Seismological Observations of the Seasonal Rain and Aquifer Induced Seismicity in Southeastern Brazil

If you want to see the presentation, its on YT: youtu.be/jjrlkM8zuMs
[copy and paste the link on your browser, you cannot click on it apparently]
(it will live there until the end of may 2020)

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Abstract number EGU2020-10161

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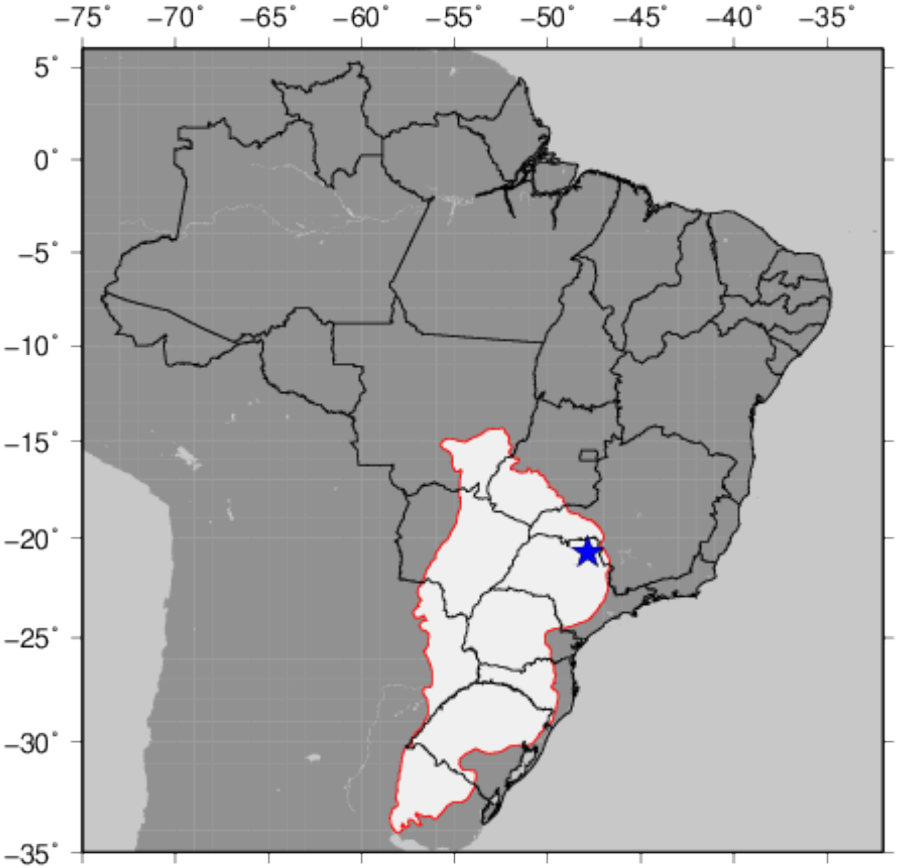
Introduction

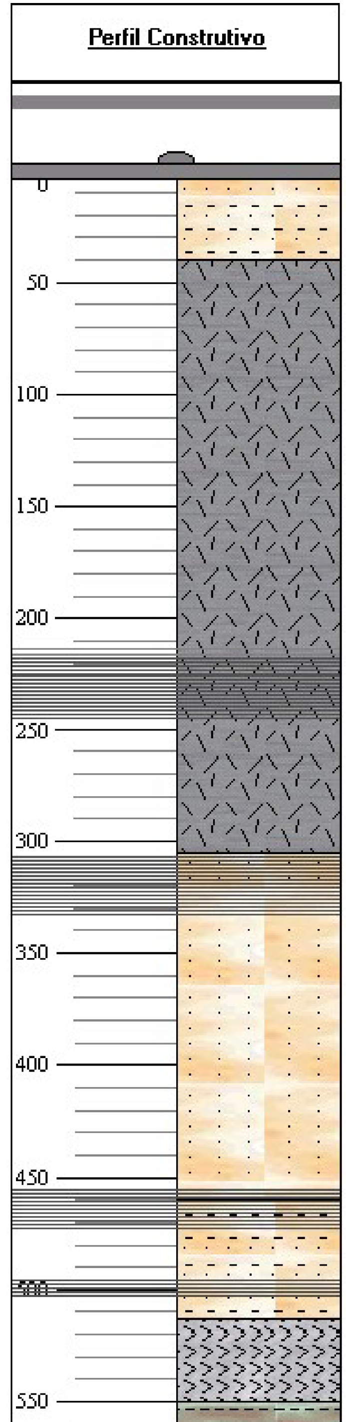
- Study area: SE of Brazil, 400 km NW from the the city of São Paulo
- Located on top of the northern edge of the Paraná Basin, and over the Guaraní aquifer.
- This is part of one of the largest flood basalt provinces



Introduction

Zone characterized by a shallow strata division and aquifer system.

