



CPTEC

Centro de Previsão de Tempo e Estudos Climáticos



MINISTÉRIO DA CIÊNCIA E TECNOLOGIA
INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS

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



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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**.

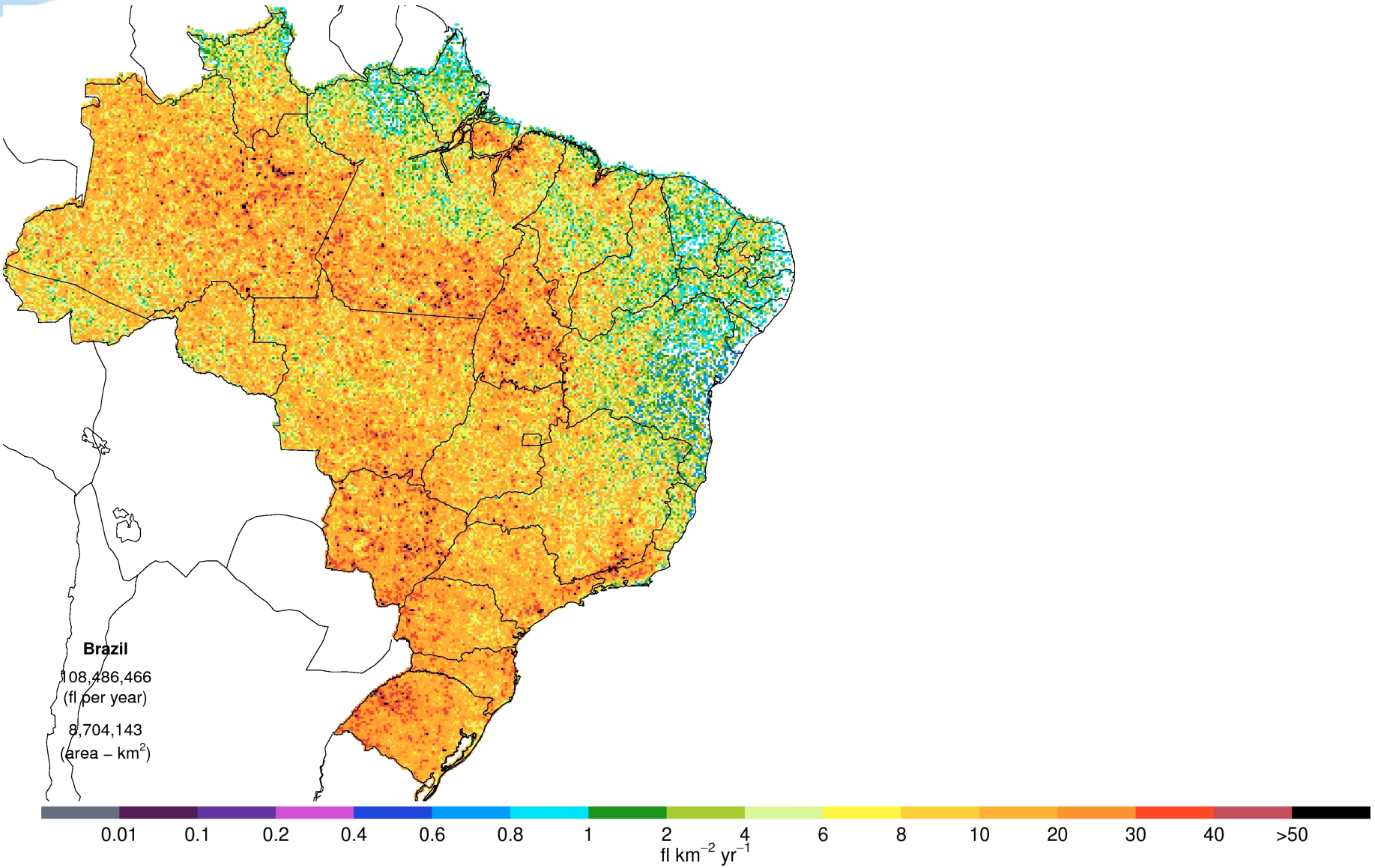
1) Compile total lightning climatology and rainfall over the tropics in 0.10° resolution:

- 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:

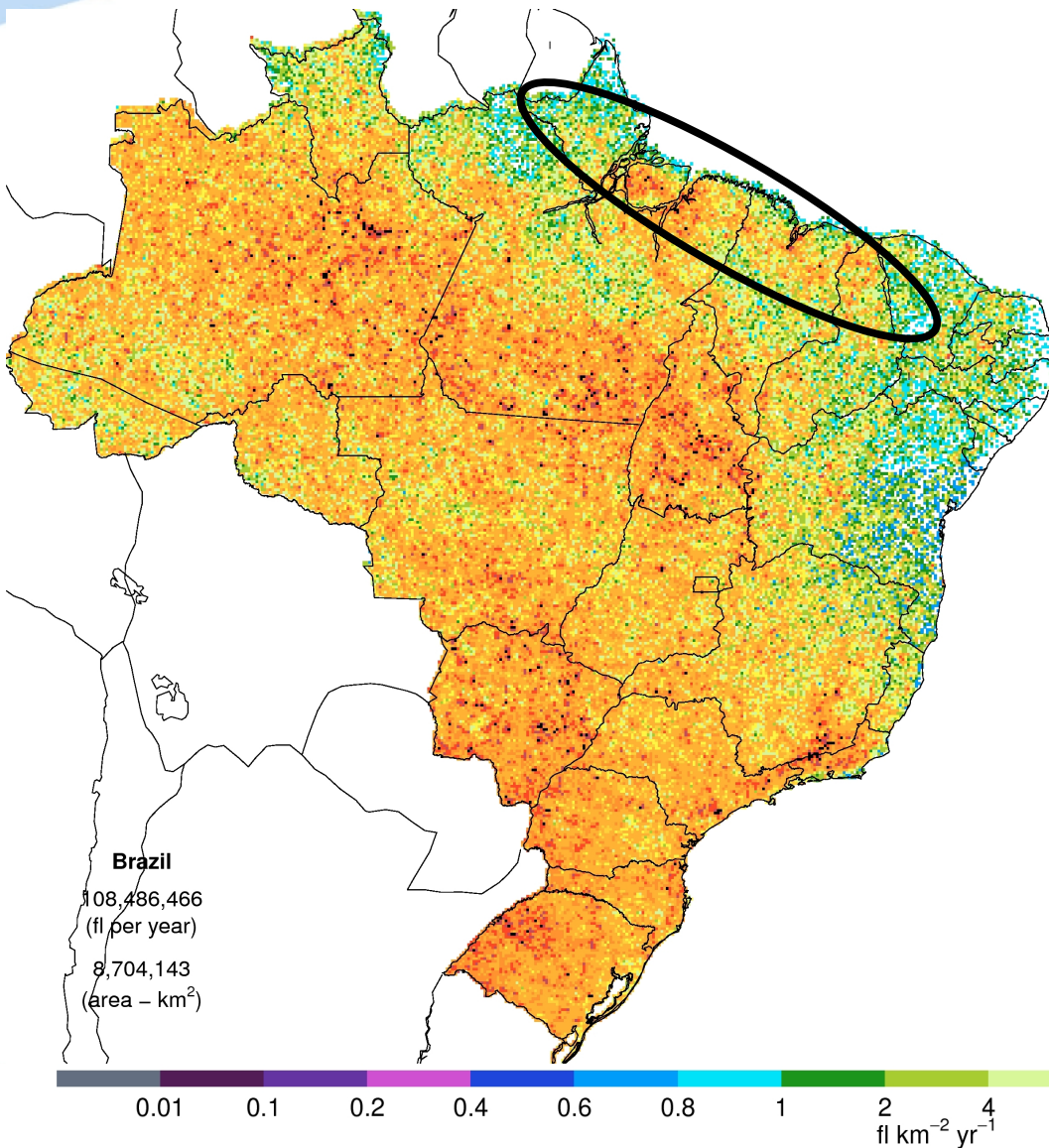
- Used the pre-boost swath to compute the total view time and number of flashes in a 0.50° resolution;
- Compiled yearly estimated total number of flashes in each 0.50° pixels from 1998 to 2008;
- Quantile linear regressions to calculate tendencies per quantile.

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

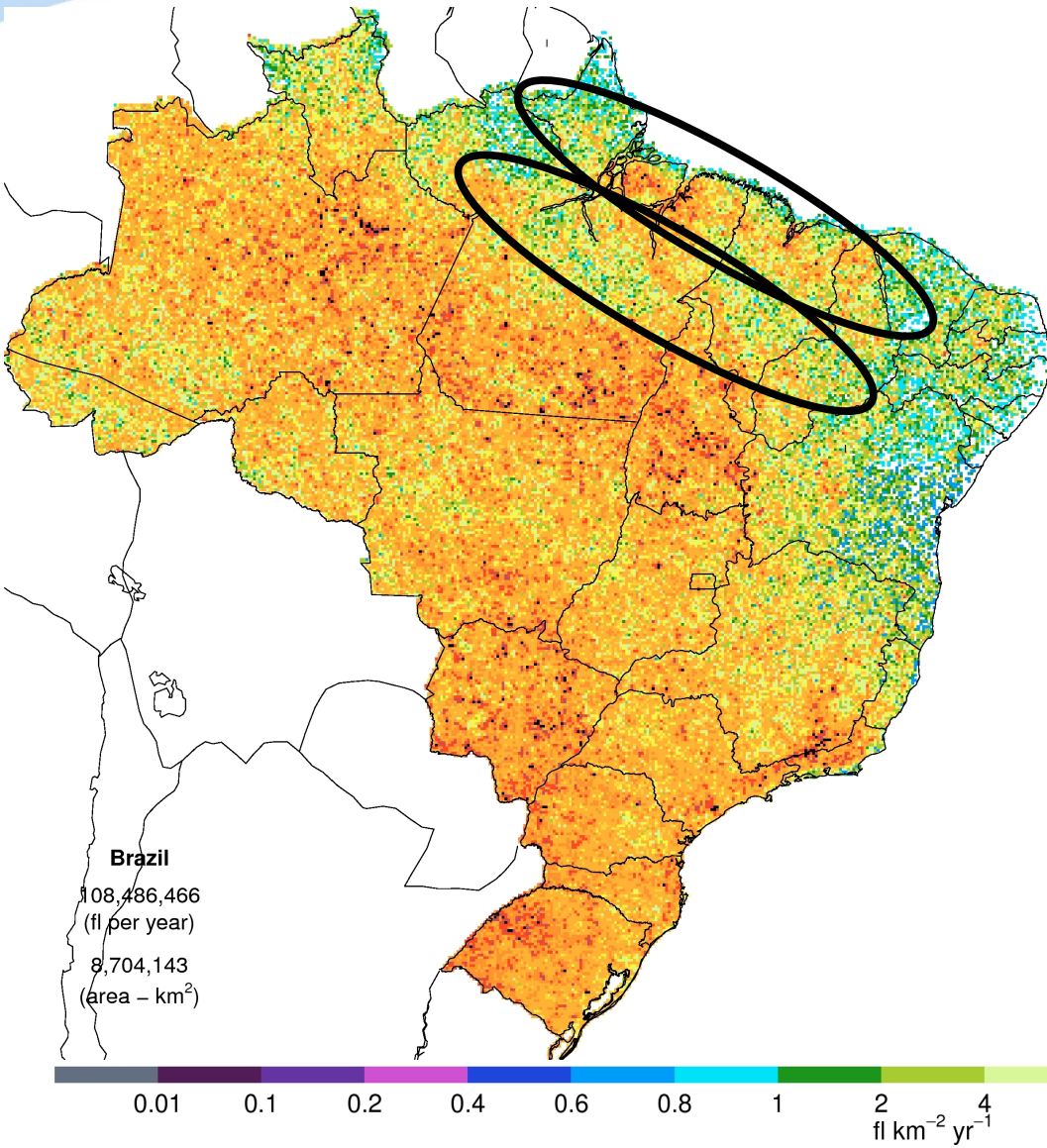


TRMM total flash rate density (FRD) climatology over Brazil (1998-2009)

