Methods for estimating the peak season in time series data

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Outline

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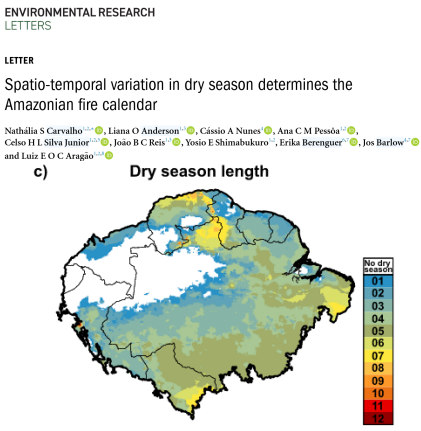
Introduction

- Better estimations of the fire season in the Amazon forest could foster better town planing and improve responses to excessive fire smoke.
- Previous studies focused on the dry rather than the fire season and its regional patterns.
- Besides, it is common practice to assume a fixed fire season.
- We present pixel-wise estimation of the fire season in the Amazon based on fire spot detected by VIIRS.
- We developed a new method for estimating peak-seasons given intensity data over time.

Deforestation by slash and cut (*Corte e queima*). Source: [DAMV+22].

Amazonian fire calendar

- Start, end, & length of the dry season in the Amazon.
- Rain data (CHIRPS 1989-2019) on a 10Km grid.
- The dry season are the consecutive months with rainfall below 100 mm.
- Regions are neighborhoods with the same season start & end.
- Critical fire periods are regions of similar dry season determined by k-means clustering.
- Their results area available online for download and visualization.



Source: [CAN+21].

Justification

- Fire in the Amazon is anthropogenic, not endemic.
- Fire is a cause and a tool in the deforestation and forest degradation processes.
- An accurate fire calendar could improve decision-making and public policy design.
- A fire calendar could provide some required data for fire prevention and control.

Research objective

- Establish the beginning and end of the fire season in the Amazon rainforest with as much detail as available data allows.

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Software

- R language [IG96].
- R packages *dplyr* and *ggplot2*.
- R packages for vector (*sf* [Peb18]) and raster (*terra* [Hij20]) data.
- R package *sicegar* for double-sigmoidal regression [CTW18].
- Analysis code available on GitHub.

Data

- We used 5 years of world fire data from VIIRS NPP (from 2019 to 2023, 10.213.4267 registries).
- We aggregated these data by month into a grid of 0.25°.

Peak and threshold

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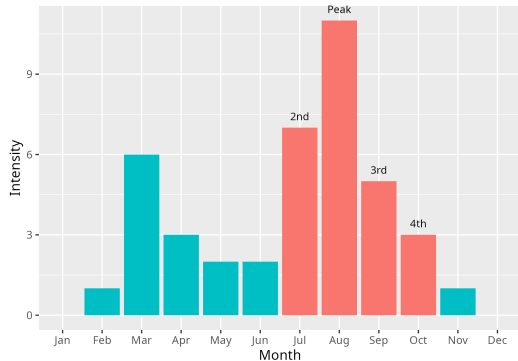
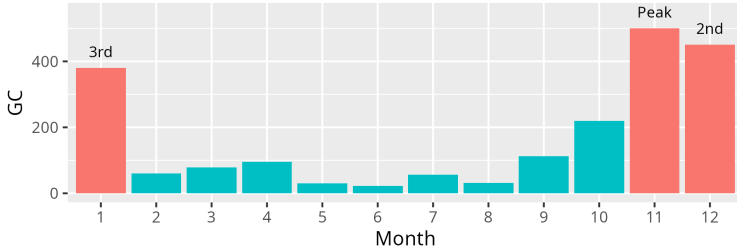
- Proposed by Guilherme Mataveli.
- A season is a subset of contiguous months that host the peak and at least 60% of the total intensity (observations) of a phenomenon.



Peak and threshold example

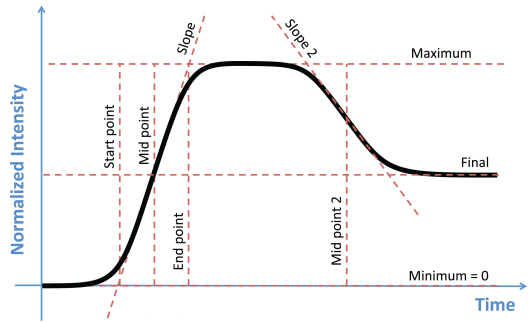
Month	GC
1	380
2	60
3	78
4	96
5	30
6	22
7	56
8	32
9	112
10	220
11	500
12	450



Iteration	Test Months	Chosen	Season	Cum. Sum
1	Peak	11	11	500 (25%)
2	10 or 12	12	11-12	950 (47%)
3	10 or 1	1	11-12-1	1330 (65%)

Double-sigmoidal fitting

- Input data represents intensity measured over time.
- Growth happens in two phases: exponential intensity increase until level off at a maximum level (first sigmoidal function); decay to a lower intensity or even zero (second sigmoidal).
- The midpoints are assumed as the start and end of the season.



