity indicates that the index is a useful tool to forecast fire occurrence worldwide, because it is based on vegetation and climate factors that are regionally dependent.

1. Introduction

Impacts of vegetation/wild-land fires are prominent in questions which involve past and future climate change. During the evolution of man fire was used in the most remote regions, however, in recent decades various sectors of society have expressed preoccupation with the indiscriminate use of fire. Burning of biomass plays an important role in global emissions of carbon containing and other trace gases. For instance vegetation fires on a global scale are the second largest source of greenhouse gas emissions argue that the amount of carbon dioxide released in Indonesian fires in 1997 and 1998, was equivalent to 25% of the total CO2 emissions due to the combustion of fossil fuels.

Distinct patterns of vegetation changes associated to future climate changes have been found to raise the possibility of increase fire activity. In this sense, Justino et al. [2010a] based on a potential fire index (PFI) found that under greenhouse warming conditions the PFI foresees an increase in the fire risk area, particularly for the Amazon region. They concluded, furthermore, that changes of vegetation predicted to occur in the future lead to substantial modifications in the magnitude of the PFI, and may potentially extend the length of the fire season due to induced longer drought periods as compared to current conditions. The impact of climate change in Africa has been recently explored focusing on temperature, precipitation, and extreme events, which includes drought/floods.

Despite the relevance of vegetation fires in determining global vegetation patterns and the atmospheric concentration of greenhouse gases. There do not exist systematic investigations focusing on the future fire risk in Africa based on models which include the interchange between climatic variables and vegetation pattern. Africa is subject to most of the fires globally detected (50% of all detected) mainly occurring in savanna regions. This study, therefore, aims to investigate the atmospheric susceptibility to fire occurrence in Africa based on a Potential Fire Index (PFI) for both present day and future climate conditions. The PFI takes into account the daily values of maximum temperature (tmax), precipitation (prec), vegetation types and the minimum relative humidity (RH).

2.**Methodology**

To evaluate the fire risk in Africa climate data delivered by ENSEMBLES Regional climate models validation and future projections have been utilized (http://sites.google.com/site/rt3validation/africa, Mariotti et al. [2011]). The RegCM3 is integrated for a continuous transient scenario simulation for the 120 year period 1980-2100. Initial and 6-hourly lateral boundary conditions and SSTs necessary to run the model are obtained from a corresponding simulation with the ECHAM5 AOGCM. The scenario has a GHG concentration described by the SRESA1B emission scenario.

The PFI methodology is based on the temporal and spatial empirical evidence of the occurrence of hundreds of thousands of vegetation fires in Brazil during the last 20 years. Even though the vast majority of these fires are of anthropogenic origin and spread over most of the country, they are related to the annual climate cycle since the purpose of the burnings is a fast and efficient removal of the natural vegetation, which generally is for agricultural purposes. The PFI methodology is based on the principle that the vegetation fire risk increases with the duration of dry periods. The type and natural cycle of vegetation defoliation, maximum temperature and relative humidity of the air are also included in order to compute the PFI. The reference of the calculations is the Number of Dry Days or Days of Drought (DD), which is a hypothetical number of days without precipitation obtained by periods during the precedent 120 days. It is very reasonable, therefore, to check the validity of this approach to different regions such as the African continent.

3. **Results and Concluding Remarks**

In what follows the monthly evolution of the PFI as well as its components are shown. It should be noted that the largest number of vegetation fires in Africa occurs between December and

February (DJF) in the equatorial region and between August and October (ASO) in the Southern Hemisphere subtropical region. Therefore, the analyses conducted here are restricted to these months. Figure 1a shows the daily maximum air temperature at 2m averaged between December and February for the PD simulation (1980-2000). There are evidently higher temperatures along the equatorial belt and in the subtropical Africa with values as high as 37C. Lower values are predominant in Northern Africa. As expected, analyses for relative humidity demonstrated that areas with high temperature are also dominated by low relative humidity (Fig. 1b). These conditions intuitively may favor intensified fire occurrence. However, climate conditions as delivered by the days of drought (DD) shed some light on the role of precipitation. For instance the equatorial region (5N-15N) exhibits larger values of DD or long periods without rain (up to 1), whereas the sub-tropical region is dominated by small values of DD which may be interpreted as frequent precipitation (Fig. 1c). The combination of these three factors (Tmax, RH and DD) associated with vegetation pattern simulates the potential fire risk (PFI). As shown in Figure 1d,e,f, the atmospheric

The combination of these three weather factors (Tmax, RH and DD) associated with vegetation pattern simulates the potential fire risk (PFI). The impact of the DD on the PFI is highlighted by the weakening of fire risk between 0-20S. Despite high temperatures and moderate relative humidity this region does not show high PFI due to small DD which indicates frequent precipitation associated with the ITCZ. Furthermore, the dominant vegetation pattern in this region is evergreen or semi-evergreen forests, the fuel of which consists of densely packed litter layers and the canopies of trees are most live material. It is interesting to note that the vegetation pattern as delivered by the CCSM, HadCM3 and ECHAM disagree on the Saharan desert extension but they do show similar biome elsewhere.