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

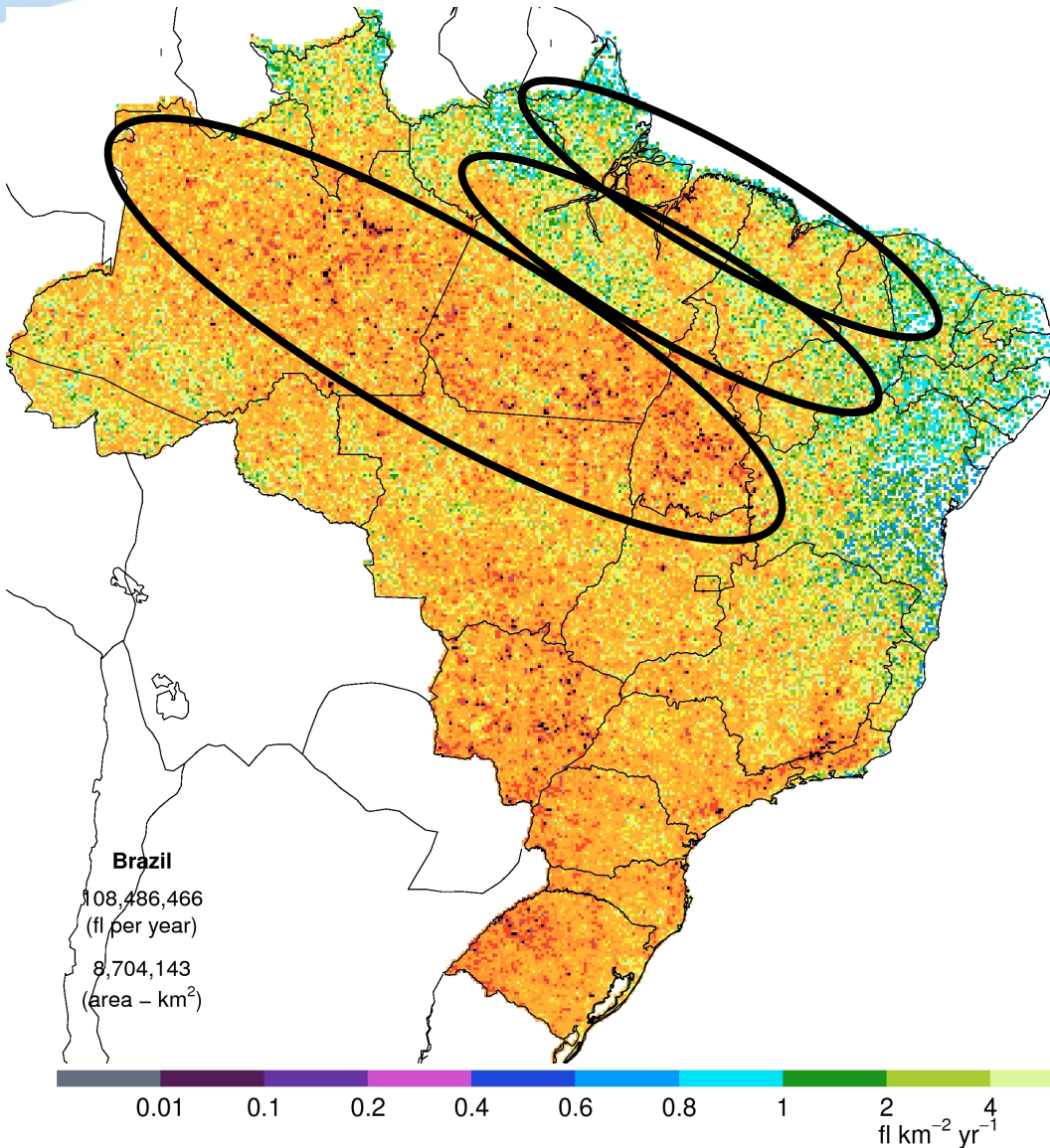


TRMM total flash rate density (FRD) climatology over Brazil (1998-2009)



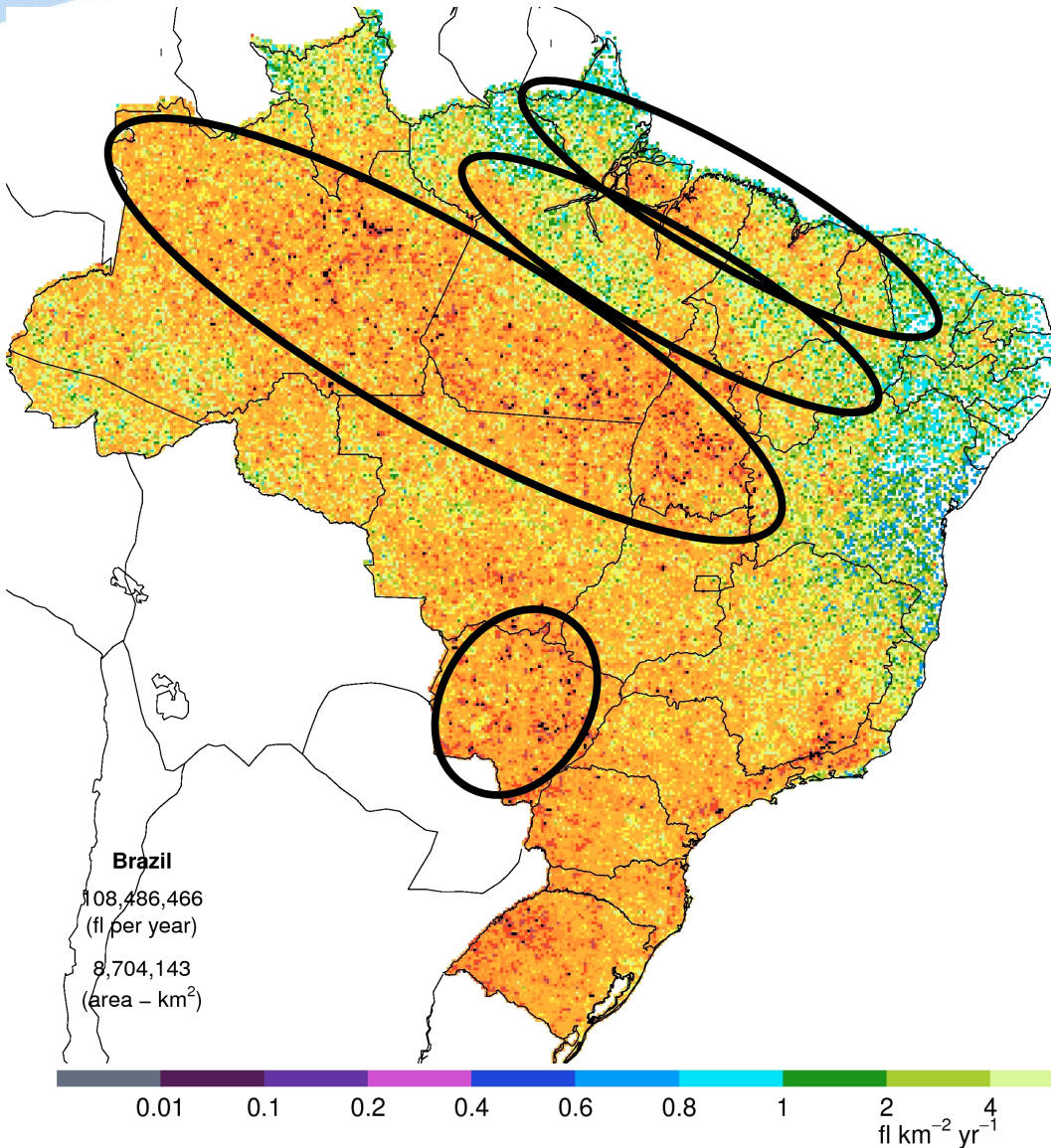
- Sea breeze, coastal squall lines, easterly wave convection, ITCZ;
- Coastal squall lines (minimum activity);

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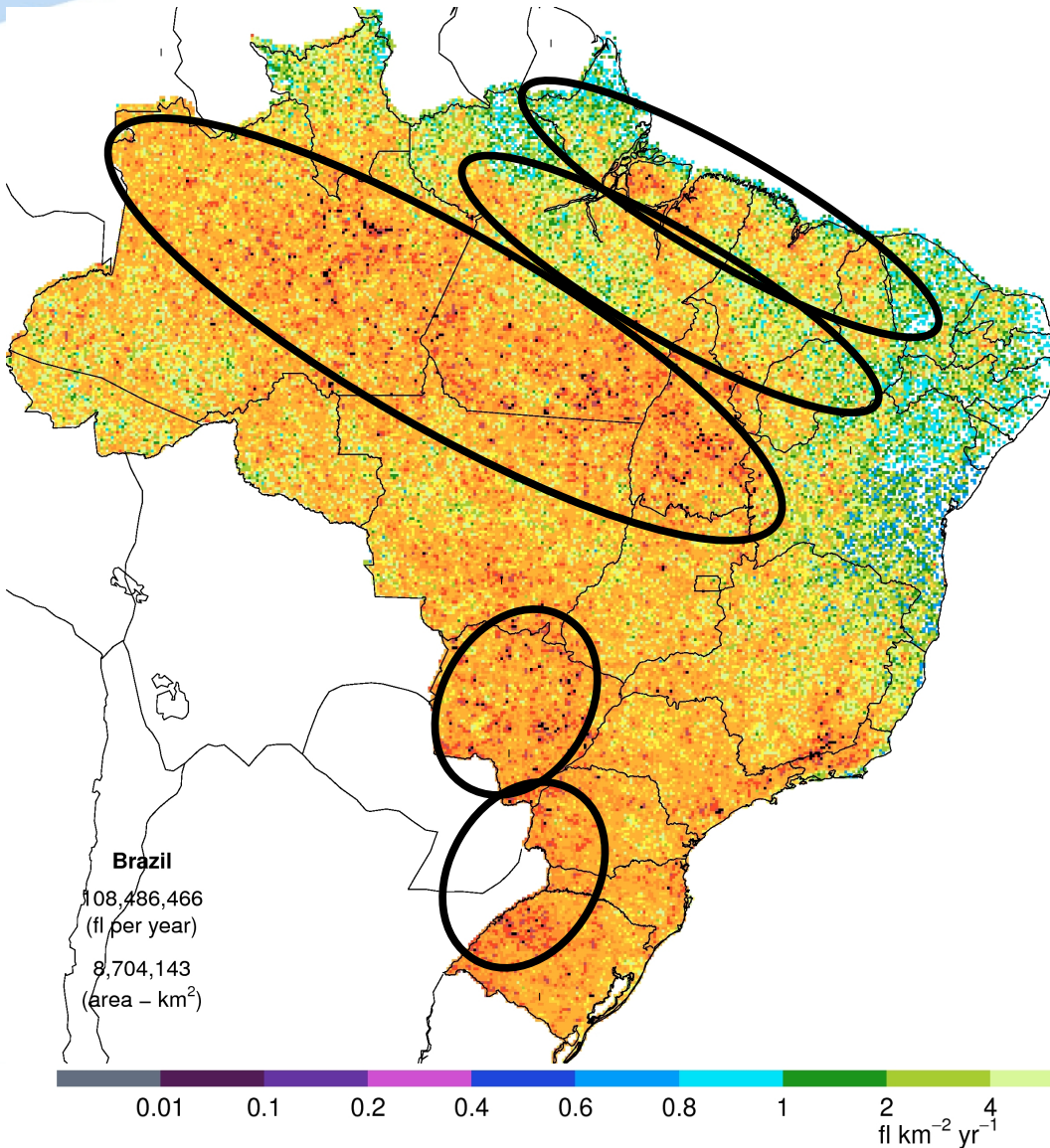
- Sea breeze, coastal squall lines, easterly wave convection, ITCZ;
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- Amazonian convection (local, squall lines, MCS, SACZ, ITCZ);