Source: [CTW18].

Logistic function

$$I(t) = f_{sig}(t) = \frac{I_{max}}{1 + exp(-a_1(t - t_{mid}))} \qquad (1)$$

Where [CTW18]:

- $I(t)$ is the intensity as a function of time t.
- The parameters to fit are I_{max}, t_{mid}, and a_1.
- I_{max} is the maximum intensity observed.
- t_{mid} is the time at which intensity has reached half of its maximum.
- a_1 is related to the slope of I_t at $t = t_{mid}$ via $\frac{d}{dt}I(t)t = t_{mid} = a_1 I_{max}/4$.

Double-sigmoidal function

Multipy two sigmoidal functions [CTW18]:

$$f_{dsig-base}(t) = \frac{1}{1 + exp(-a'_1(t - t'_{mid1}))} \frac{1}{1 + exp(-a'_2(t - t'_{mid2}))} \quad (2)$$

- Let t^* be the time at which $f_{dsig-base}(t)$ is maximal.
- Let $f_{max} = f_{dsig-base}(t^*)$.
- $$I(t) = f_{dsig}(t) = \begin{cases} c_1 f_{dsig-base}(t) \text{ for } t <= t^* \text{(growth phase)} \\ c_2 f_{dsig-base}(t) + I_{final} \text{ for } t > t^* \text{(decay phase)} \end{cases}$$
- $c_1 = \frac{I_{max}}{f_{max}}$
- $c_2 = \frac{(I_{max} - I_{final})}{f_{max}}$

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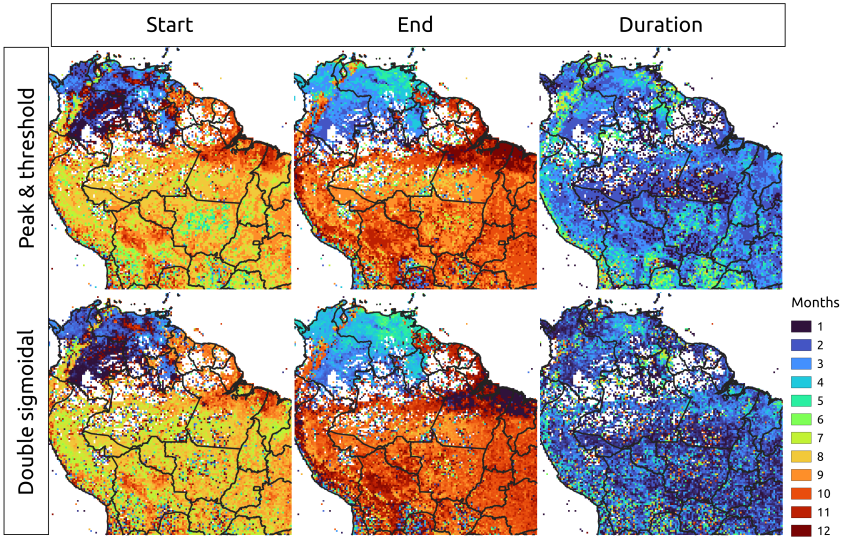
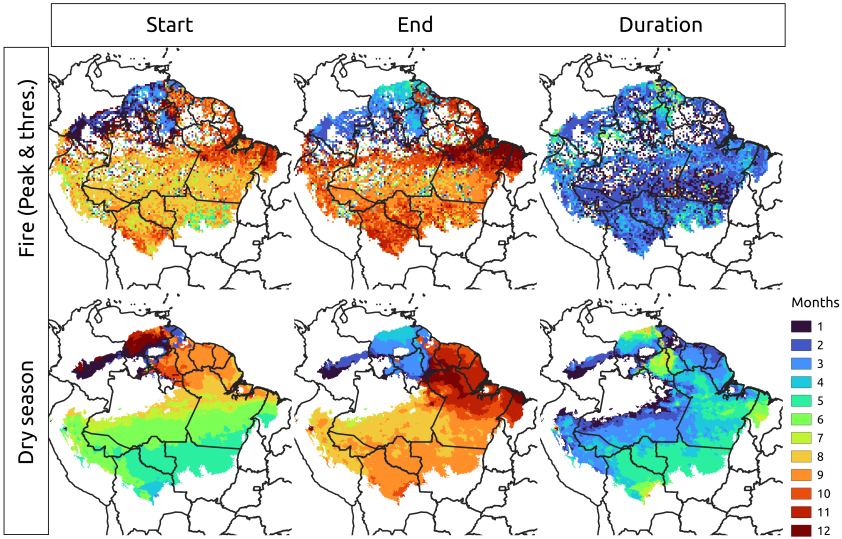
Results


