

Total lightning and precipitation over Brazil: An overview from 12-years of TRMM satellite



Rachel Albrecht¹, Kleber Naccarato², Osmar Pinto Jr.², Iara Pinto²

¹ Center for Weather and Climate Studies (CPTEC/INPE)

² Atmospheric Electricity Laboratory (ELAT/INPE)

WWW.CPTEC.INPE.BR

Tropical Rainfall Measuring Mission (TRMM) was designed to measure the spatial and temporal variation of the precipitation in the tropics:

- **Precipitation Radar (PR)**
- **TRMM Microwave Imager (TMI)**
- **Visible and InfraRed Scanner (VIRS)**
- **Cloud and Earth Radiant Energy Sensor (CERES)**
- **Lightning Imaging Sensor (LIS)**

TRMM satellite was launched in late 1997 and is still operating, giving us 13+ years of measurements to this date of rainfall and total lightning (intracloud and cloud-to-ground):

- and we (scientists) know that rainfall is not always well correlated to lightning production...
- ... but some decision makers don't (i.e., power companies, etc.).

1) The objective of this study is to create a total lightning climatology map over Brazil and relate it to its associated precipitation, showing the correlations (or lack of correlations) between lightning and rainfall. We also rank cities according to:

- total lightning flash rate density (**FRD** – fl km⁻² yr⁻¹);
- rainfall rate (**RR** – mm yr⁻¹)
- rain yield per flash (**RYF** - kg fl⁻¹)

$$\begin{aligned}\mathbf{RYF} &= (\text{rain amount}) / (\text{number of flashes}) \\ &= (\mathbf{RR})/(\mathbf{FRD}) * 1e6\end{aligned}$$

small RYF ---> more flash per rain

large RYF ---> less flash per rain

2) As we now have more than a decade of measurements, we “can try to find” some tendency signals on **FRD** and **RR**.

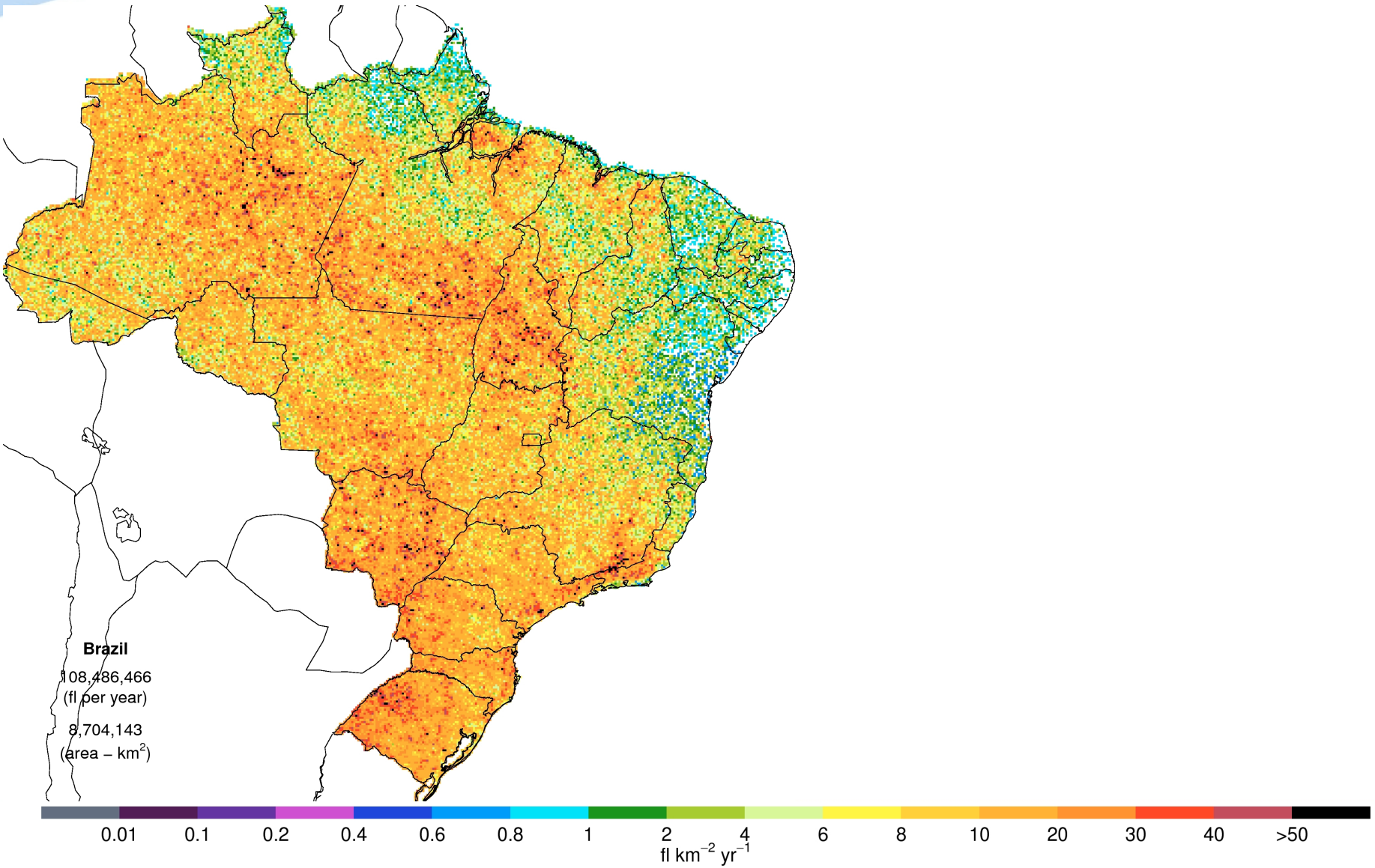
1) Compile total lightning climatology and rainfall over the tropics in 0.10° resolution:

- Track LIS CCD (charged coupled device) at each individual orbit in a 0.10° grid;
- FRD calculated by the cumulative method:
$$\text{FRD} = (\text{sum of all flashes in a } 0.10^\circ \text{ pixel}) / (\text{sum of all view time in the same } 0.10^\circ \text{ pixel})$$
- RR was taken from 3B43 TRMM product (0.25° resolution), and interpolated into 0.10° ;
- Find maximums (FRD and RR) over the whole Brazilian territory, and rank them.

2) Tendency signal:

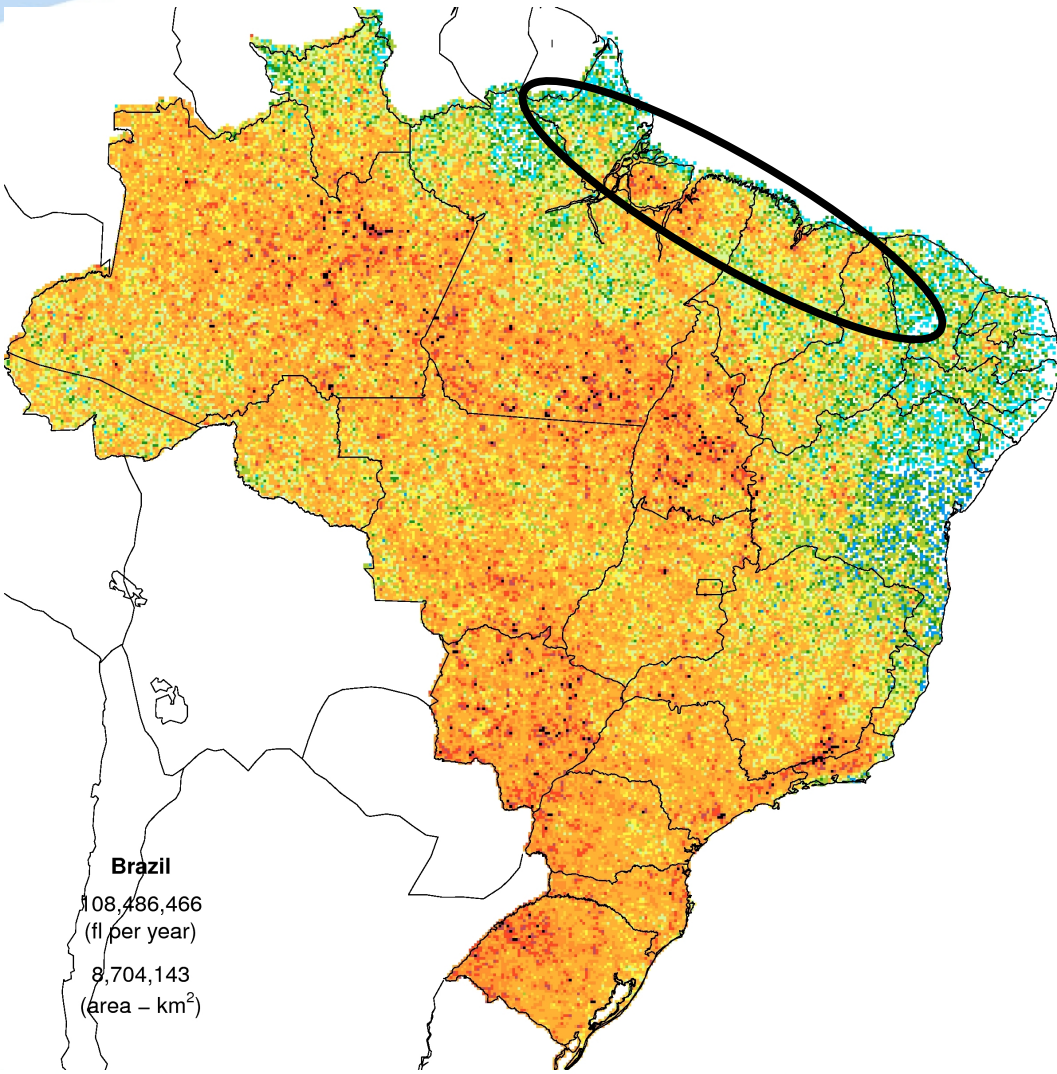
- Used the pre-boost swath to compute the total view time and number of flashes in a 0.50° resolution;
- Compiled yearly estimated total number of flashes in each 0.50° pixels from 1998 to 2008;
- Quantile linear regressions to calculate tendencies per quantile.