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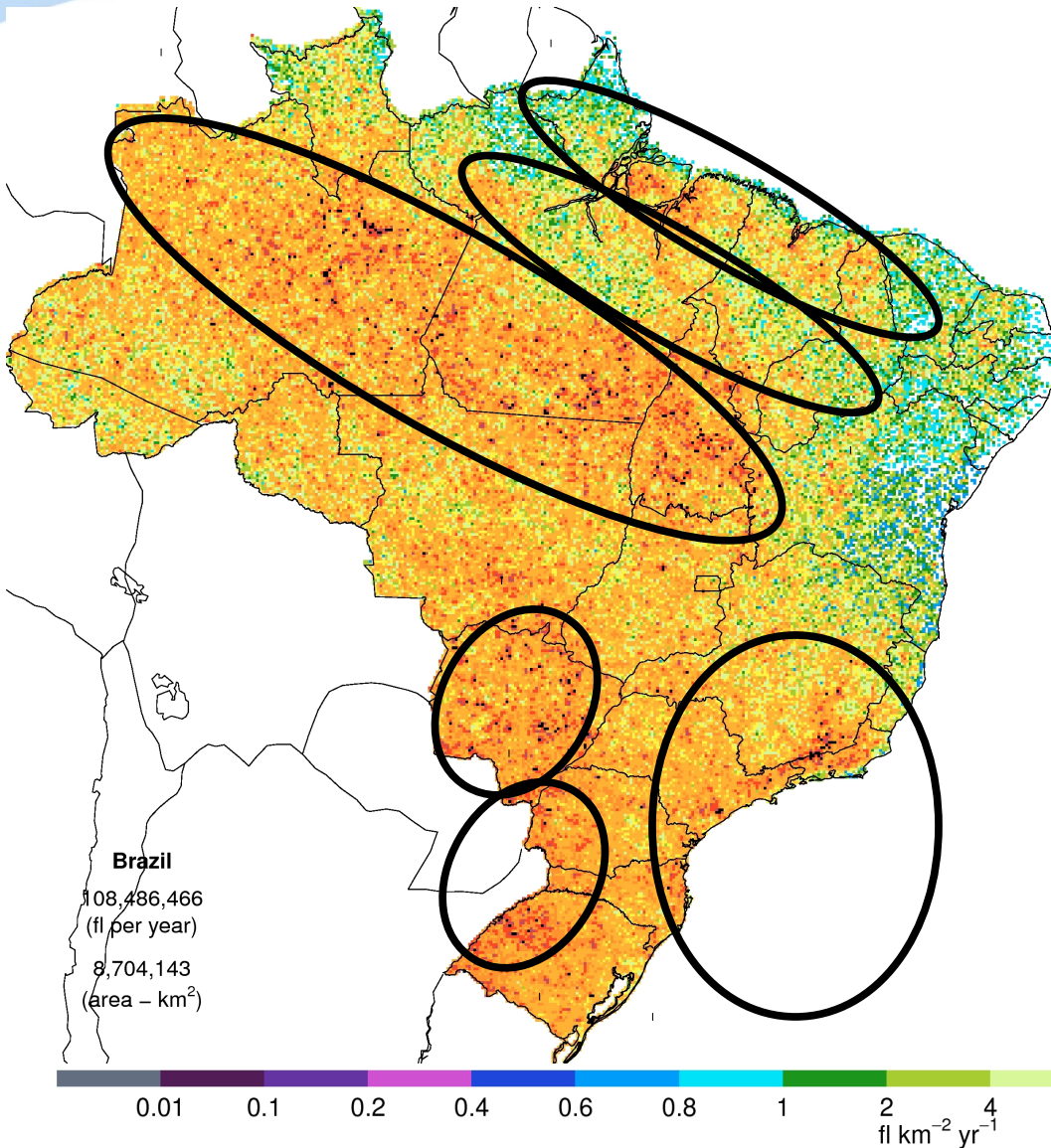
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- MCS, local convection;

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



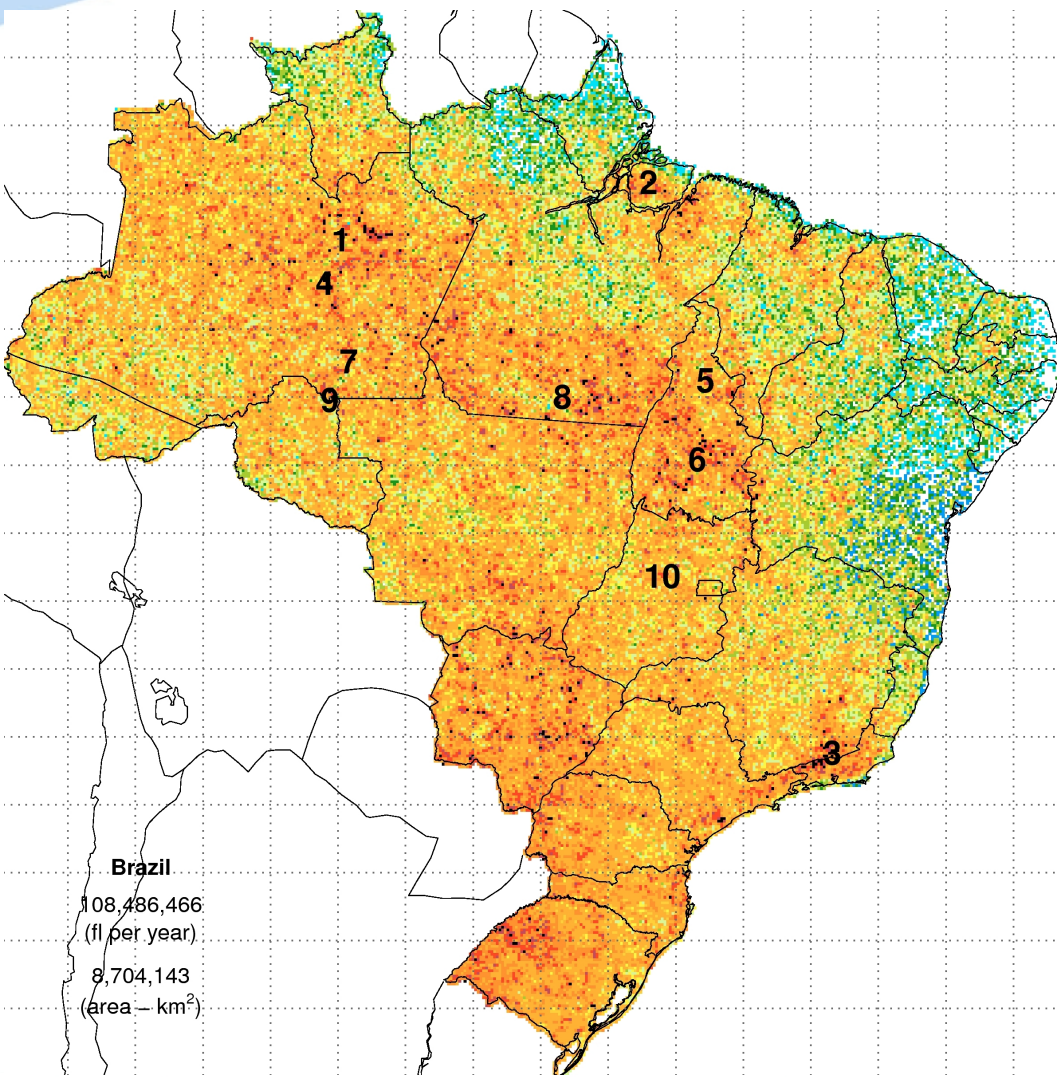
- Sea breeze, coastal squall lines, easterly wave convection, ITCZ;
- Coastal squall lines (minimum activity);
- Amazonian convection (local, squall lines, MCS, SACZ, ITCZ);
- MCS, local convection;
- MCS originated in Argentina, cold fronts;

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

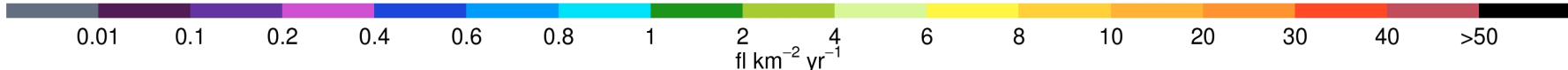


- Sea breeze, coastal squall lines, easterly wave convection, ITCZ;
- Coastal squall lines (minimum activity);
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- MCS, local convection;
- MCS originated in Argentina, cold fronts;
- (Sea breeze, SACZ) + local topography

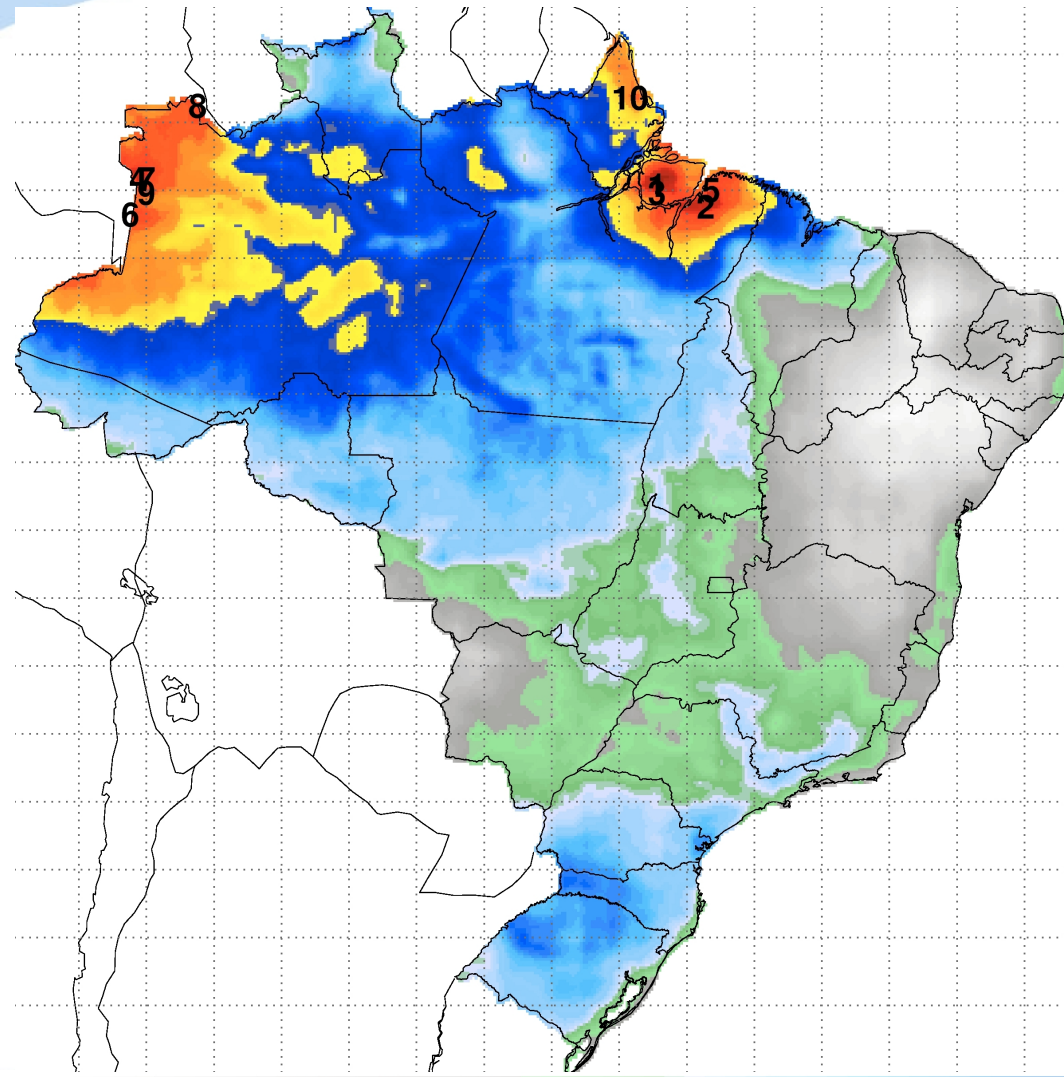
Ranking of TRMM total flash rate density (FRD) climatology over Brazil (1998-2009)