Start
End
Duration
Peak & threshold
Double sigmoidal
Months
1
2
3
4
5
6
7
8
9
10
11
12

Fire & dry seasons

- Carvalho et al., [CAN+21] is actually about the establishing the dry season rather than the fire season.
- They use the fire spots to validate their results.
- Instead, we're using the fire spots to estimate the fire season and use [CAN+21], to validate them.

Fire & dry seasons



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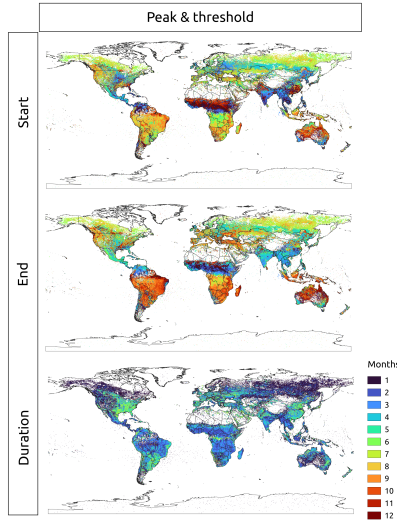
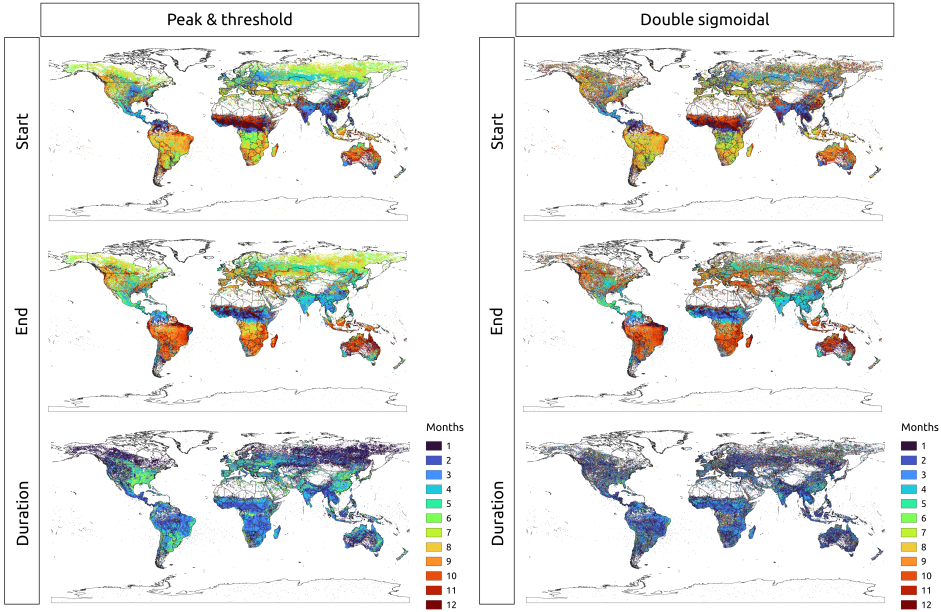
Final remarks

- We ran both methods for the world.
- Both peak & threshold and double-sigmoidal methods can be employed to estimate season of Earth Observation phenomena besides fire.
- Source code available at https://github.com/albhasan/seasonmetrics.




Peak & threshold
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Next steps

- Research question *Is the fire season changing? If so, how?*
- Estimate the fire season over 20 years of data (using MODIS).
- Compute yearly deviations from the 20-year estimation. Choose particularly dry years.
- Check how well the fire season fits inside the dry season. Is the peak of the fire season inside the dry season? Is it centered?
- Generate figures and data to answer the research question.

References I

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- Ross Ihaka and Robert Gentleman, *R: A Language for Data Analysis and Graphics*, Journal of Computational and Graphical Statistics **5** (1996), no. 3, 299.
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