TRMM total flash rate density (FRD) climatology over Brazil (1998-2009)



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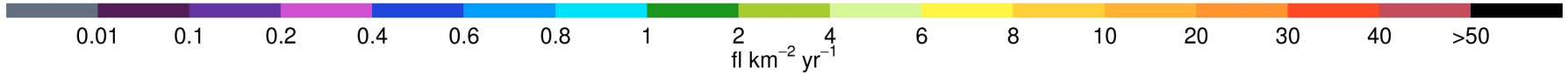
- Sea breeze, coastal squall lines, easterly wave convection, ITCZ;



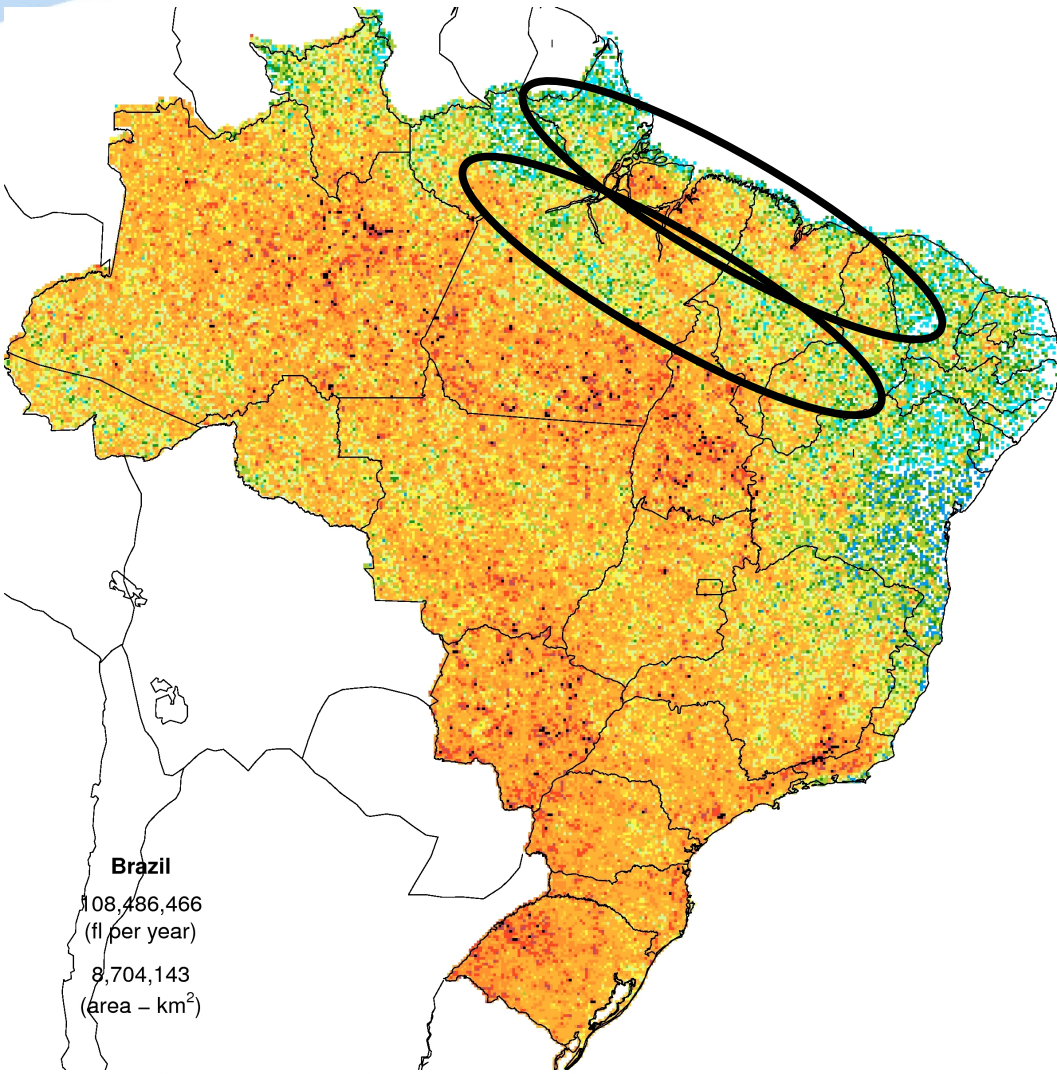
Brazil

108,486,466
(fl per year)

8,704,143
(area - km²)

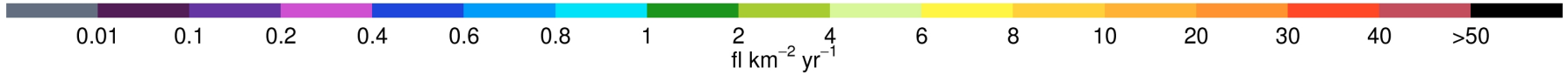


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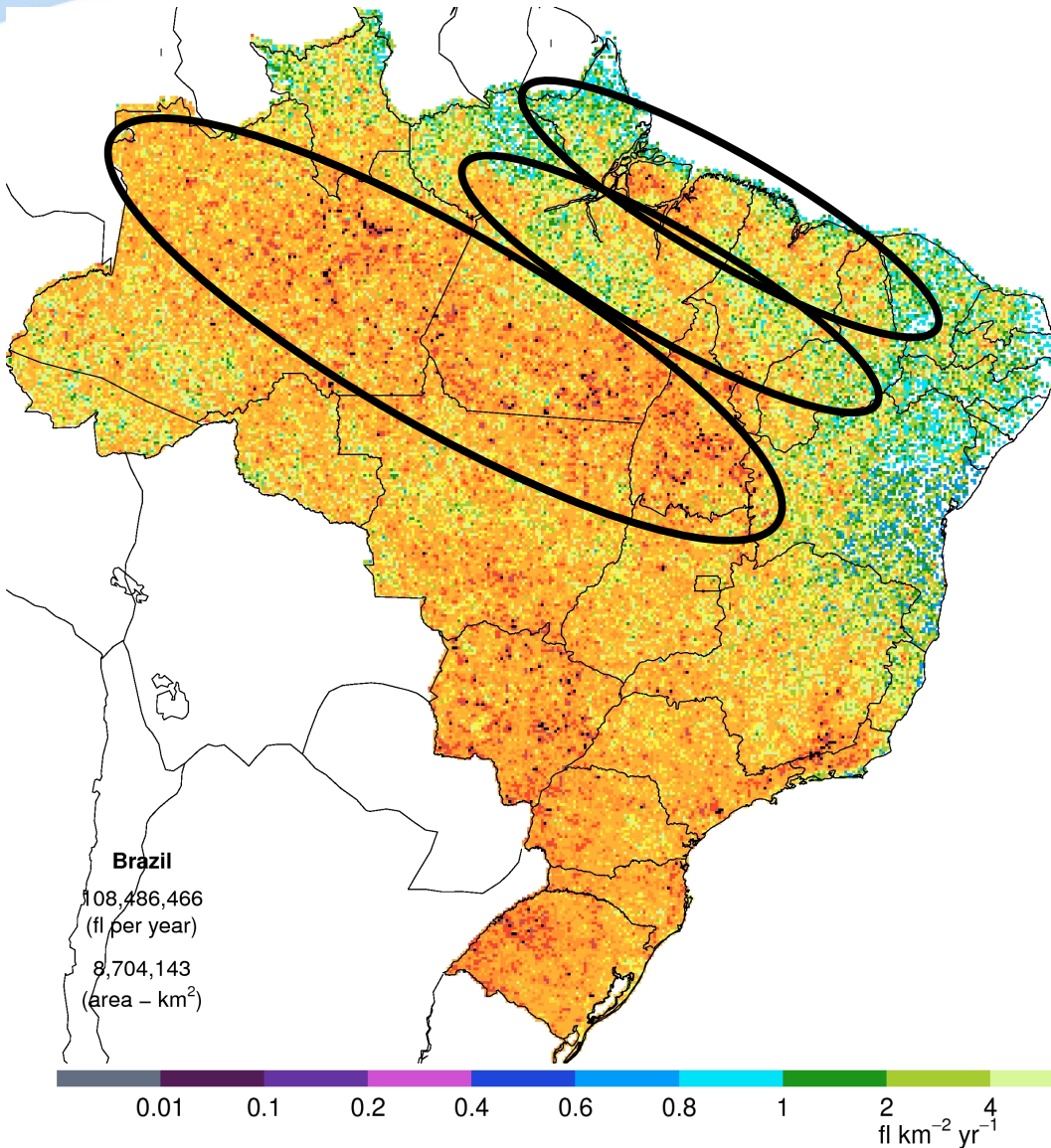


- Sea breeze, coastal squall lines, easterly wave convection, ITCZ;
- Coastal squall lines (minimum activity);

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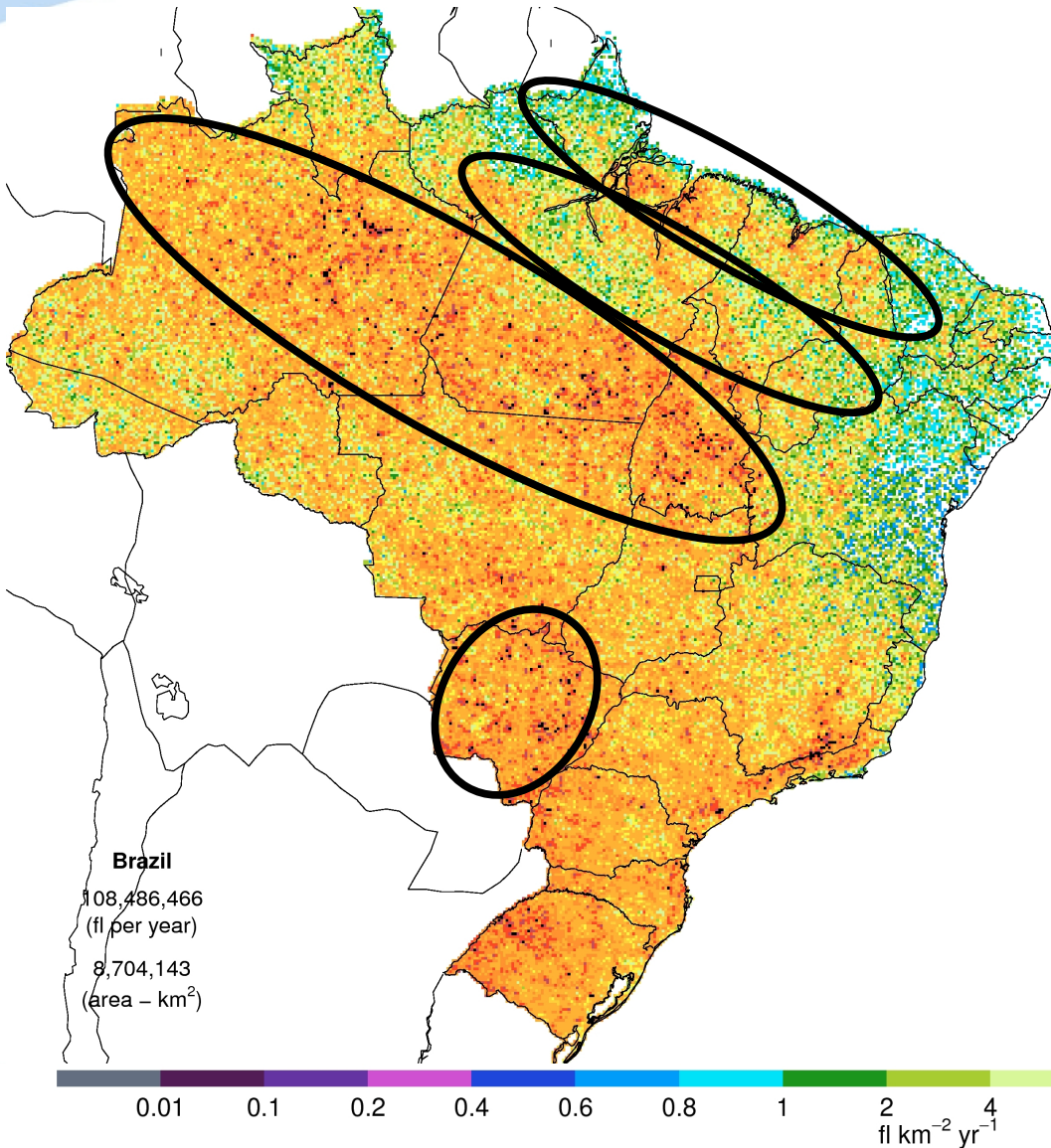