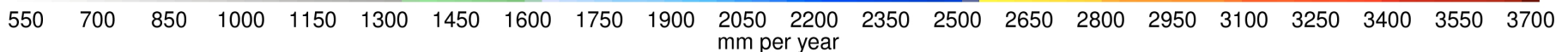
Rank	FRD	City
1	93.5	Cláudio, AM
2	89.9	Anajaz, PA
3	88.9	Belmot, MG
4	88.7	Piraiuara, AM
5	86.5	Cajueiro, TO
6	82.0	Estrema, TO
7	81.5	Santa Rosa, AM
8	80.2	Bela Vista, PA
9	77.9	Machadinho d'Oeste, RO
10	77.4	Castrinópolis, GO



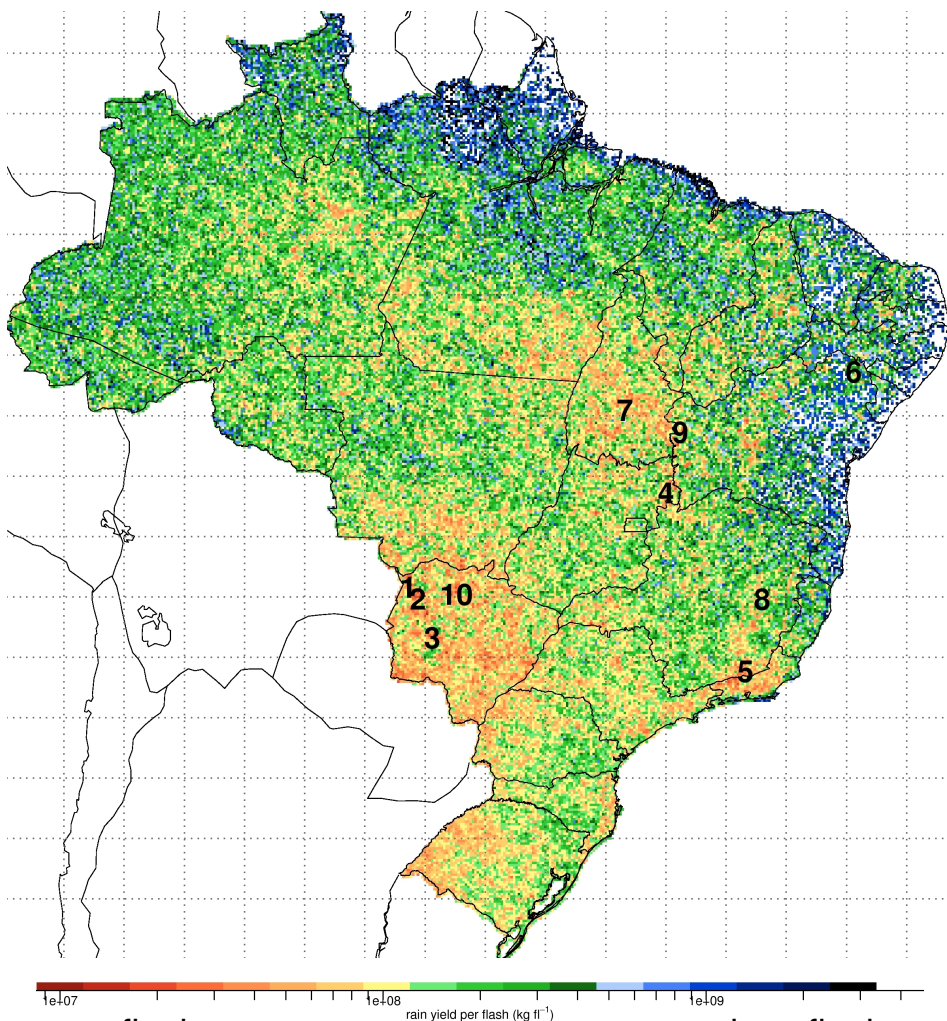
Ranking of rainfall (RR) climatology over Brazil (1998-2009)



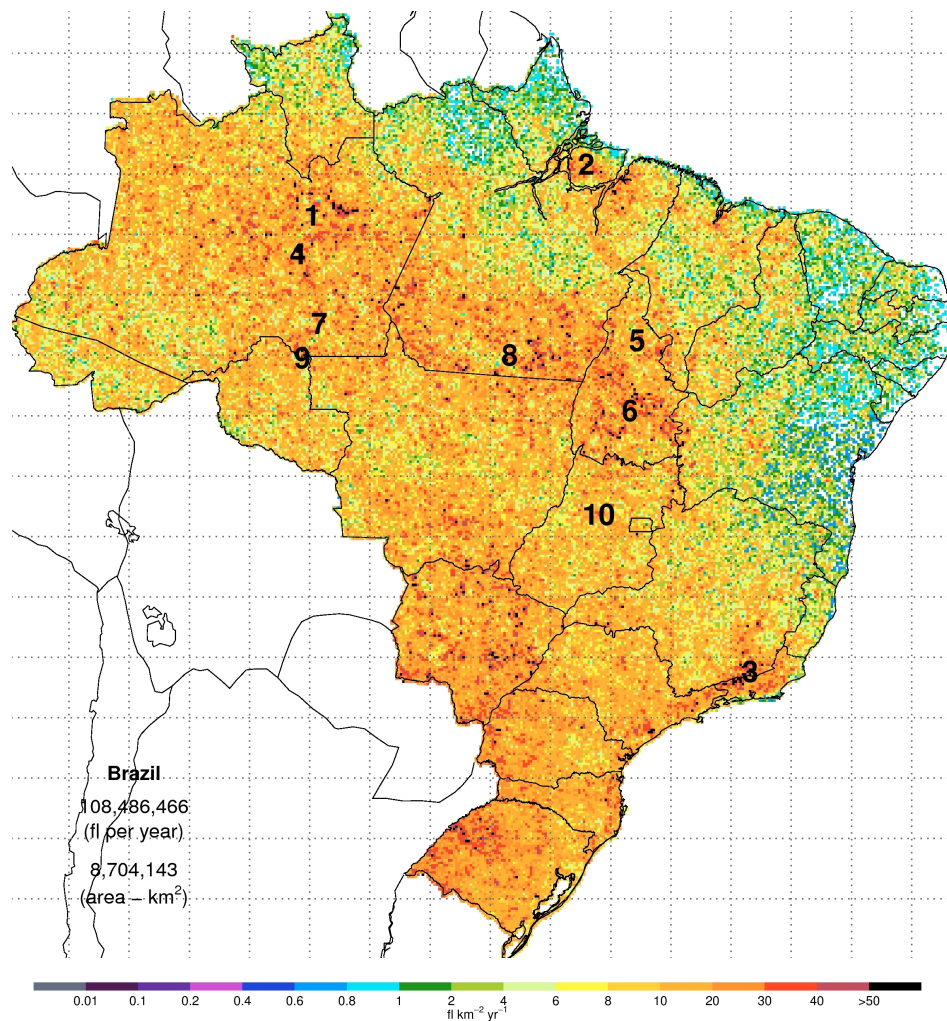
Rank	RR	City
1	3680	São Gabriel, PA
2	3559	Jupariteua, PA
3	3508	Vicente, PA
4	3470	Vilia Bittencourt, AM
5	3400	Santa Isabel do Pará, PA
6	3350	Manguari, AM
7	3348	Vilia Bittencourt, AM
8	3320	Macuxixiri, AM
9	3247	Mangari, AM
10	3216	Cachoeira Grande, PA



Rain yield per flash (RYF)



Flash rate density (FRD)

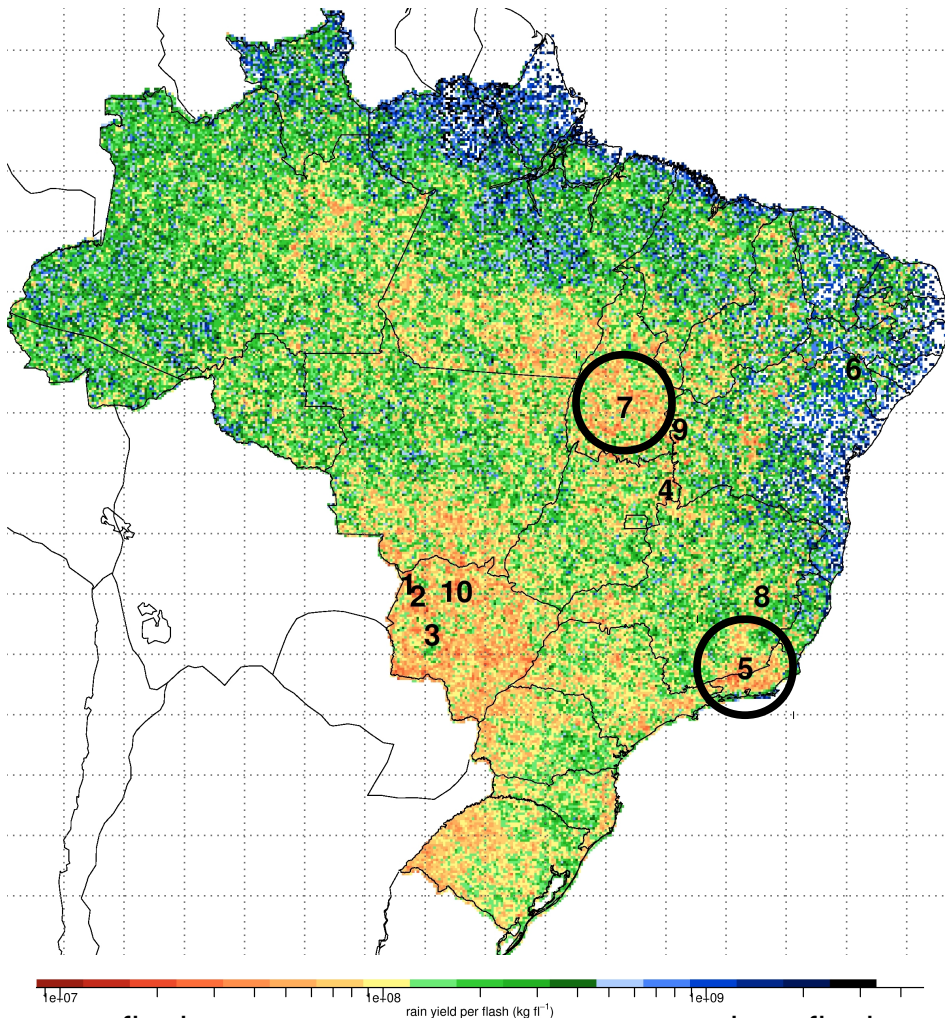


Brazil
 108,486,466
 (fl per year)
 8,704,143
 (area - km^2)