Composed by intermittent layers of Sandstone and Basalt, that overlay the Botucatu Sandstone formation, which is part of the Guarani aquifer.



-Well log example: Nearest logged profile of a water well, from a nearby town less than 10km away (there are no profiles in our study area).

-Wells in our area are not registered with the local government nor the Brazilian geological service.

-While our information shows different thickness of layers the composition is the same.

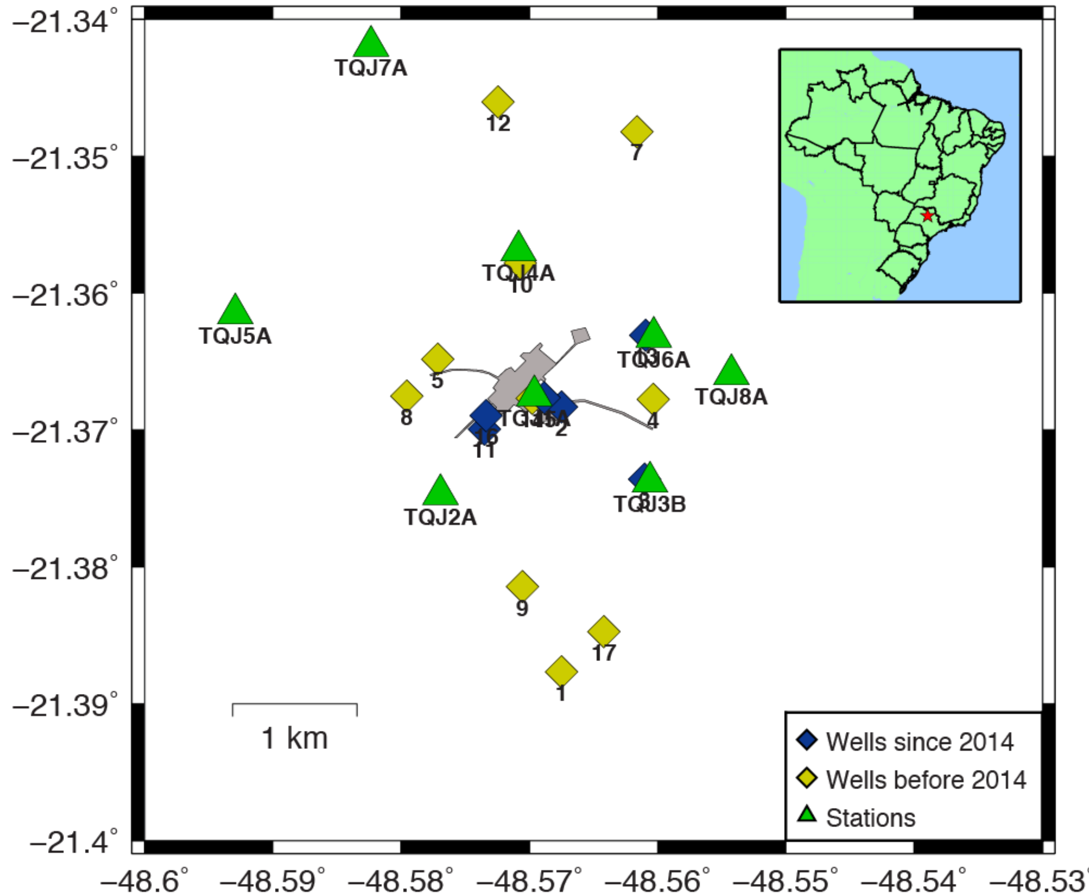
The water wells

This is a farming area, it's the main economic activity.

Gray area is the "urban region" (painted generously, urban area is a bit smaller).