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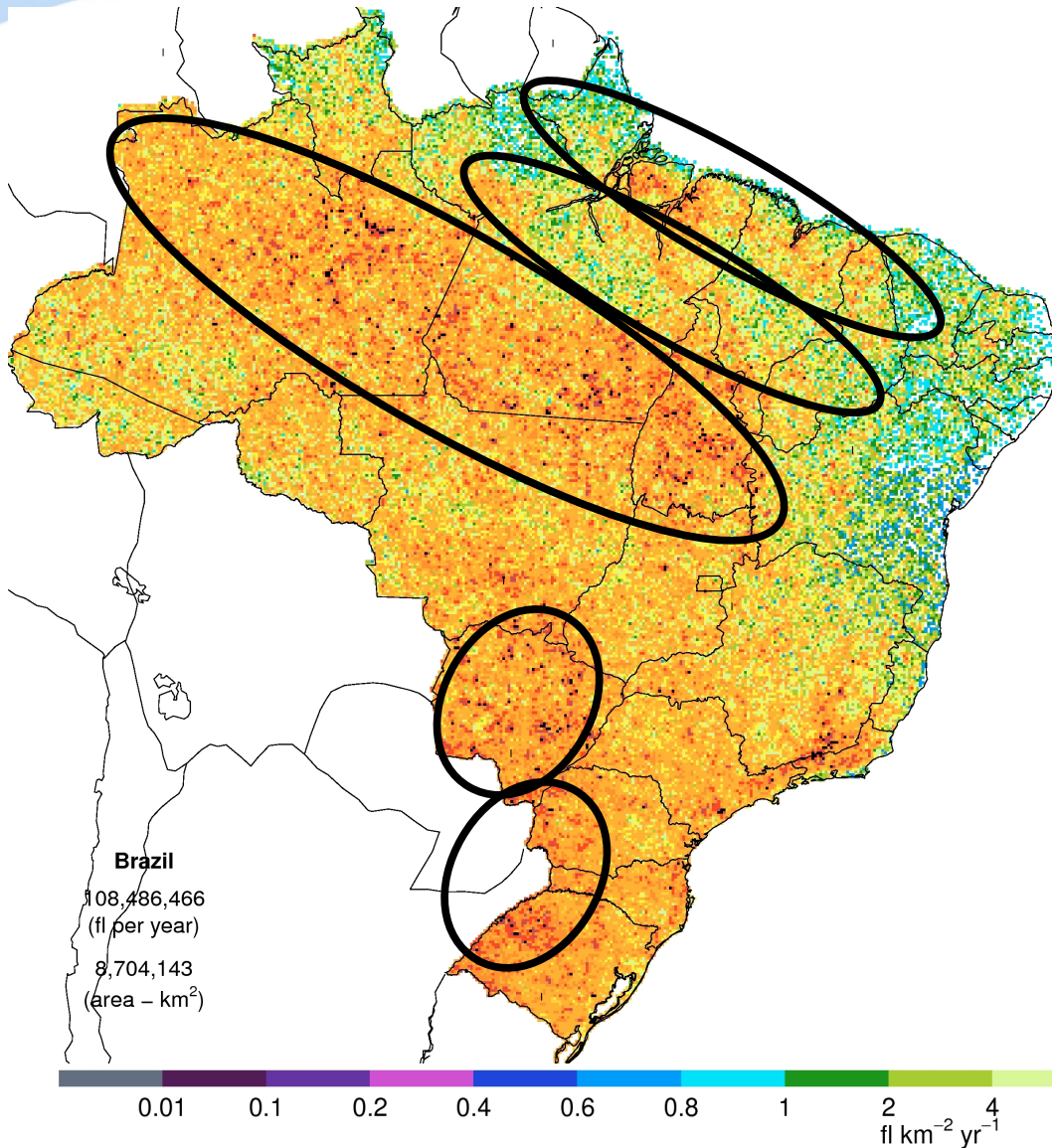
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- Coastal squall lines (minimum activity);
- Amazonian convection (local, squall lines, MCS, SACZ, ITCZ);

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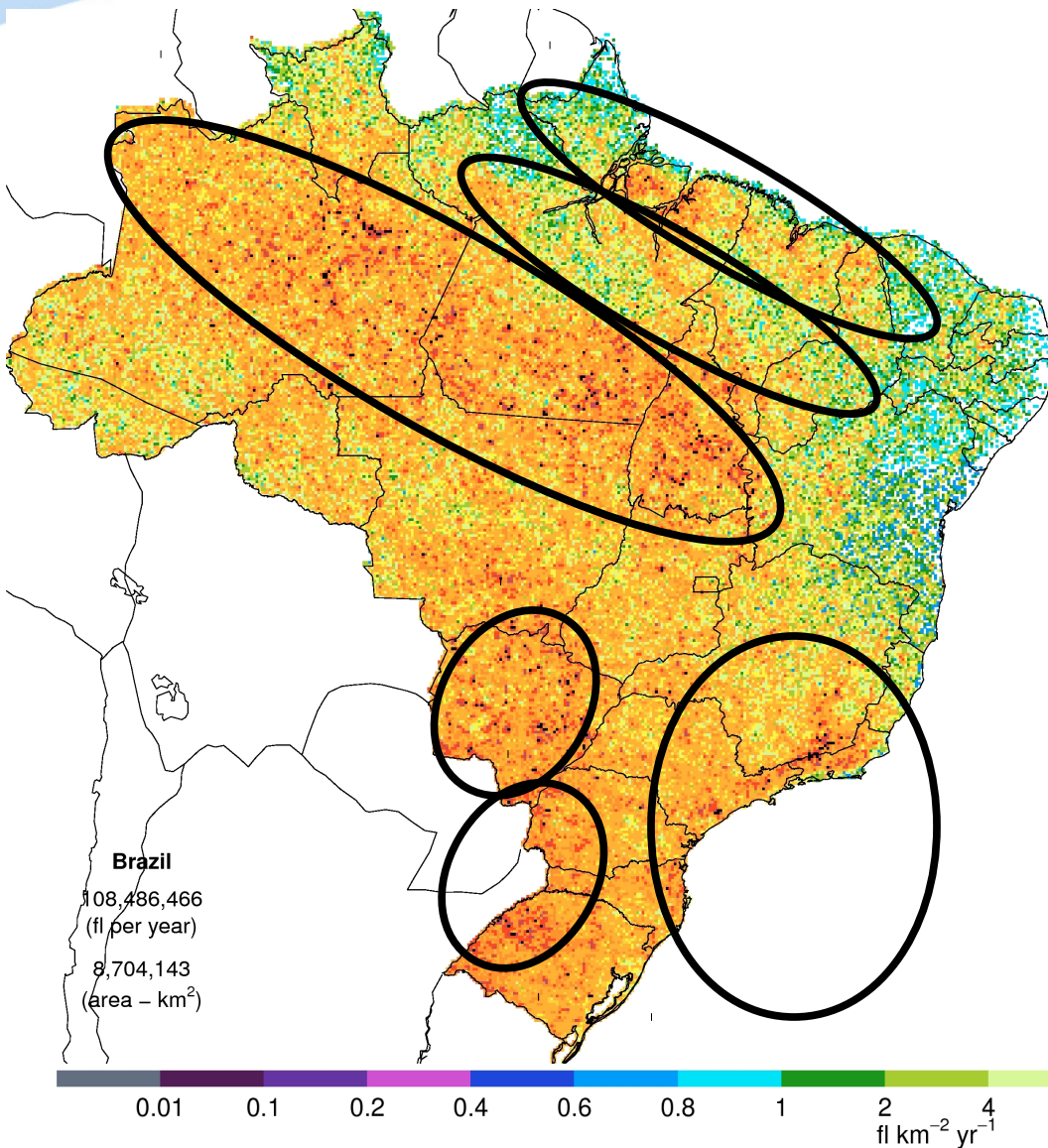
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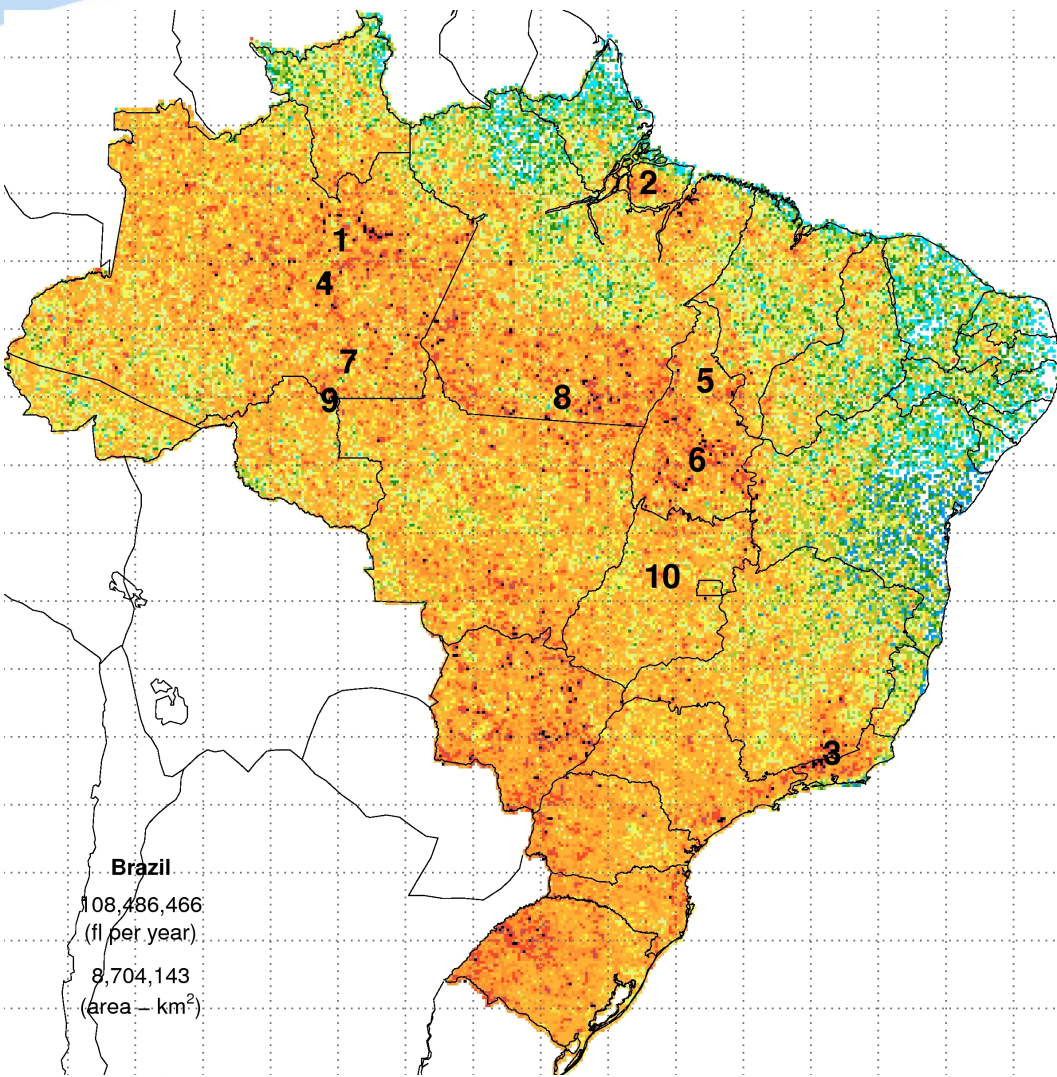
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- MCS, local convection;
- MCS originated in Argentina, cold fronts;

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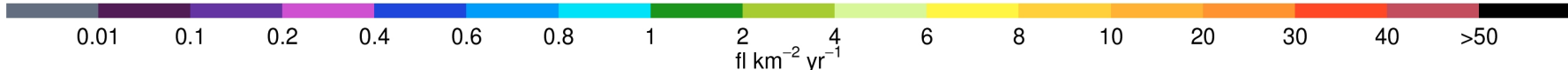


- Sea breeze, coastal squall lines, easterly wave convection, ITCZ;
- Coastal squall lines (minimum activity);
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- MCS, local convection;
- MCS originated in Argentina, cold fronts;
- (Sea breeze, SACZ) + local topography