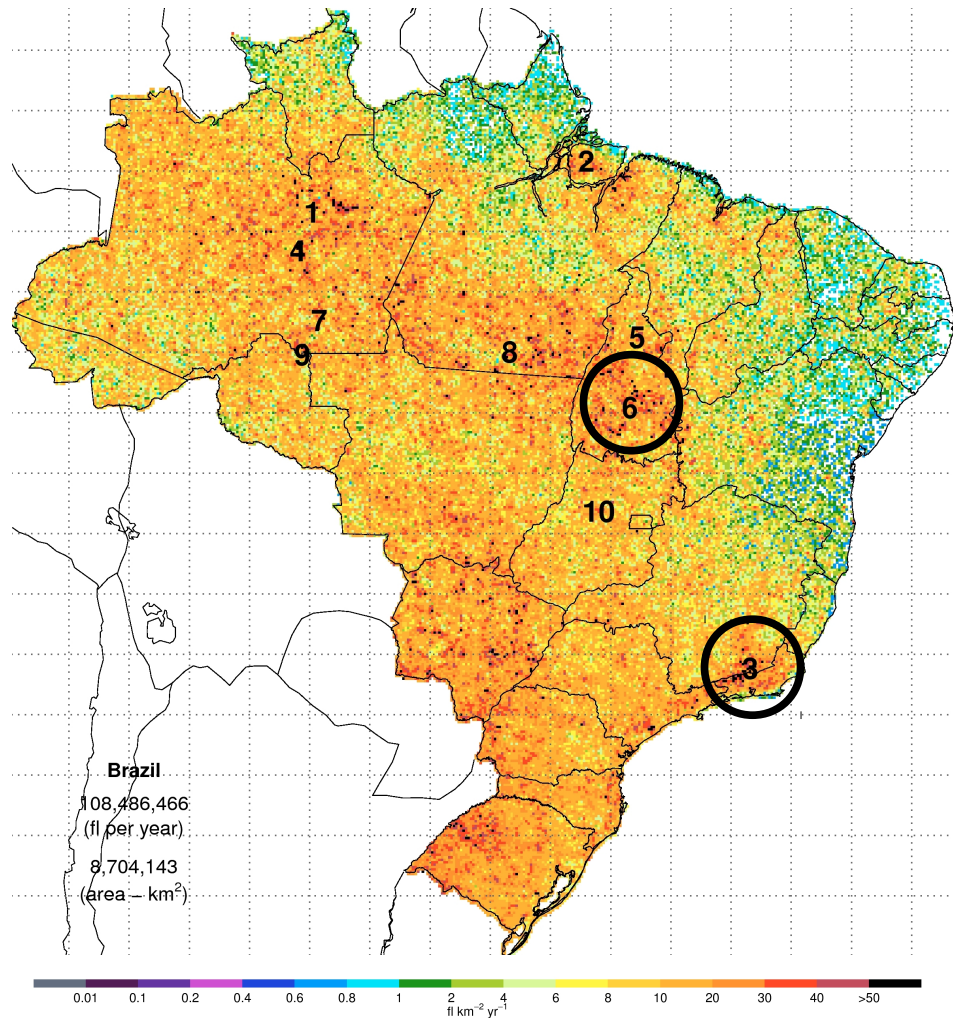
more flash
per rain

less flash
per rain

Rain yield per flash (RYF)



Flash rate density (FRD)

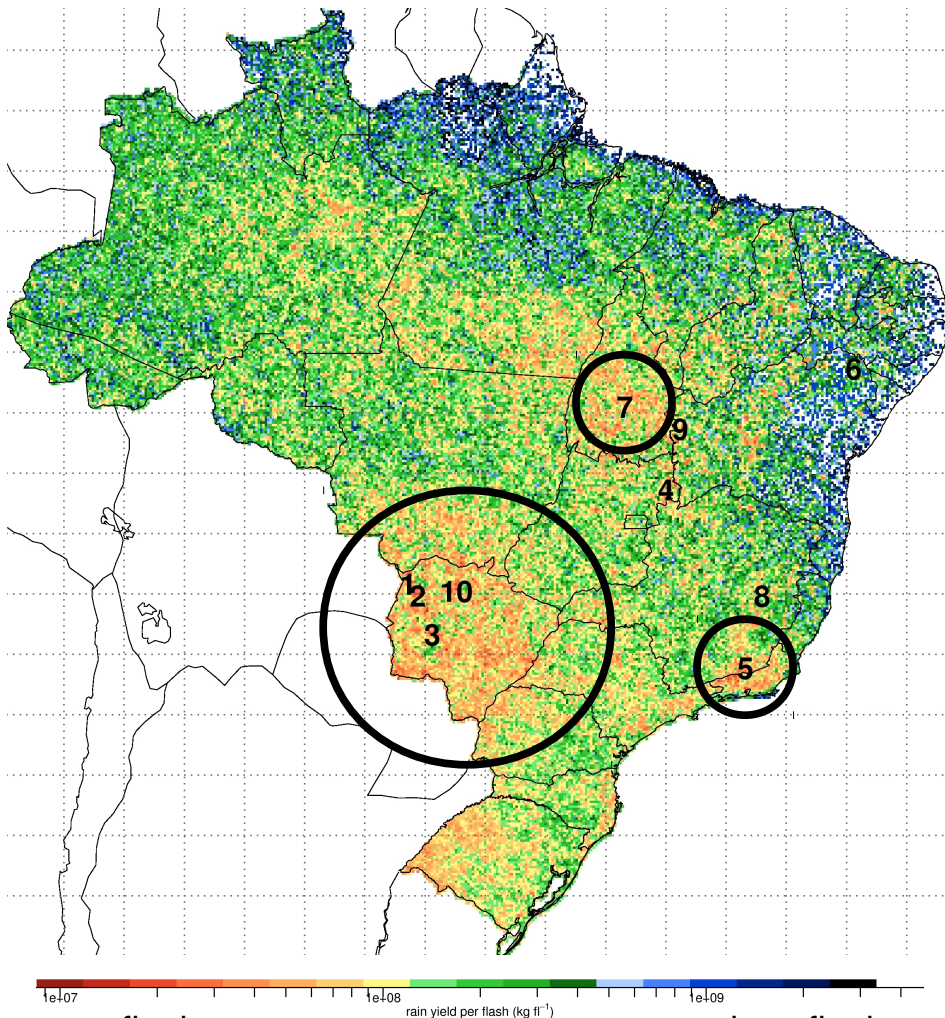


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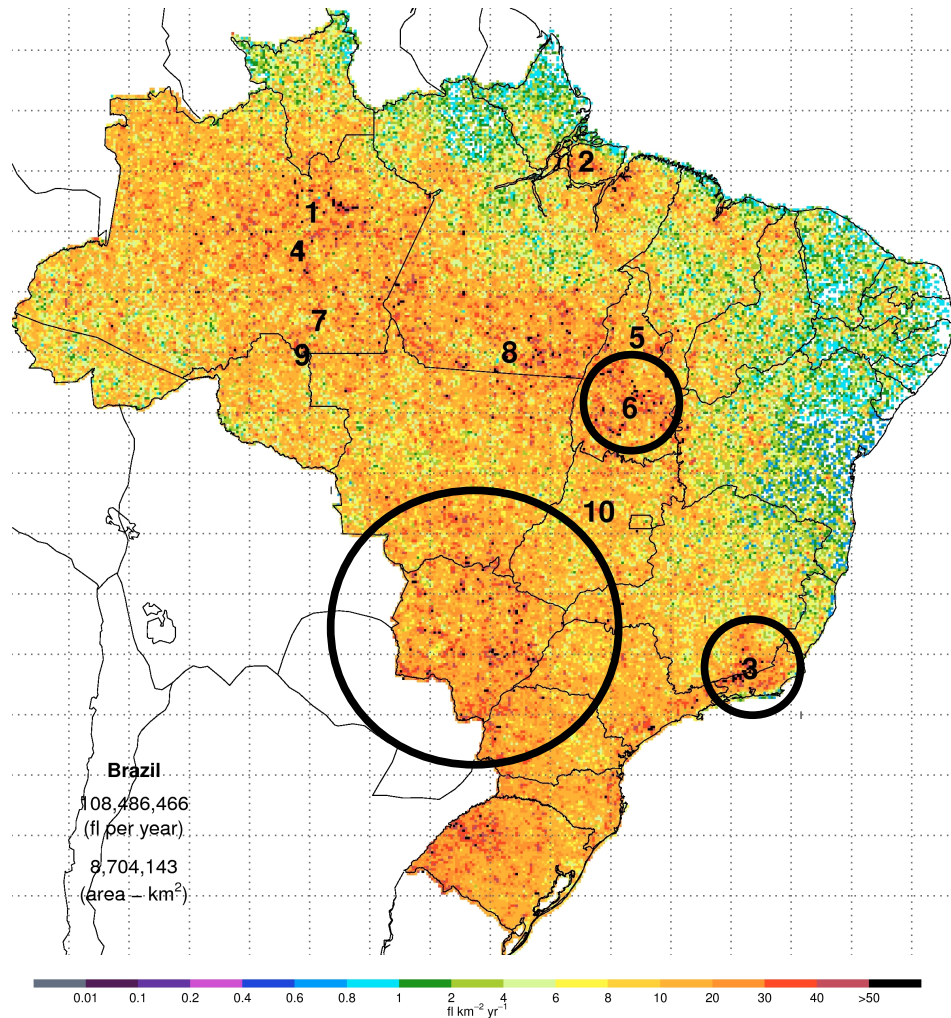
more flash
per rain

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Rain yield per flash (RYF)



Flash rate density (FRD)

