Fire Risk Factor- Summary of the Calculation Method

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The Idea of Fire Risk Factor.

Fire Risk Factor (RF) was developed internally at CPTEC, based on the analysis of hundreds of thousands of fires across the major biomes (vegetation classes) of Brazil over recent years, as a function of environmental conditions, and meteorological history in the area of each fire event. (Setzer et al. 2002, Sismanoglu et al. 2002). The factor is based on the idea that with increased number of days without rain, the risk of fire for the vegetation increases; other factors included in the analysis include the amount and pattern of leaf-fall for the natural vegetation, maximum temperature and minimum relative humidity of the air as well as the presence of fire in the region of interest. A fundamental variable in these calculations is "Dry Days" or drought, (S), which is the estimated number of days without any precipitation over the past 120 days.

It is important to remember that RF indicates the likelihood that the vegetation will burn and that the in the majority of cases fire events are caused by human activities and not natural events such as lightening strikes. In this context windspeed is not included in our calculations, since it is more a factor in fire propagation rather than initiation: in fact when winds are significant people tend to avoid starting fires out of fear of unforeseen damages. Soil moisture is also not considered in our calculations since it is tied to precipitation history and not necessarily valid; for example , an area which was deforested and whose vegetation dried for a period of several months could be burned several days after an intense rainfall event, even the subsoil, being complete with organic material could be ready for a burn if there were strong sun and the air temperature was sufficiently high.

The 'Observed RF' is the result of measured data from ground stations, as compared to ' Estimated RF' for some days and 'Predicted RF' for some weeks are calculated using the output of numerical models of rainfall, air temperature and relative humidity using Observed RF as the initial conditions.

Data sources

The data on maximum temperature and minimum relative humidity at 1800 hours (UTC) at the surface are taken from the NCEP analysis done at CPTEC by the global scale model Global T213 at 62 km resolution. There is also the option of "kriging" data from meteorological stations for the entire area.

Values for precipitation were obtained at a 4 km resolution from estimates of precipitation generated by DSA from satellite images from GOES-10 and MSG-2. We chose to use the estimates from satellite images since the density of climate stations is limited in various regions and this is the most important variable in the risk factor calculation.

The map of vegetation types was adapted from the most recent mosaic Vegetation Index image of South America generated by DSA with AQUA MODIS images. 5 principle classes of

vegetation were used: Closed wet forest, Open wet forest, Contato+ Campinarana, Seasonal Deciduous + Semi-deciduous and Not-forested.

Predictions for RF for up to 3 days are generated from the products of regional ETA models at 20 km resolution and from the global scale model T213 at 62 km resolution. In addition the BRAMS models at two resolutions and ETA at 40 km resolution were also used in this research. Weekly forecasts for up to one month with a resolution of 40 km were also generated from the ETA model products.

Note: Previous versions of Fire risk factor calculations continue to be maintained for applied research goals.

Calculation of Observed fire risk factor

Observed Fire Risk Factor (RF) is calculated using measured meteorological data and fire occurrence data. From this, other risk factors such as Predicted Fire Risk Factor for up to three days are calculated with the ETA models (Sismanoglu and Setzer 2004b) and Global T213, as well Future Risk Factors weekly for up to 4 weeks applying the ETA model with more extended rounds (Sismanoglu and Setzer 2004c). The sequence of calculations for RF, created and refined by Setzer (INPE, 2004) since 1998 are summarized below.

1) Daily determine the value of precipitation in mm for the geographic range covered for 11 preceding periods (1, 2, 3, 4, 5, 6 to10, 11 to 15, 16-30, 31- 60, 61-90 and 91-120 days). Data points from specific meteorological stations are 'kriged' (interpolated) for the entire area or are determined from hydroestimator estimates depending on the RF calculation version being used.

2) Calculate the "Precipitation Factor" (FP) with a value between 0 and 1, for each of the 11 time periods using an empirical exponential function for precipitation in mm of rainfall per each. The equations are as follows:

FP1 = exp (-0.14*precip)
FP2 = exp (-0.07*precip)
FP3 = exp (-0.04*precip)
FP4 = exp (-0.03*precip)
FP5 = exp (-0.02*precip)
FP6-10 = exp (-0.01*precip)
FP11-15 = exp (-0.008*precip)
FP16-30 = exp (-0.004*precip)
FP31-60 = exp (-0.002*precip)
FP61-90 = exp (-0.001*precip)
FP91-120 = exp (-0.0007*precip)

3) Calculate the Dry Days (S) by using the calculated FP values in the following equation

$$S= 105*FP1*FP2*FP3*\ldots.FP91\text{-}120$$

In this equation a rainfall event of a couple of millimeters one day previous to the one for which RF is being calculated has a much larger negative effect on the value of S than that of a rainfall event which occurred for example 2 weeks prior to the day of interest. Thus, the annual precipitation regime is incorporated into the calculation, with rainfall events identified as occurring in the dry period or not.

4) Determine the 'Basic' Fire Risk Factor for each of the 5 vegetation classes considered using the following equation:

$$RB_{n=1,5} = 0.9[\ 1+ \sin(A_{n=1,5} * PSE)]/2$$

Classification	1	2	3	4	5
Vegetation type	Closed wet forest	Open wet forest	Contato	Seasonal Decid. and Semi-decid.	Not-forested
Value for A	1.715	2	2.4	3	4

The basic risk factor has a maximum value of 0.9 and increases over time along a sigmoid curve. This pattern was chosen due to the fact that the variation in duration and intensity of solar radiation over the course of the year is also described by a sigmoid curve and as a result the phenology of natural vegetation follows the same pattern.

The following figure illustrates the range of Basic Risk Factors developed using the ideas and equations discussed above. Note that the x axis labeled " Days without rain" represents both a real period of time without precipitation as well as "Dry days" which are a hypothetical period of time without rain calculated based on the quantity and temporal distribution of past rain events. The idea of "Days without rain" or "Dry days" forms the basic principle of this method

5) Correct the Fire Risk Factor for minimum relative humidity of the air. The humidity corrected RF (RU) increases for relative humilities below 40 % and diminishes for values above this reference point. Humidity data from observations made at 1800 UTC, the predicted daily minimum. The equation for the humidity correction is:

$$RU = RB * (-0.006* UR_{min} + 1.3)$$

Where RU= Fire Risk Factor corrected for minimum relative humidity, RB= Basic Fire Risk Factor, and UR min = the minimum relative humidity of the air

6) Correct the Fire Risk Factor for the maximum air temperature. The maximum air temperature corrected RF (RT) increases for relative humilities above 30 degrees C and diminishes for values below this reference point. Air temperature data from observations made at 1800 UTC, the predicted daily maximum. The equation for the temperature correction is:

$$RT= RU *(0.02T_{max} +0.4)$$

7) Calculate the Observed Fire Risk Factor, and classify into the following categories:

Minimum: RF_{obs} between 0.0 and 0.15
Low: RF_{obs} between 0.15 and 0.4
Medium: RF_{obs} between 0.4 and 0.7

High: RF_{obs} between 0.7 and 0.95
Critical: $RF_{obs} > 0.95$

8) In the case where a hot pixel is detected in an area where the Observed Fire Risk Factor was classified as Minimum or Low, change the value of the RF_{obs} for that pixel to 0.9.

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