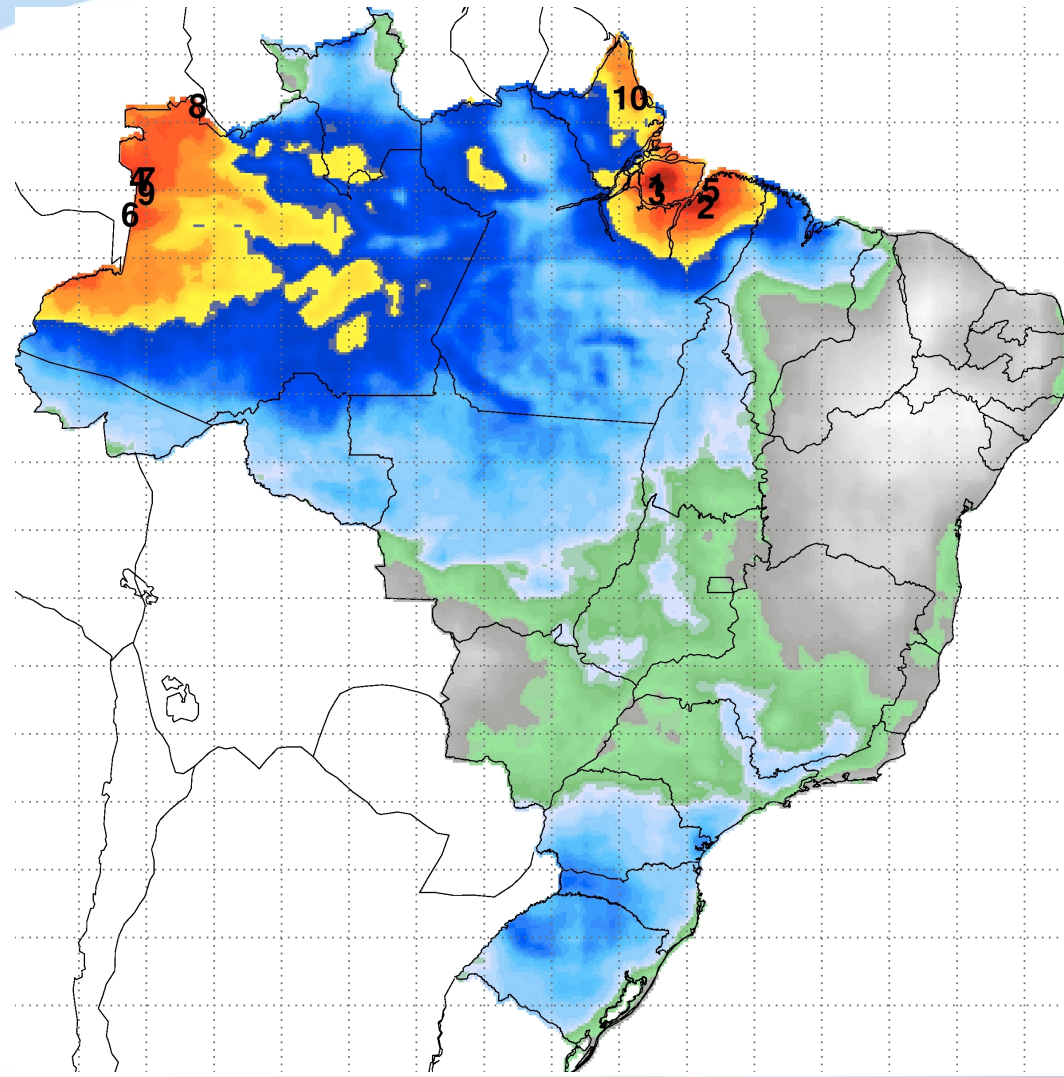
Ranking of TRMM total flash rate density (FRD) climatology over Brazil (1998-2009)



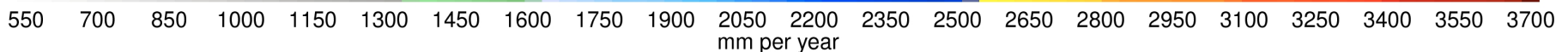
Rank	FRD	City
1	93.5	Cláudio, AM
2	89.9	Anajaz, PA
3	88.9	Belmot, MG
4	88.7	Piraiuara, AM
5	86.5	Cajueiro, TO
6	82.0	Estrema, TO
7	81.5	Santa Rosa, AM
8	80.2	Bela Vista, PA
9	77.9	Machadinho d'Oeste, RO
10	77.4	Castrinápolis, GO



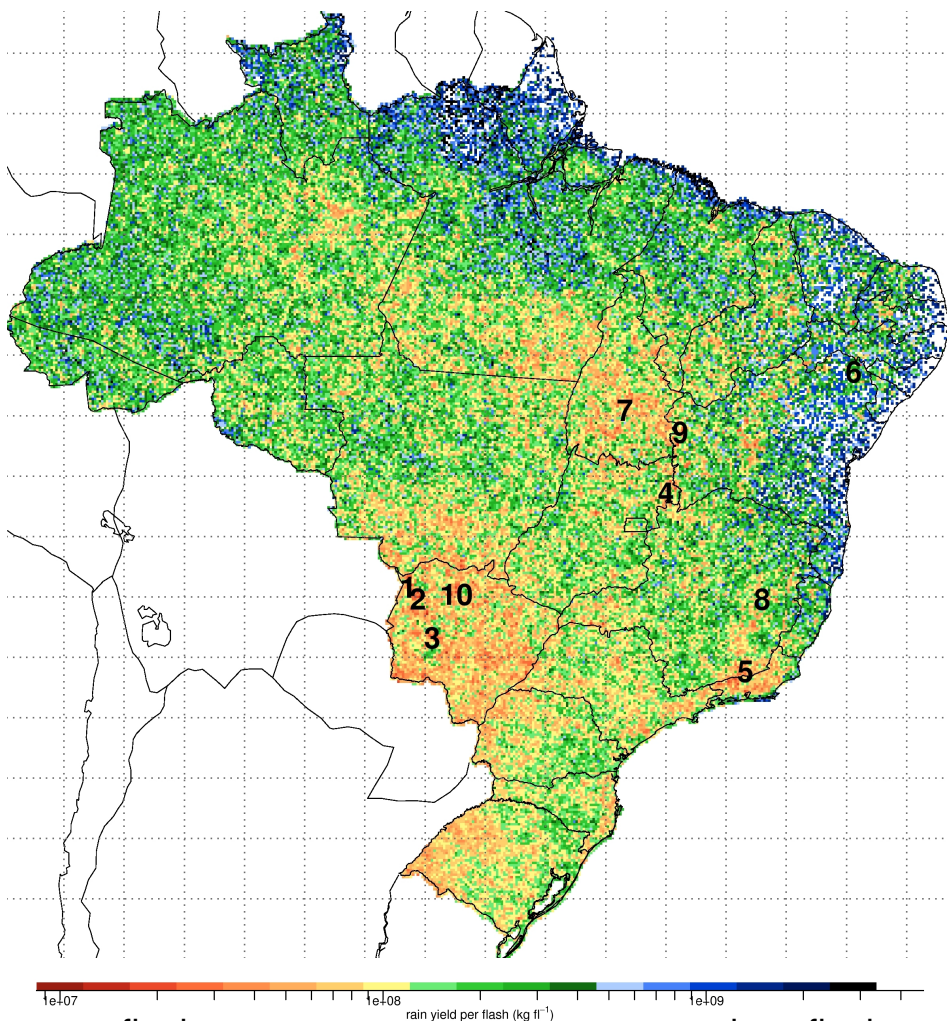
Ranking of rainfall (RR) climatology over Brazil (1998-2009)



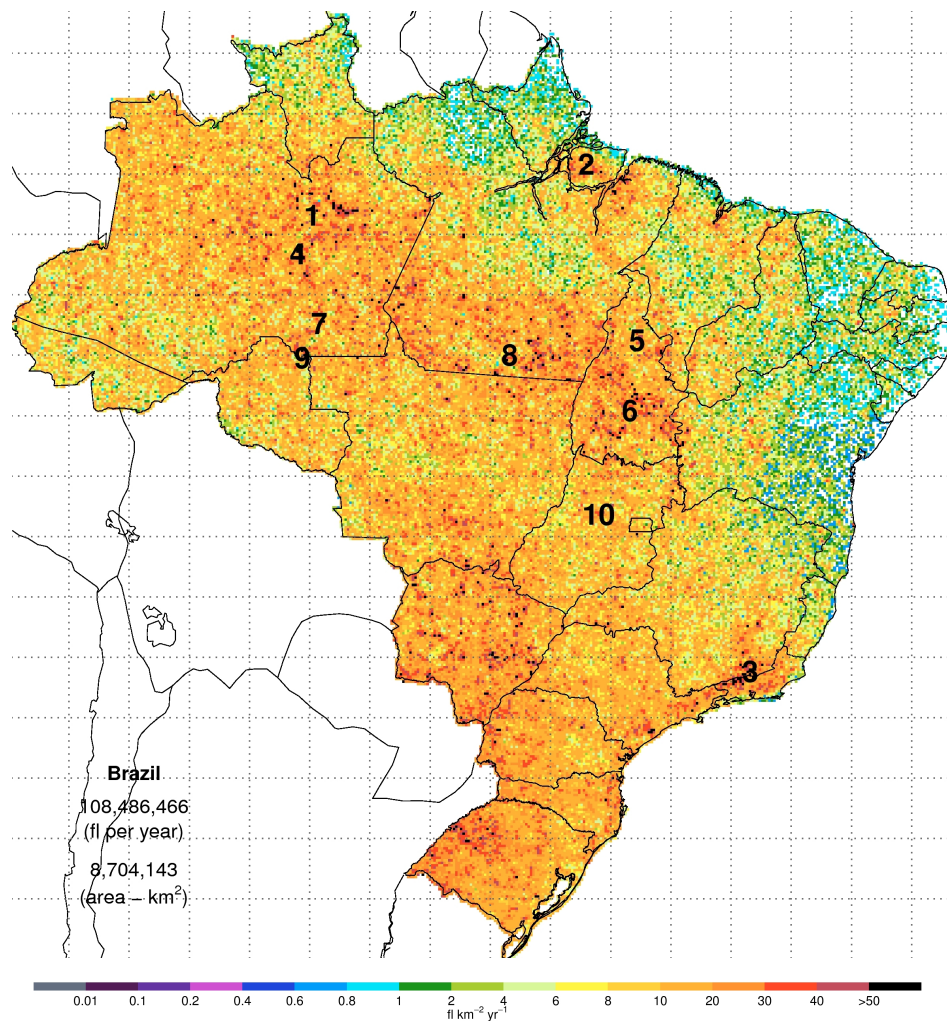
Rank	RR	City
1	3680	São Gabriel, PA
2	3559	Jupariteua, PA
3	3508	Vicente, PA
4	3470	Vilia Bittencourt, AM
5	3400	Santa Isabel do Pará, PA
6	3350	Manguari, AM
7	3348	Vilia Bittencourt, AM
8	3320	Macuxixiri, AM
9	3247	Mangari, AM
10	3216	Cachoeira Grande, PA



Rain yield per flash (RYF)



Flash rate density (FRD)