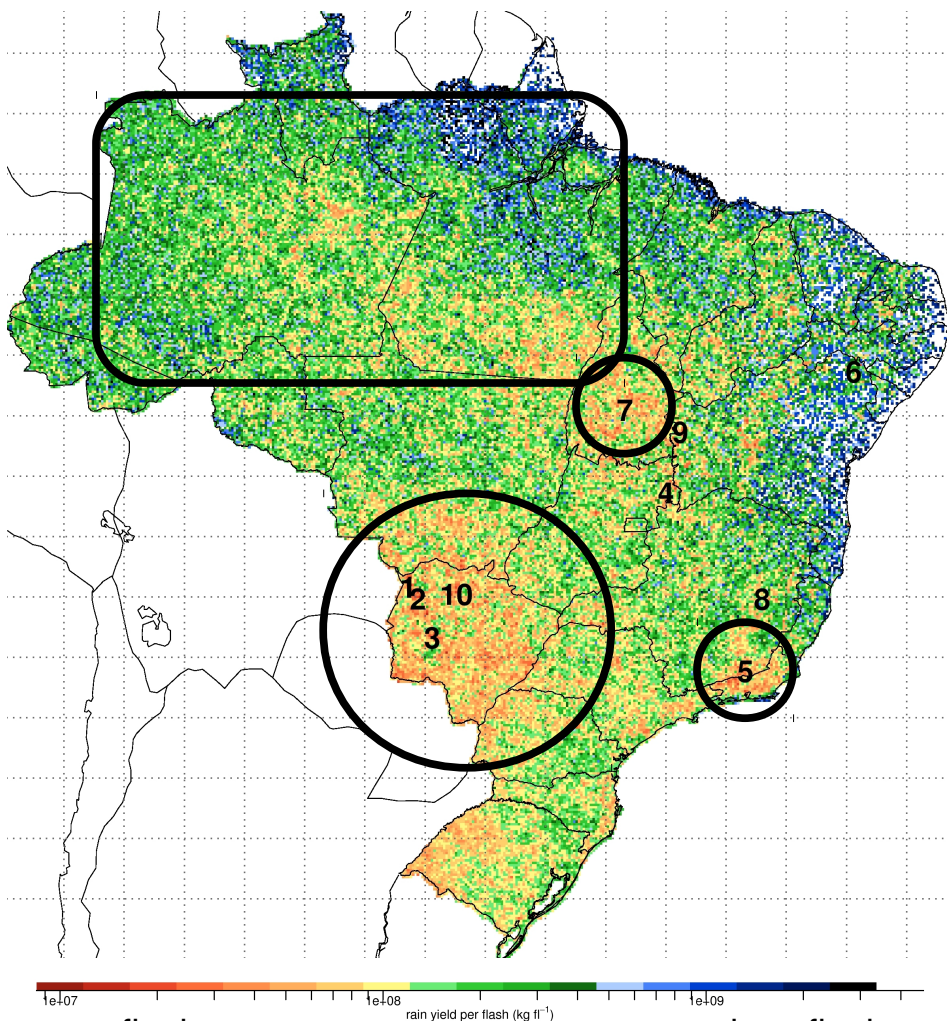


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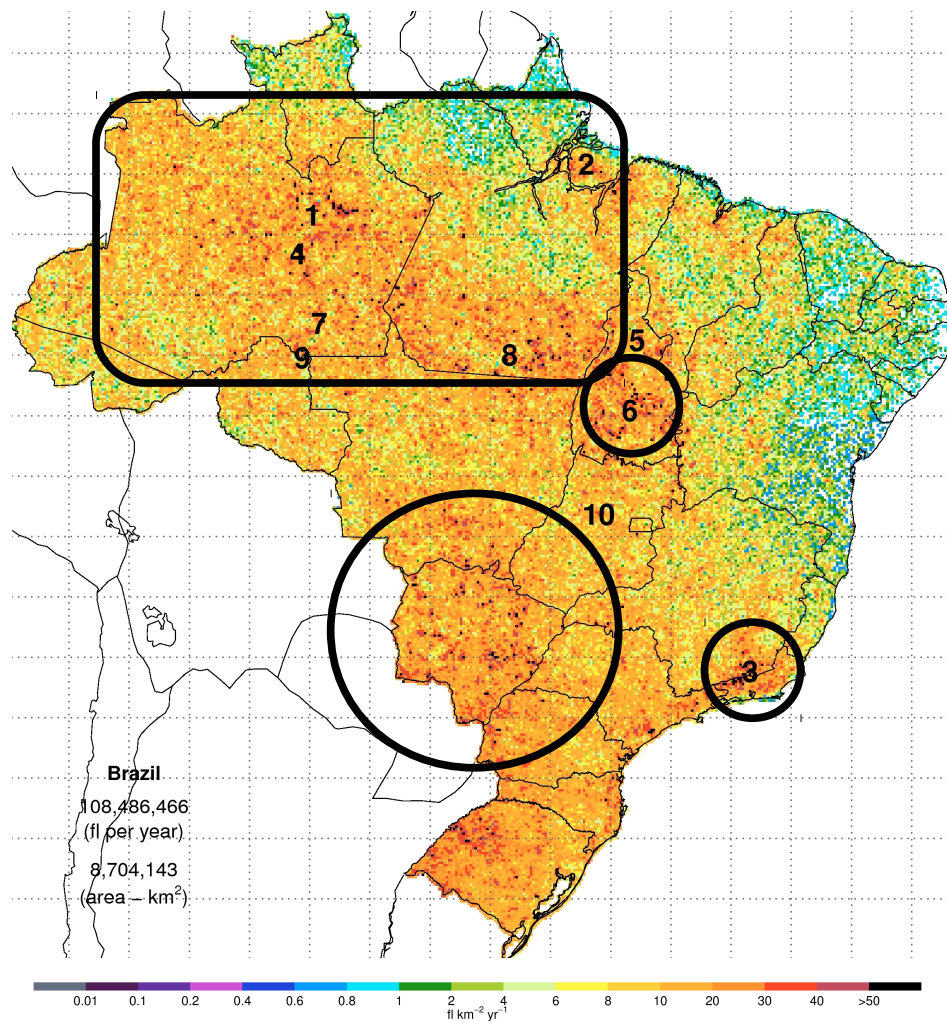
more flash
per rain

less flash
per rain

Rain yield per flash (RYF)



Flash rate density (FRD)



more flash
per rain

less flash
per rain

Tendency signal:

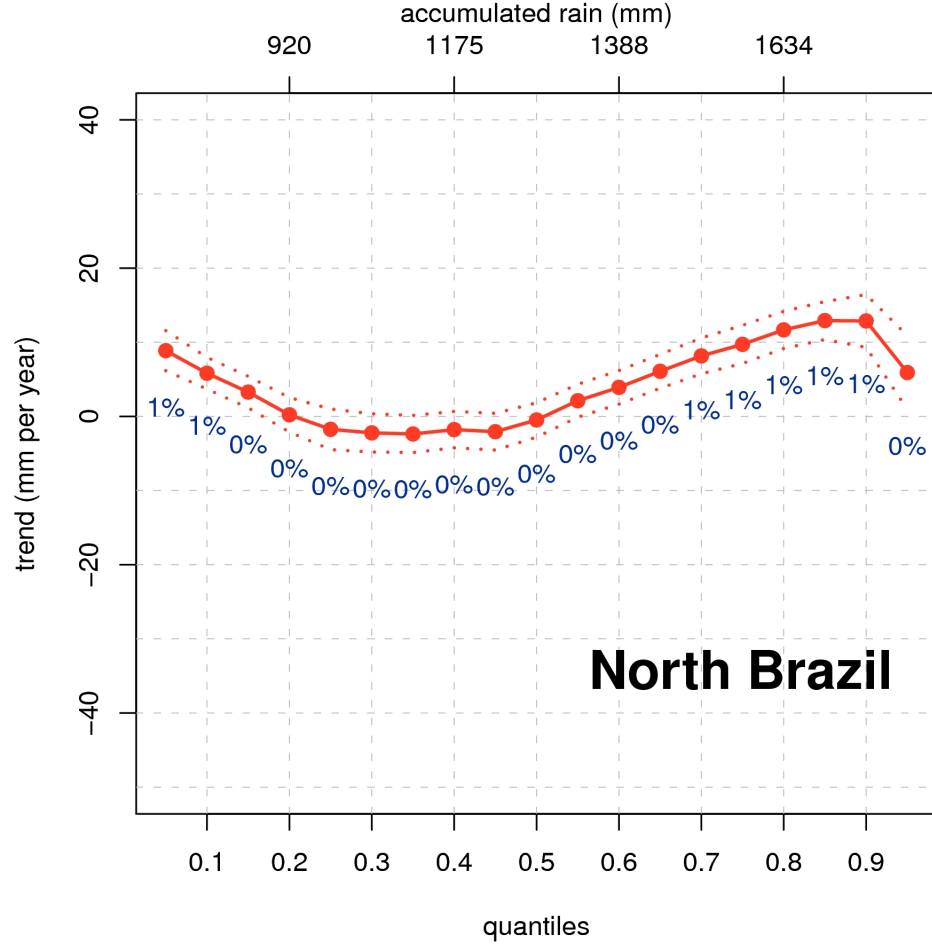
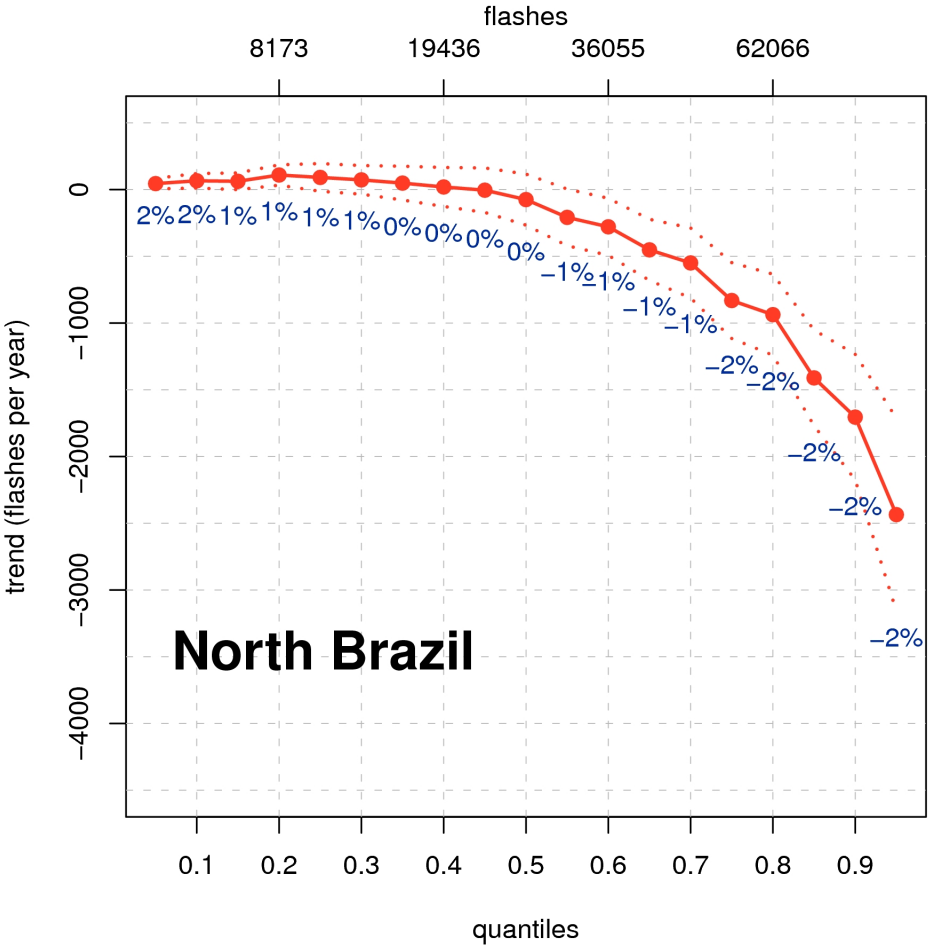
- Use the pre-boost swath to compute the total view time and number of flashes in a 0.50° resolution for each year from 1998 to 2008;
- **Quantile linear regression** calculated for Brazil's political regions:



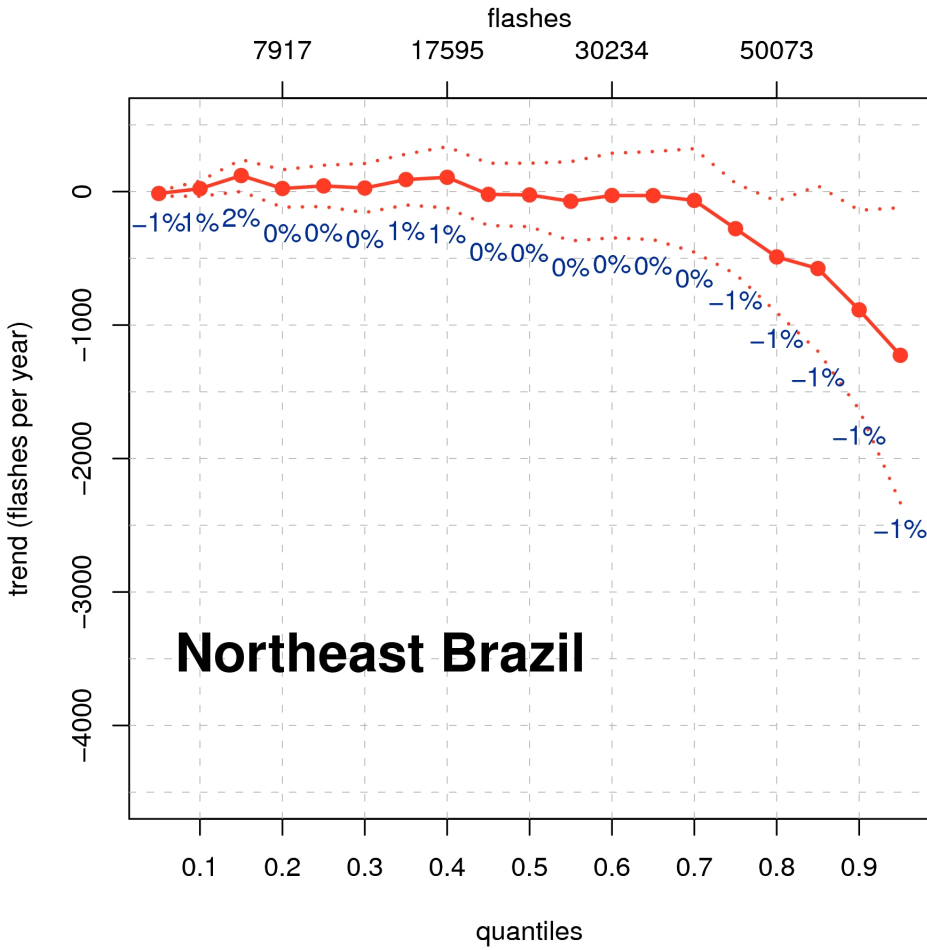
- Method to estimate the change (trend) of flash rate density (FRD) quantiles as a function of the year;
- A quantile is a point taken from the inverse cumulative distribution function of the FRD so that, for examples, the 0.7 quantile is the value such that 70% of the yearly FRD have FRD below this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