The satellite-based wildfires reveals the high number of fires in the subtropical region of Africa which includes the west and east coast. It may be stressed the high agreement between the fire index and the satellite-based fires in Angola, Zambia, Zimbabwe and Namibia.

By applying three different vegetation scenarios for current conditions and those proposed for a global warming scenario, it has been found that the future PFI is extremely sensitive to the conditions imposed by the vegetation. For instance, when forest was substituted for savannas a greater fire risk was projected. This is intensified in the situation delivered by the HadCM3 which foresees an enlargement of savannas area, as opposed to CCSM and ECHAM. In this sense, calculations of the PFI indicates that according to the anomalous atmospheric conditions predicted for the future associated with the predicted vegetation distribution, Africa will be more exposed to large scale vegetation fires.

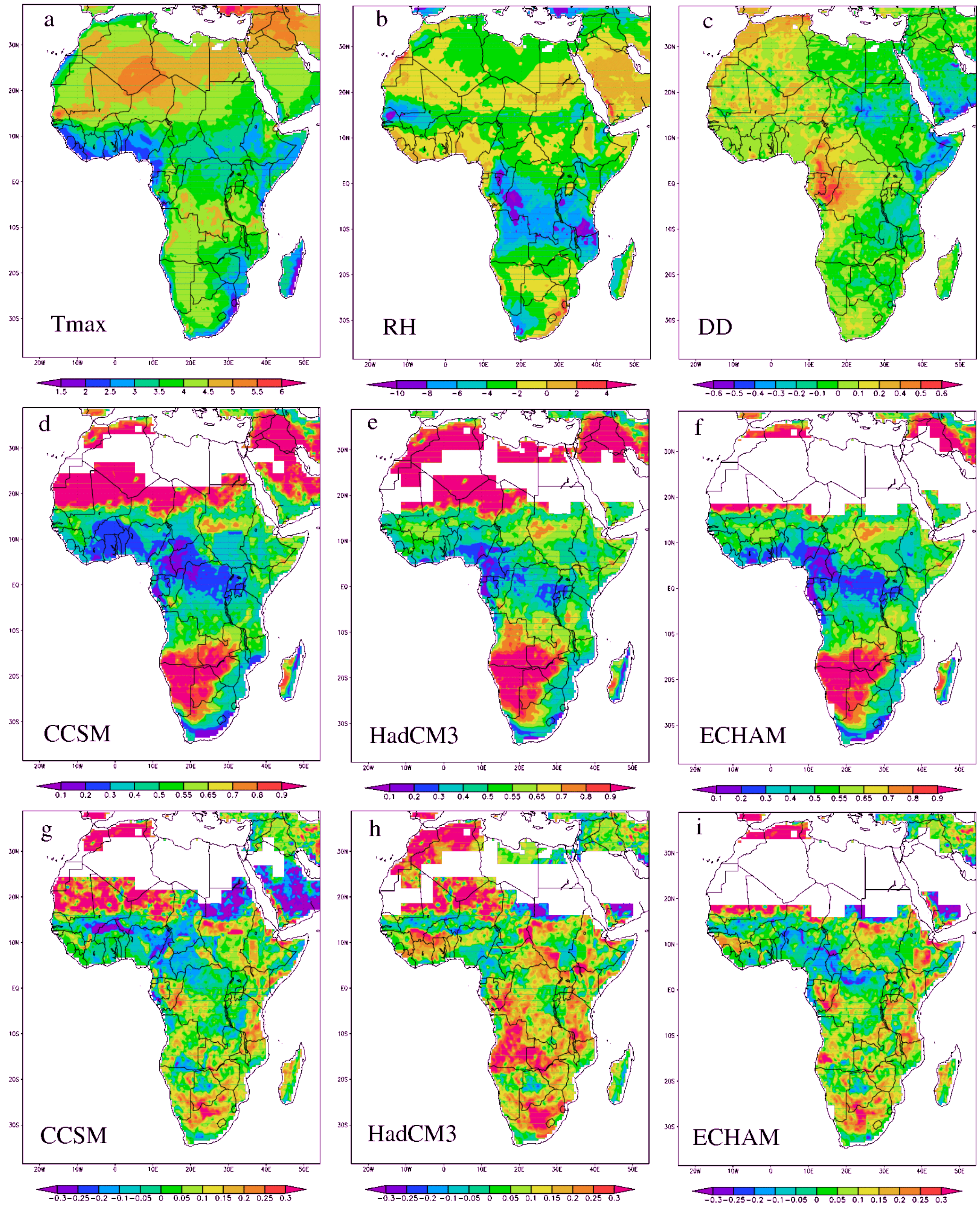

Figure 1. Greenhouse warming anomalies as compared to present day in DJF. Maximum temperature (a ,K), relative humidity (b, %) and days of drought (c). d), e) and f) show the PFI estimated from the greenhouse warming simulation based on CCSM, HadCM3 and ECHAM forced-vegetation. g), h) and i) show the PFI anomalies between greenhouse warming and present day simulation.