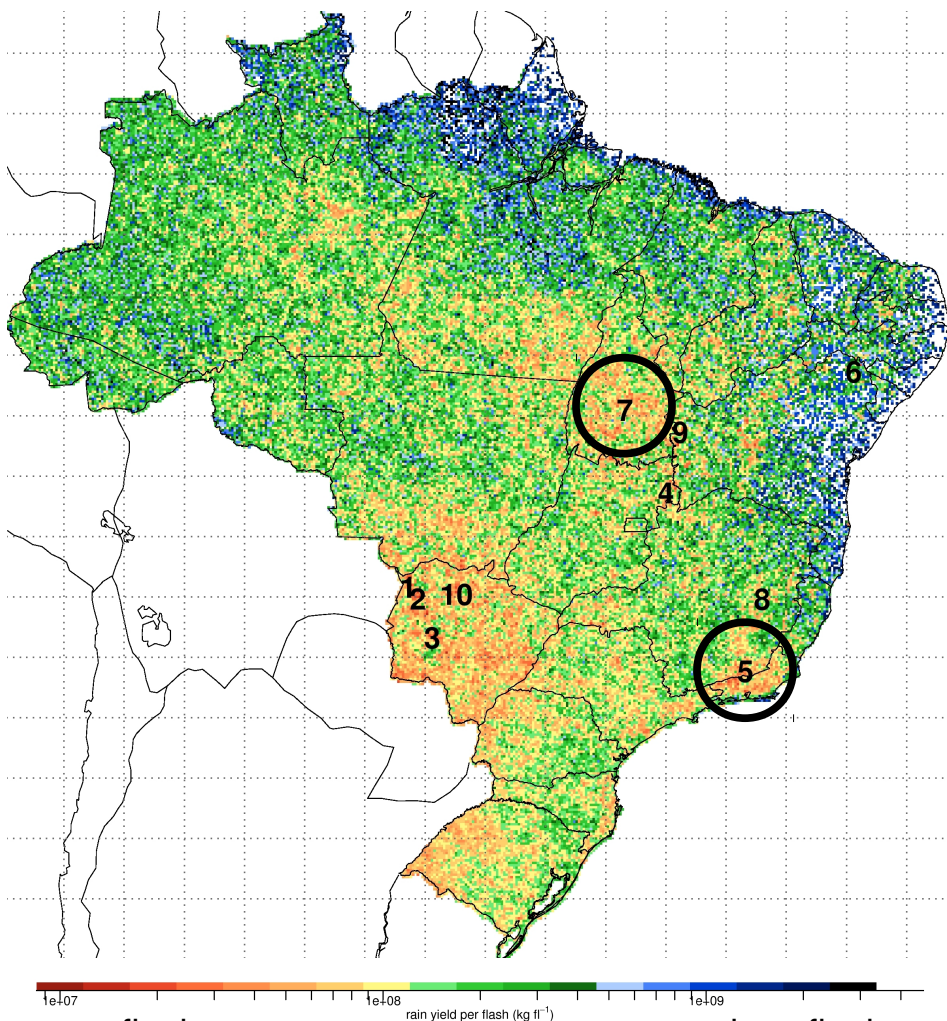


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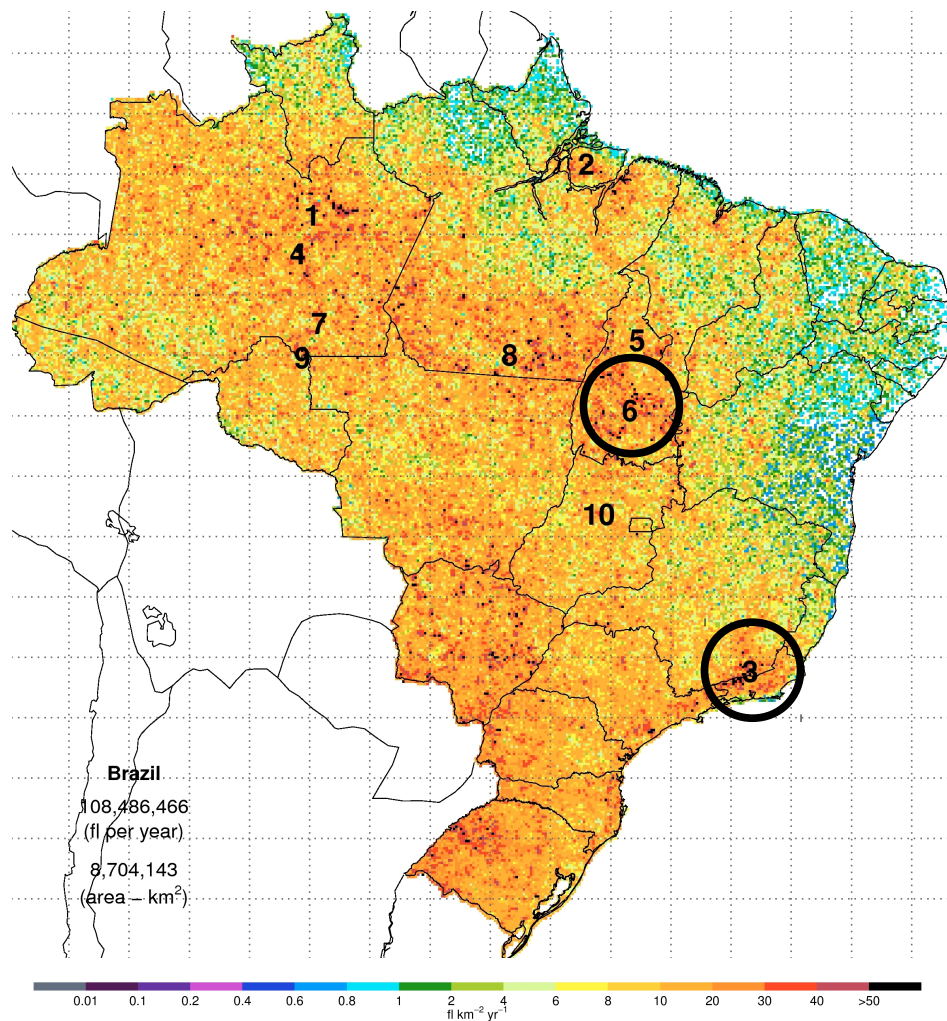
more flash
per rain

less flash
per rain

Rain yield per flash (RYF)



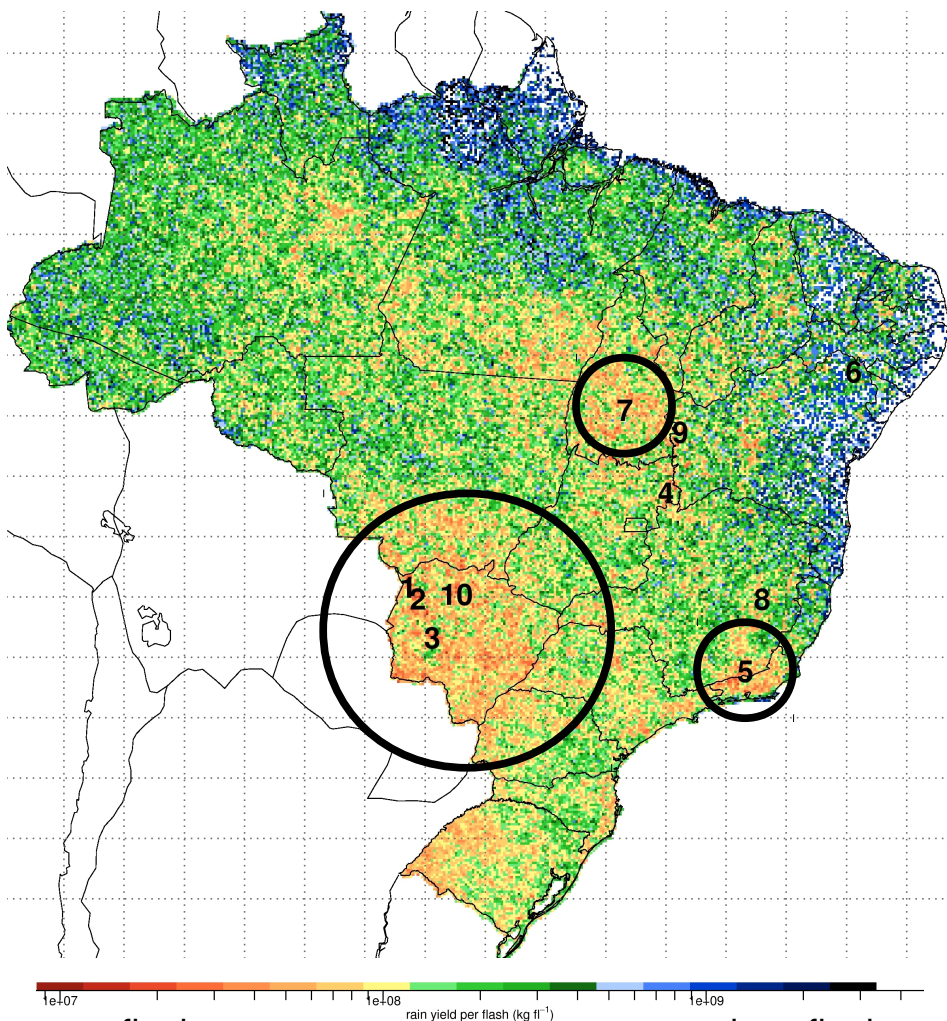
Flash rate density (FRD)



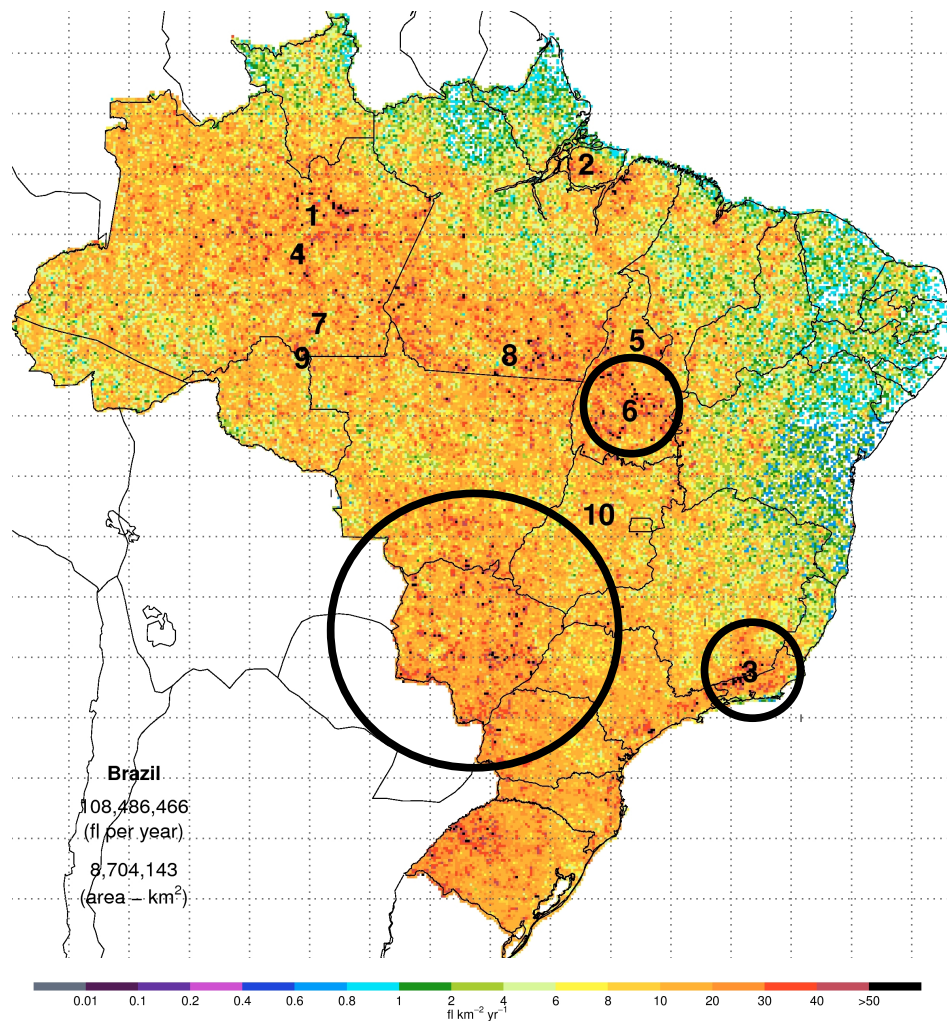
more flash
per rain

less flash
per rain

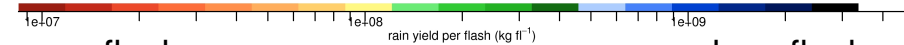
Rain yield per flash (RYF)



Flash rate density (FRD)