FLASH TENDENCY

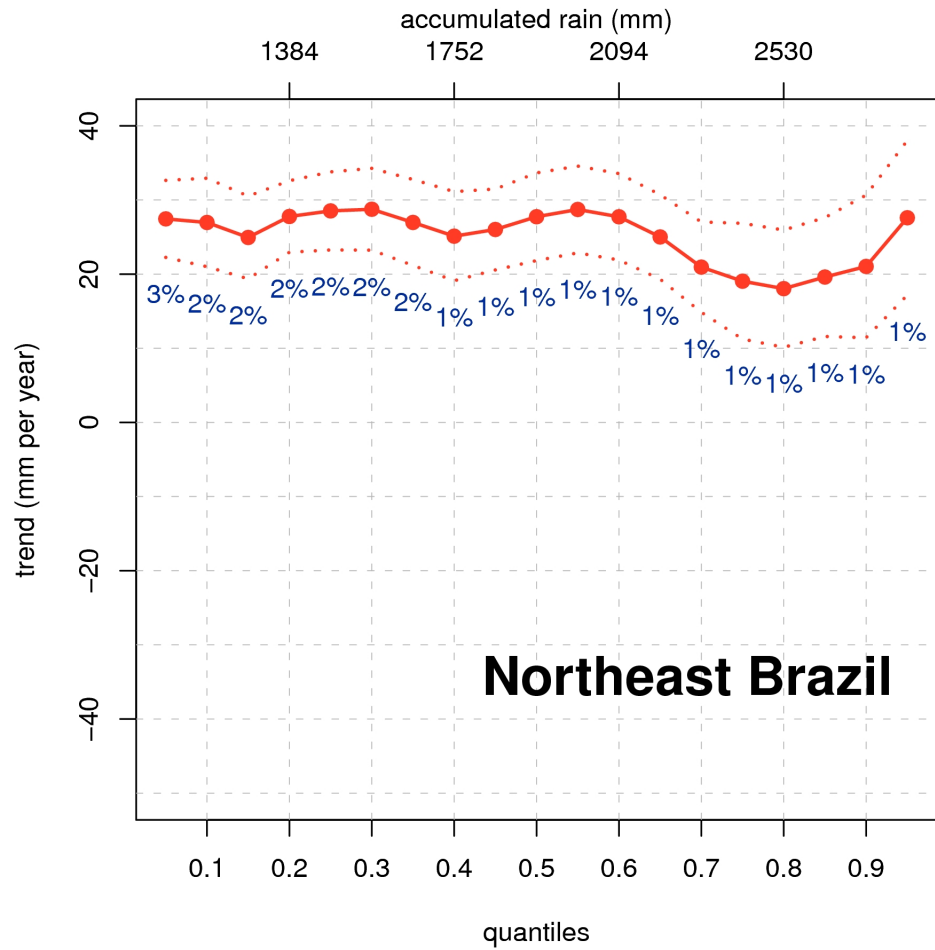
RAINFALL TENDENCY



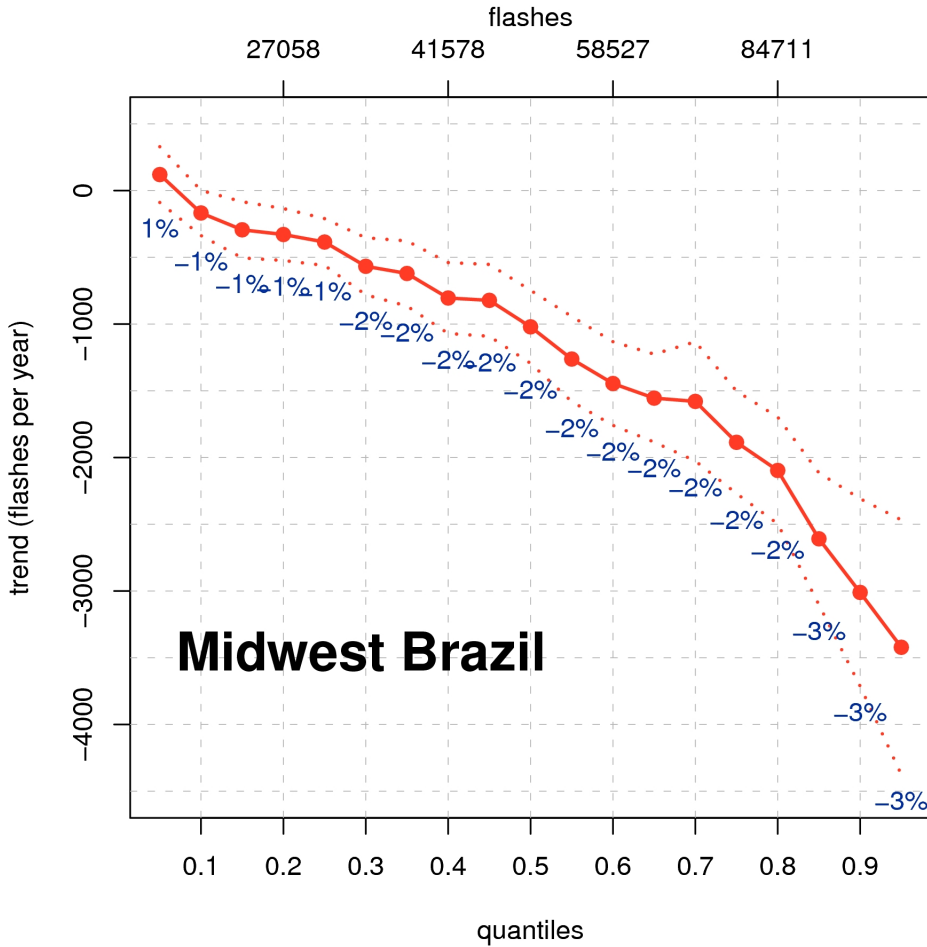
FLASH TENDENCY



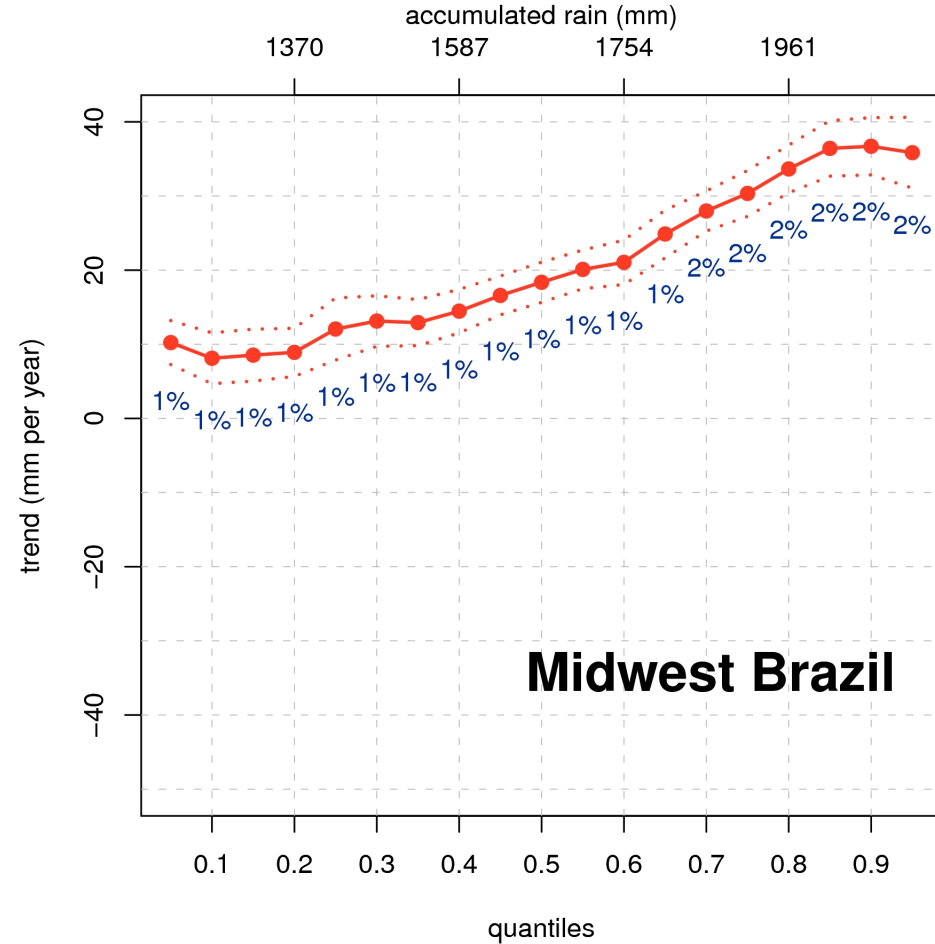
RAINFALL TENDENCY



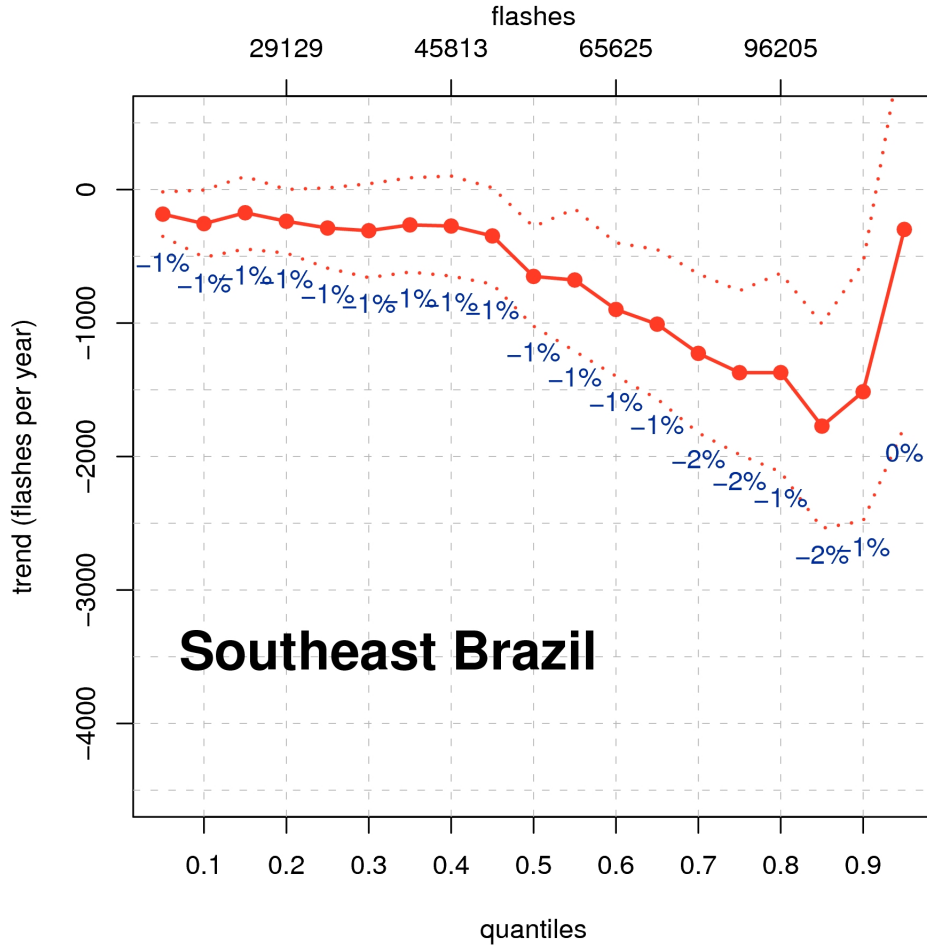
FLASH TENDENCY



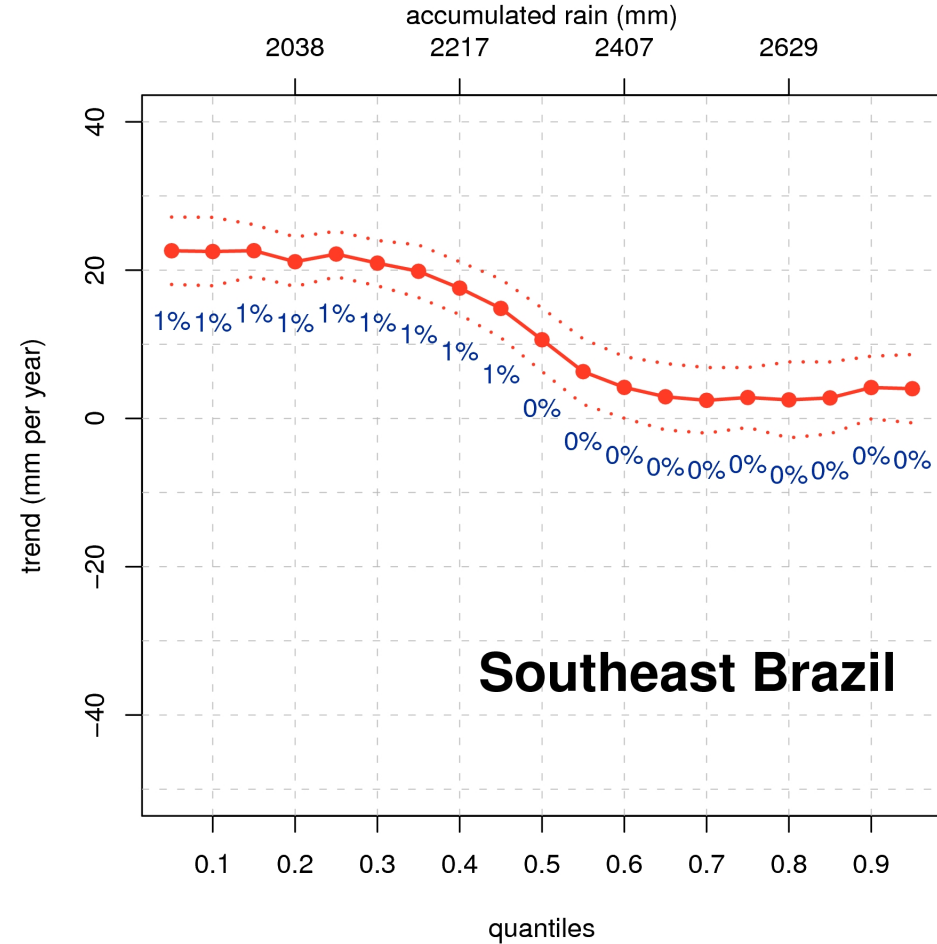
RAINFALL TENDENCY



FLASH TENDENCY

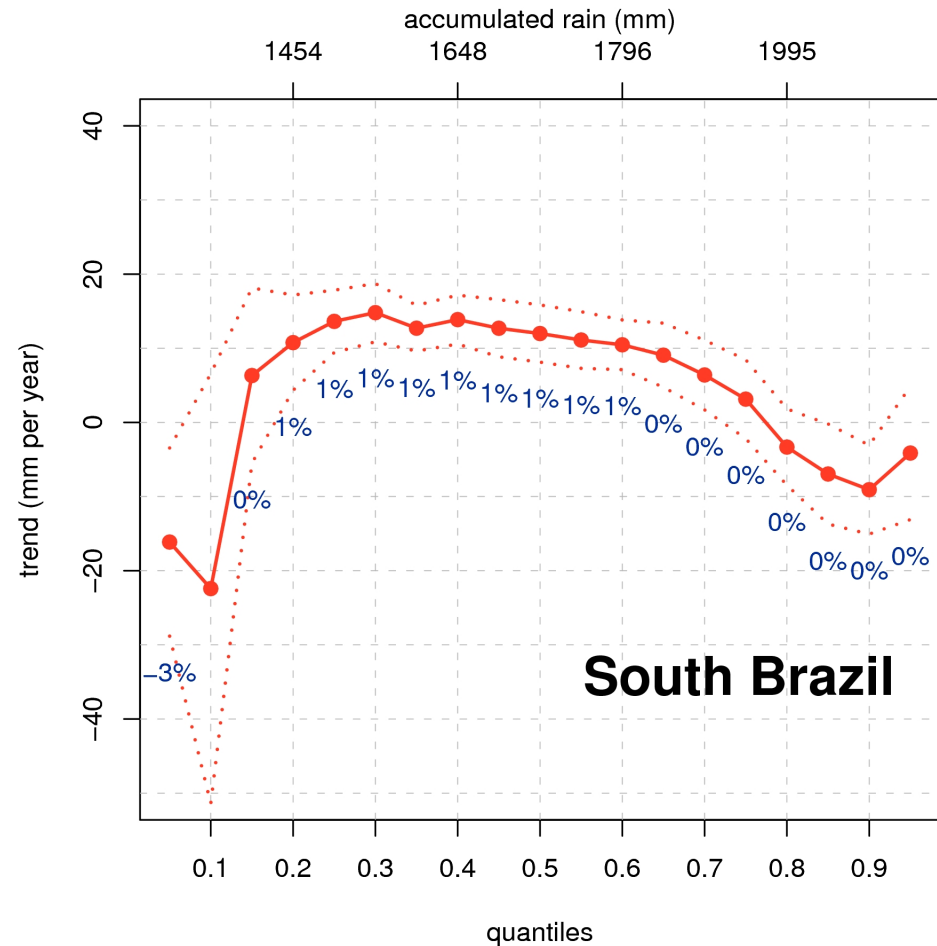
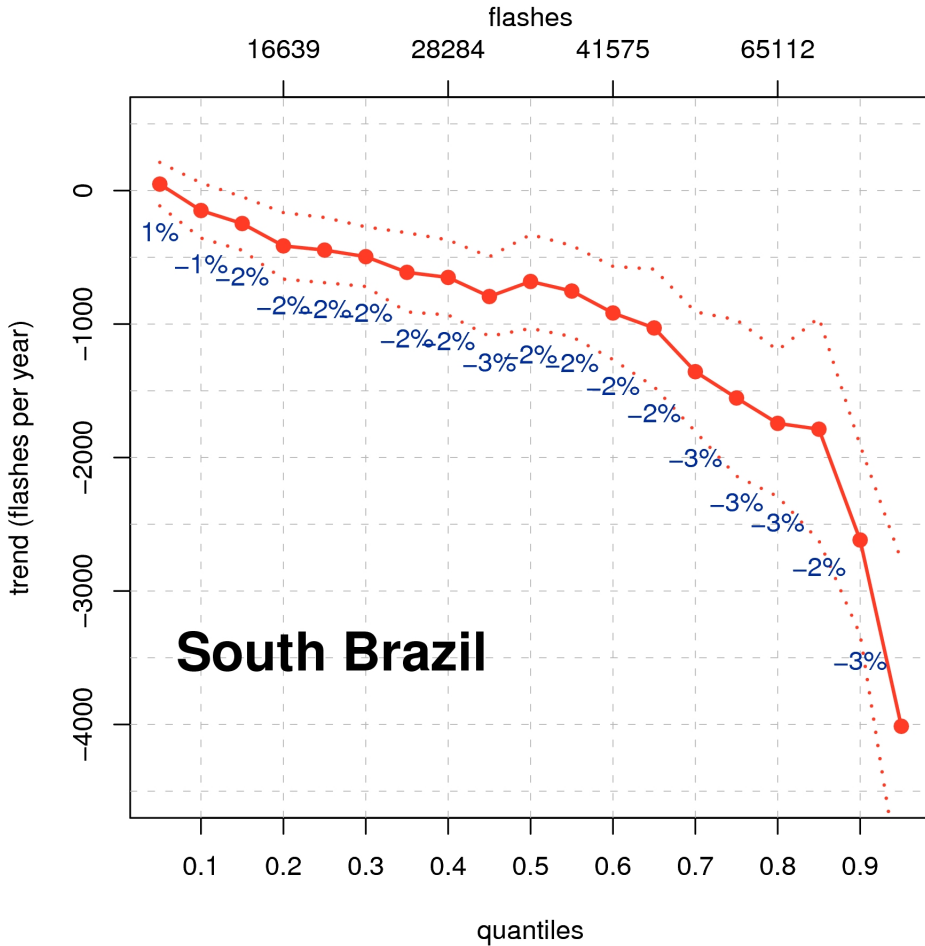


RAINFALL TENDENCY



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.