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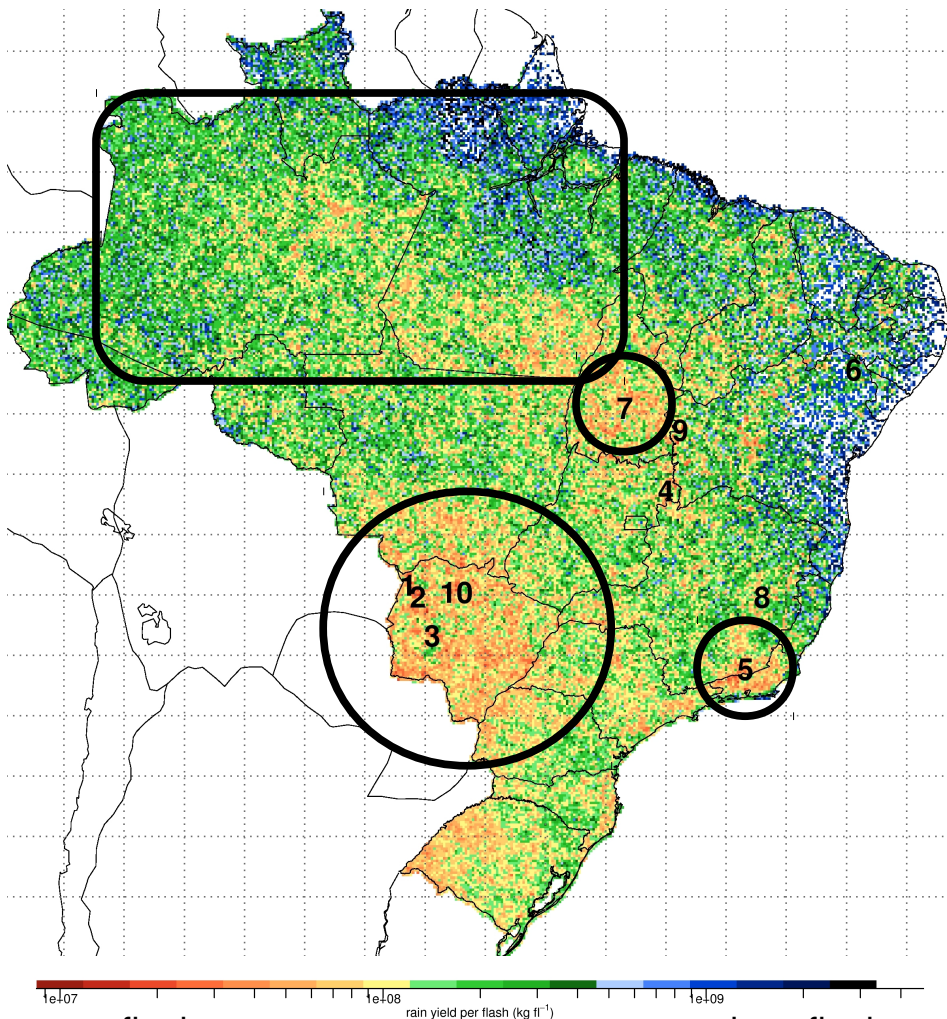


more flash
per rain

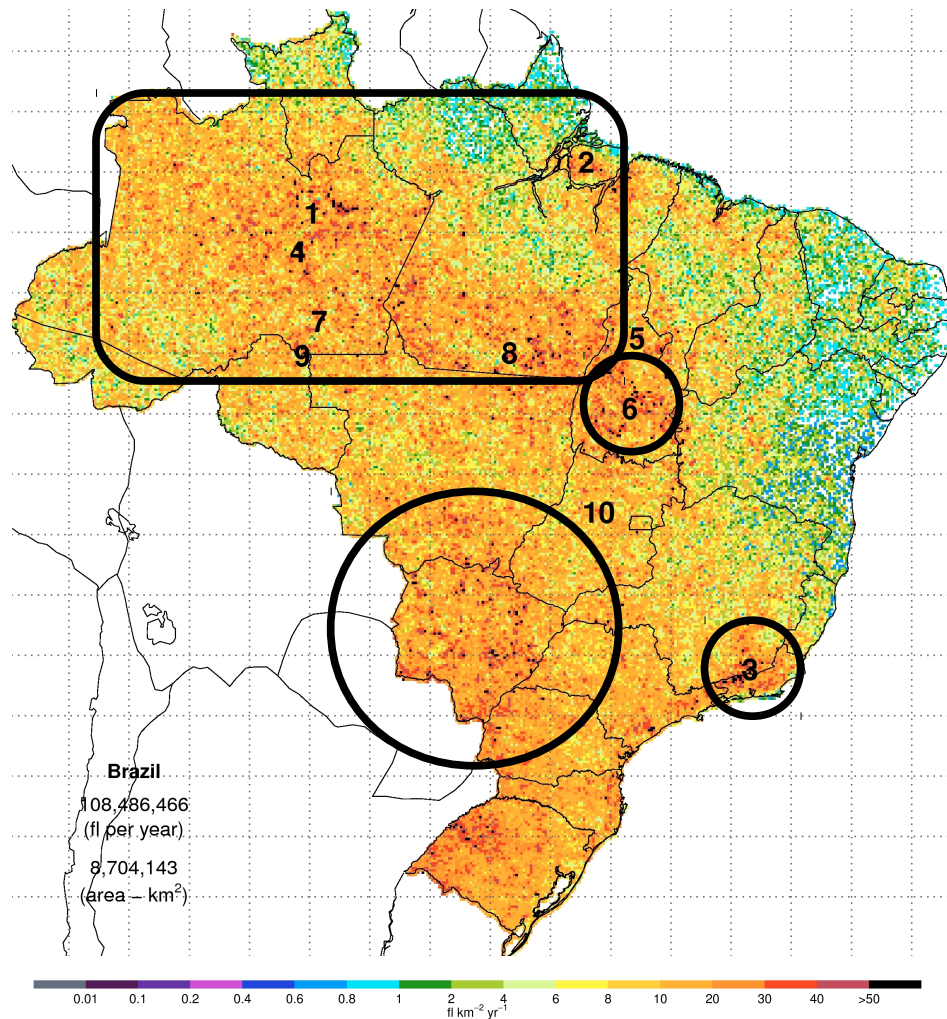
less flash
per rain



Rain yield per flash (RYF)



Flash rate density (FRD)



more flash
per rain

less flash
per rain

Tendency signal:

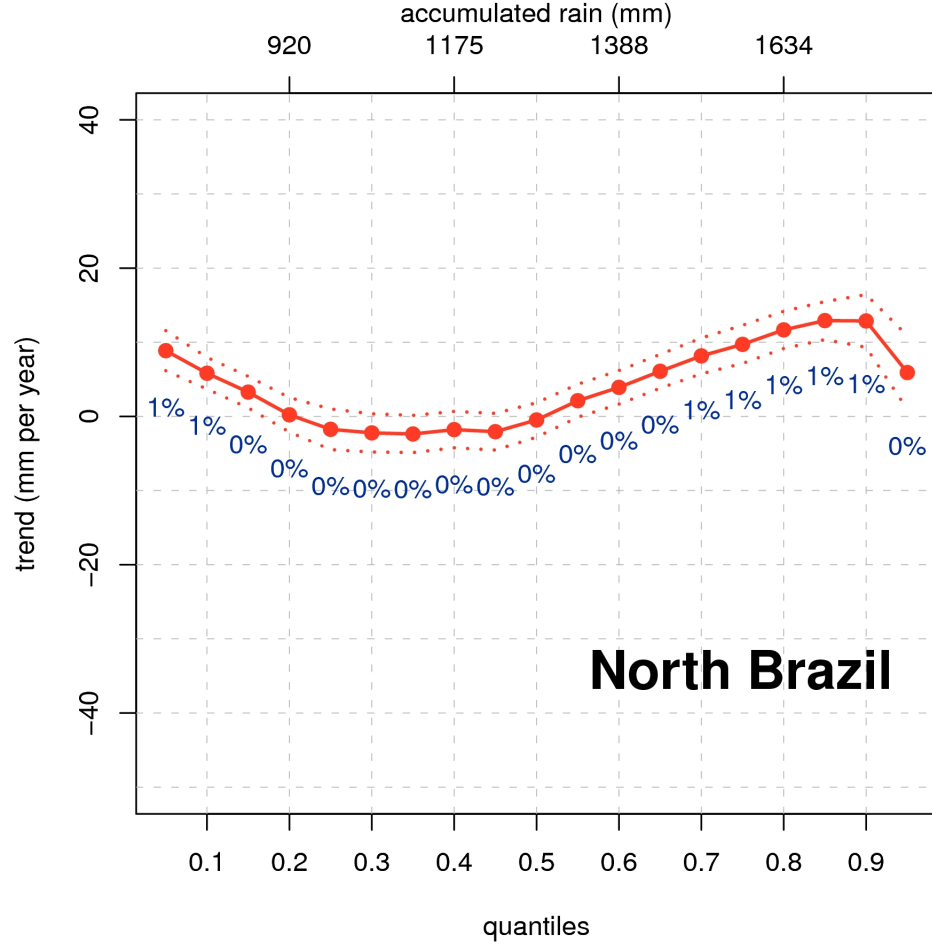
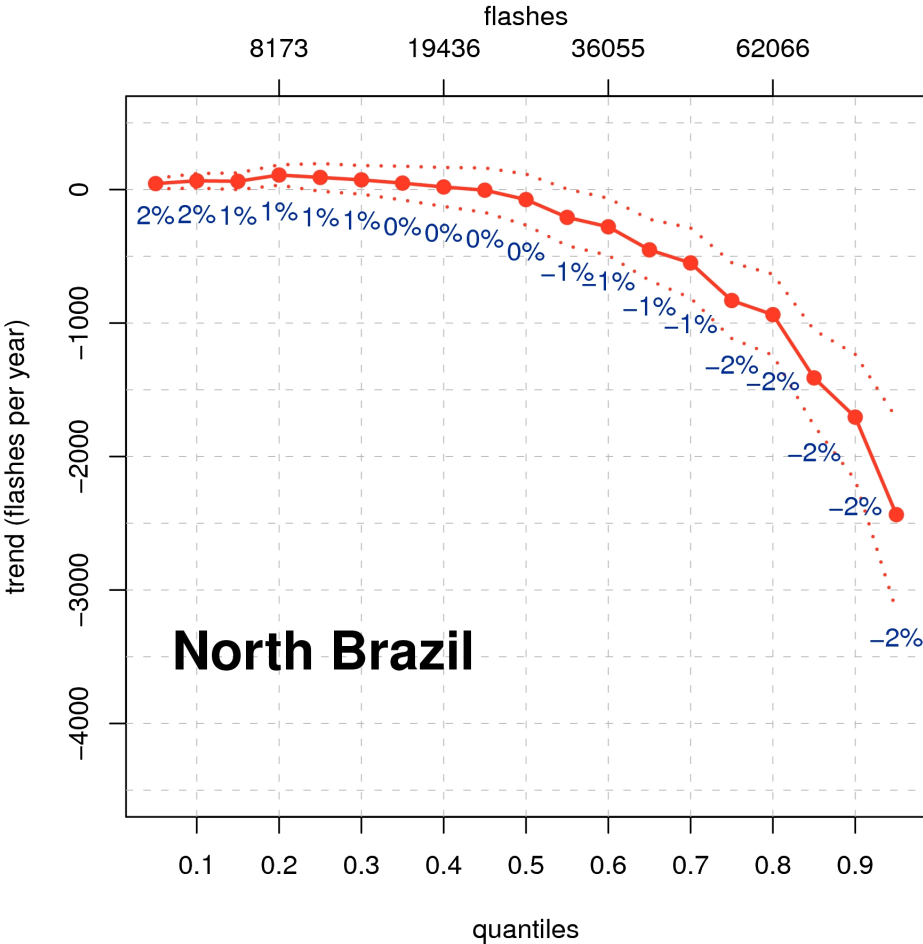
- Use the pre-boost swath to compute the total view time and number of flashes in a 0.50° resolution for each year from 1998 to 2008;
- **Quantile linear regression** calculated for Brazil's political regions:



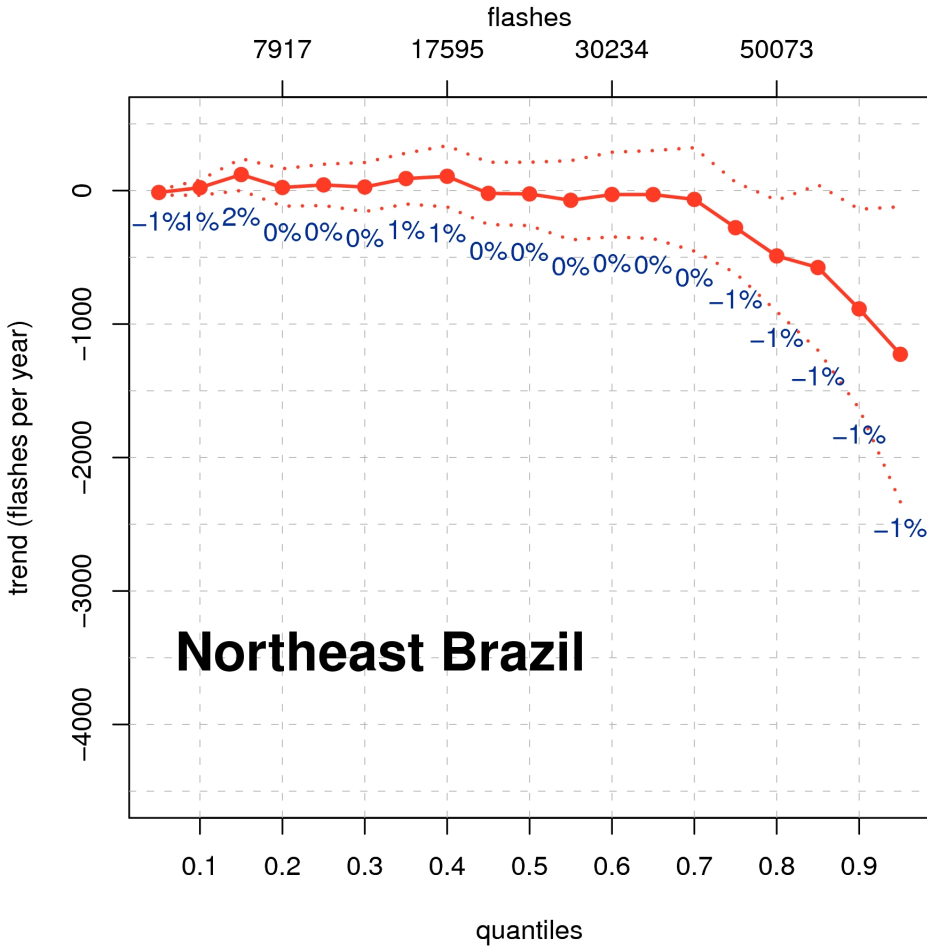
- Method to estimate the change (trend) of flash rate density (FRD) quantiles as a function of the year;
- A quantile is a point taken from the inverse cumulative distribution function of the FRD so that, for examples, the 0.7 quantile is the value such that 70% of the yearly FRD have FRD below this value (70th percentile);

FLASH TENDENCY

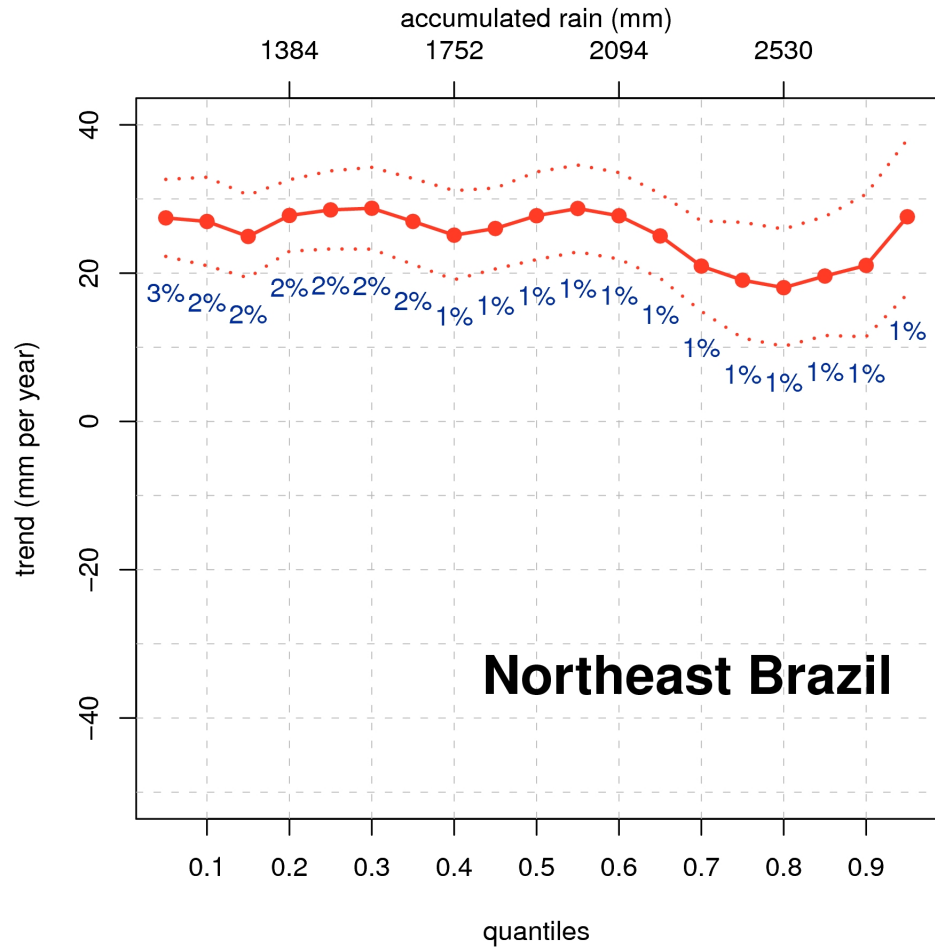
RAINFALL TENDENCY



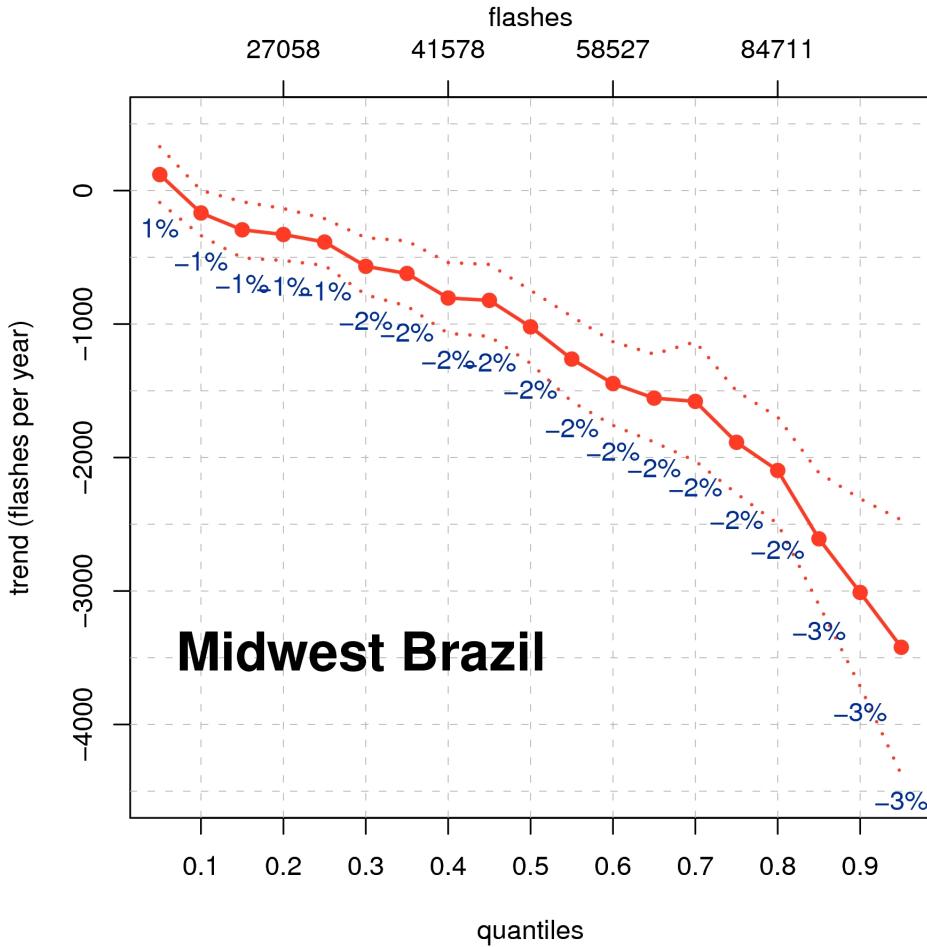
FLASH TENDENCY



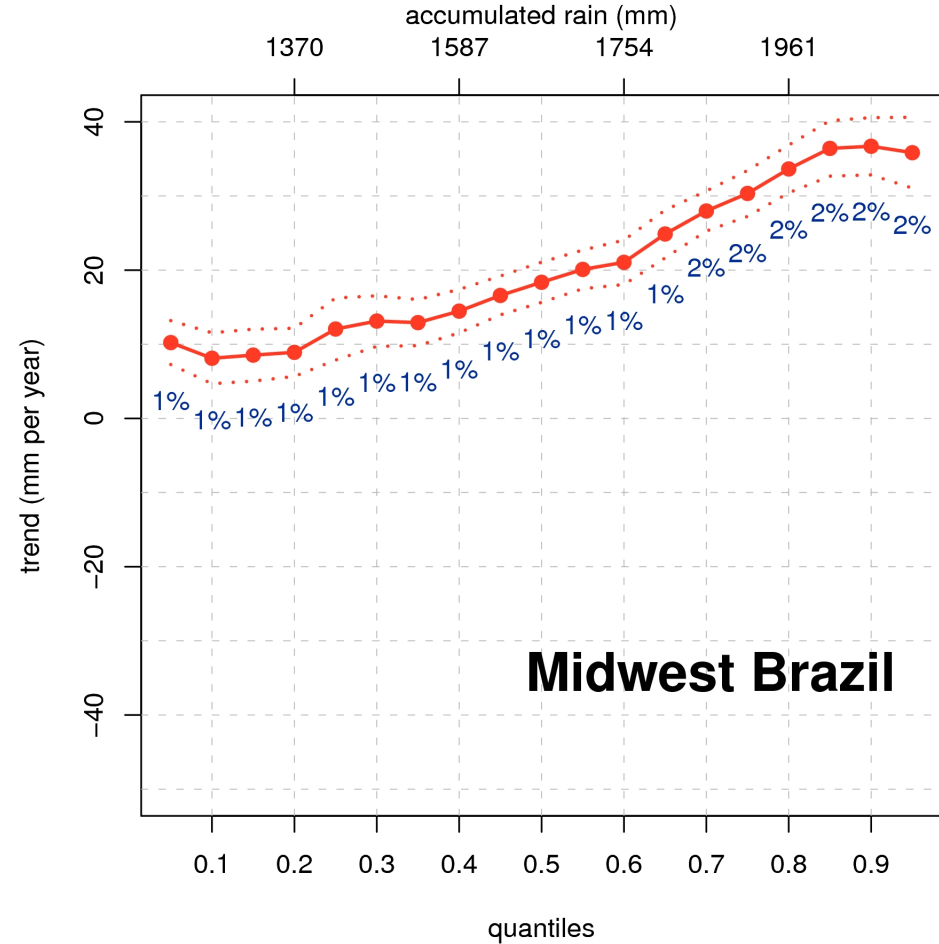
RAINFALL TENDENCY



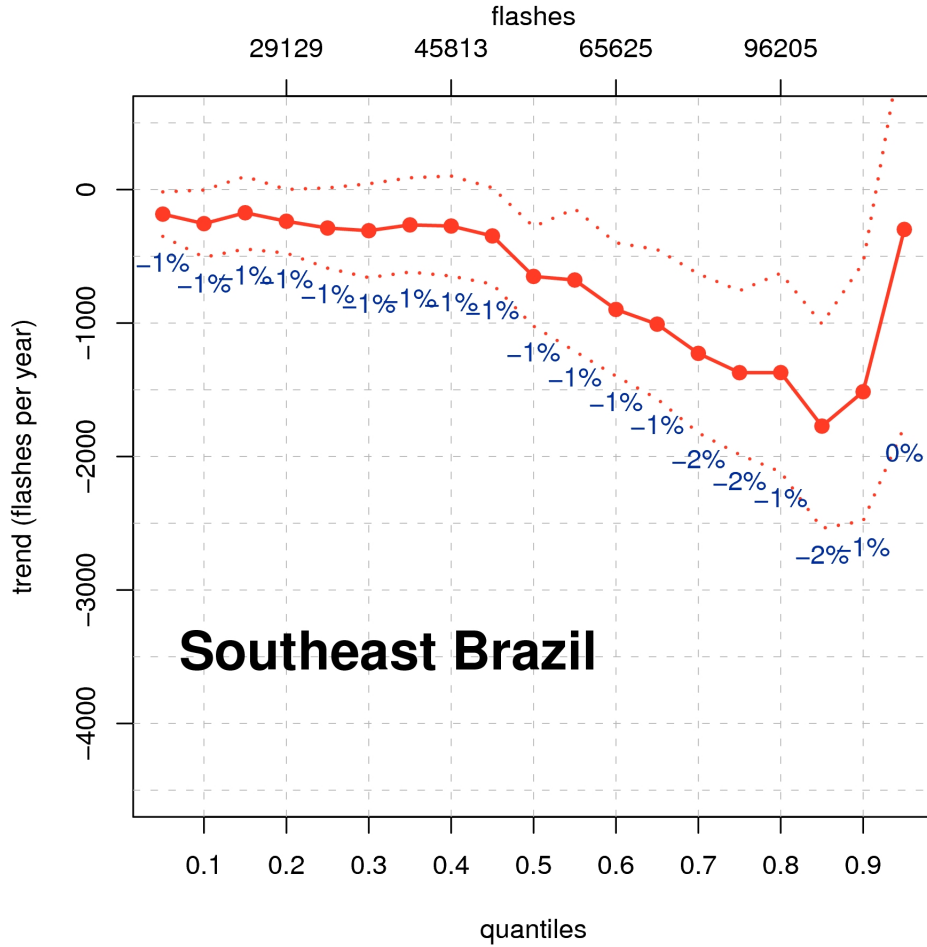
FLASH TENDENCY



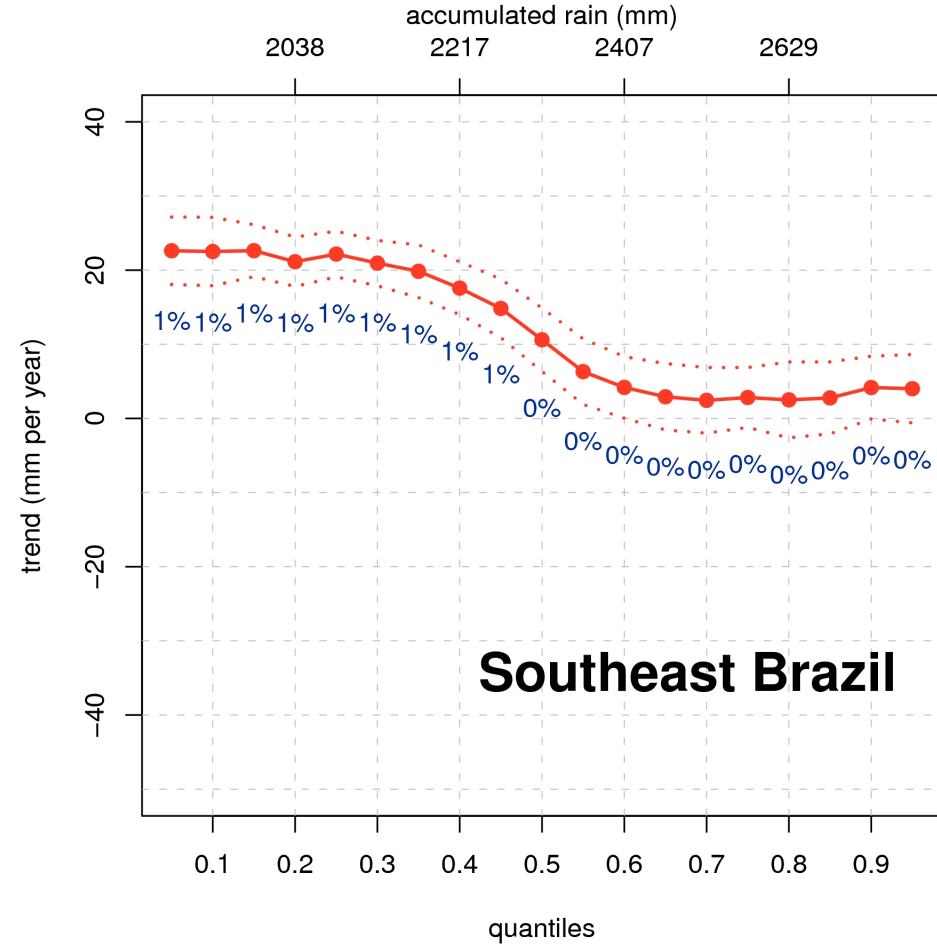
RAINFALL TENDENCY



FLASH TENDENCY

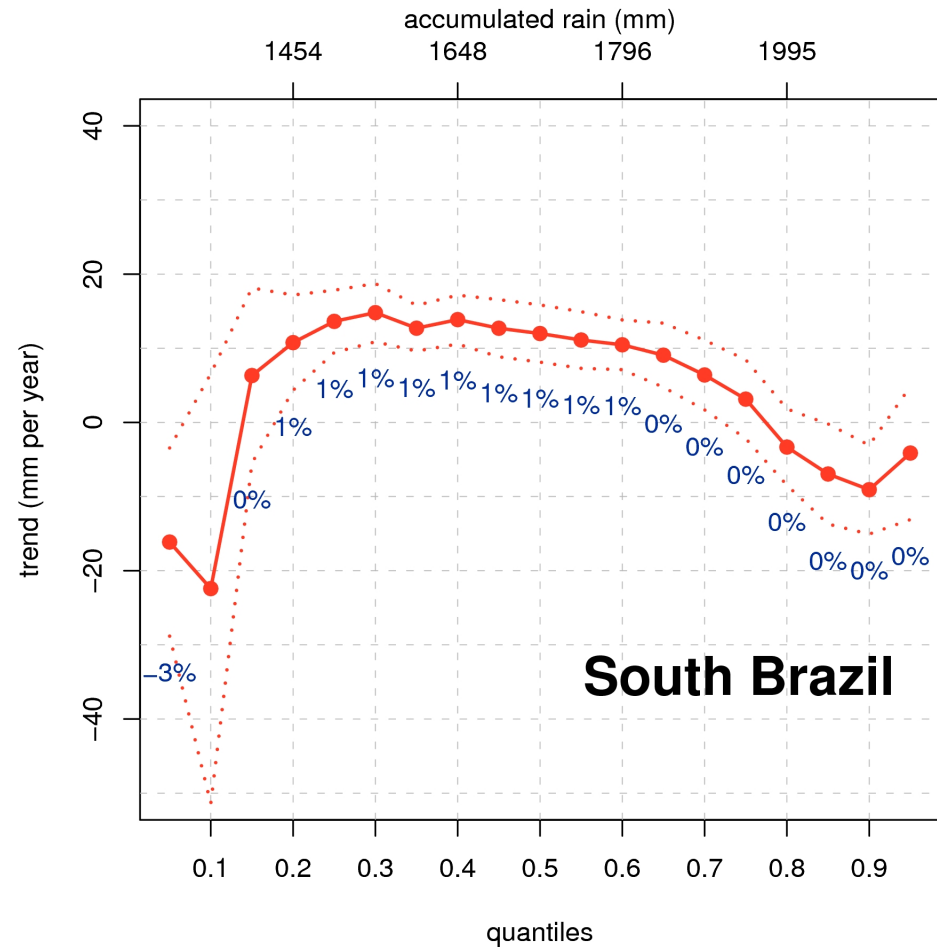
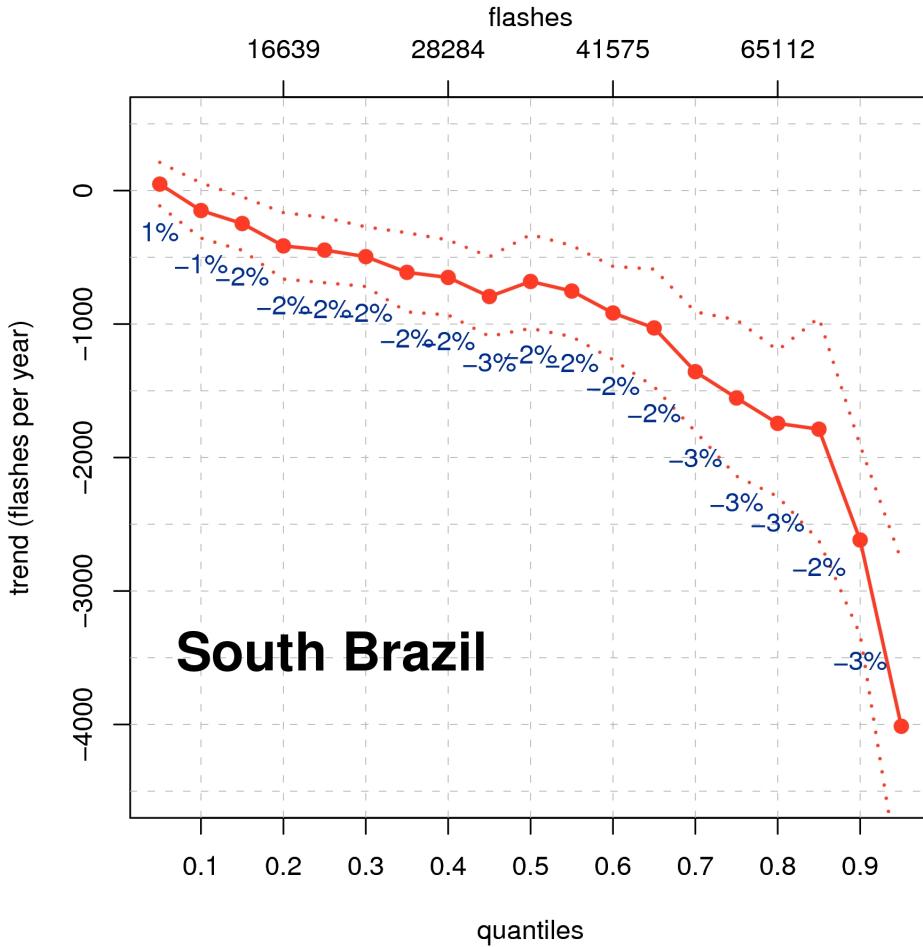


RAINFALL TENDENCY



FLASH TENDENCY

RAINFALL TENDENCY



- Brazil's total lightning “hot-spots” are concentrated in the North region (Amazon basin), except for the 3rd maximum (it is in Southeast Brazil).
- Also, the highest rainfall is observed over (and exclusively) the Amazon, but they don't coincide with the lightning “hot-spots”.
- The most efficient storms in producing lightning per rainfall (small RYF) are located in the Midwest, Southeast and South regions of Brazil.
- Total lightning and rainfall tendencies revealed small trends ($\pm 3\%$):
 - # of flashes: highest negative trends observed at the largest quantiles (highest flash rates)
 - accumulated rainfall: 1-2% increase in most of the quantiles
 - trends could be on the instruments' intrinsic errors.