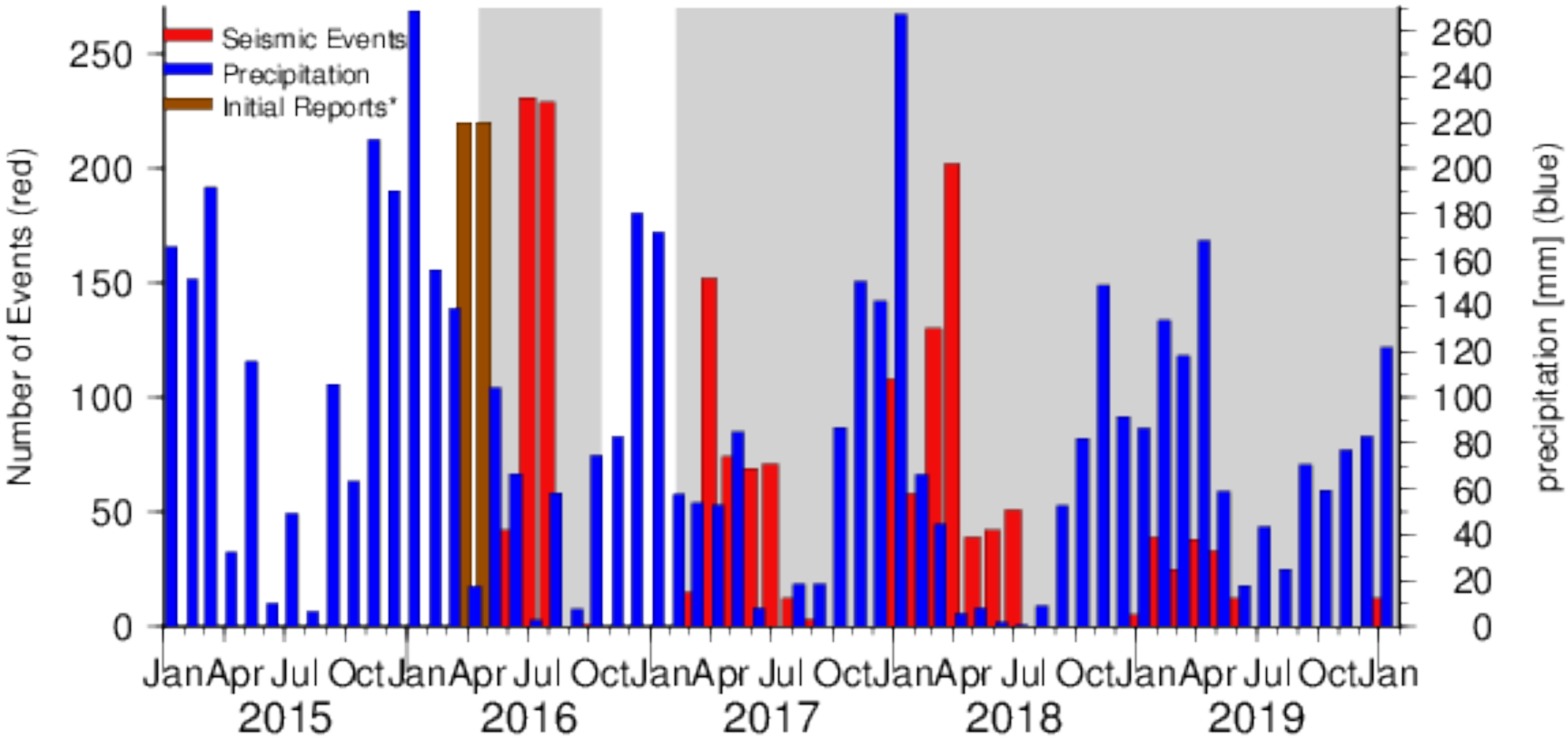
As water is needed, they drill wells, pump out water during the dry season (June - December).

When the rainy season arrives (around December), wells are no longer pumped.



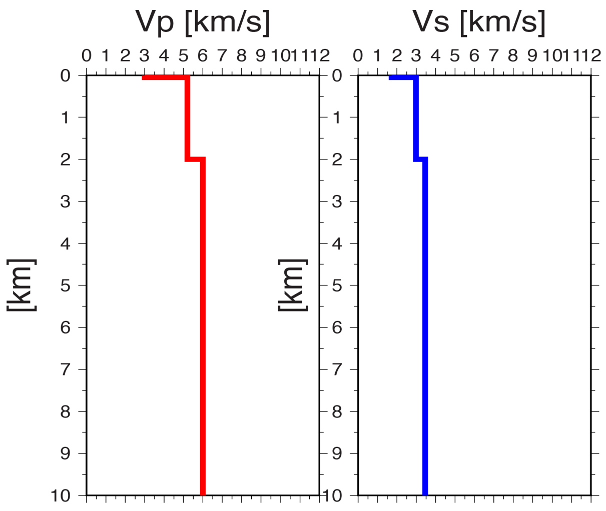
Water wells and stations in and around Jurupema (our study area). There are some "recent" wells, that were drilled a short time before (in blue), they are almost all in the area right next to the town.

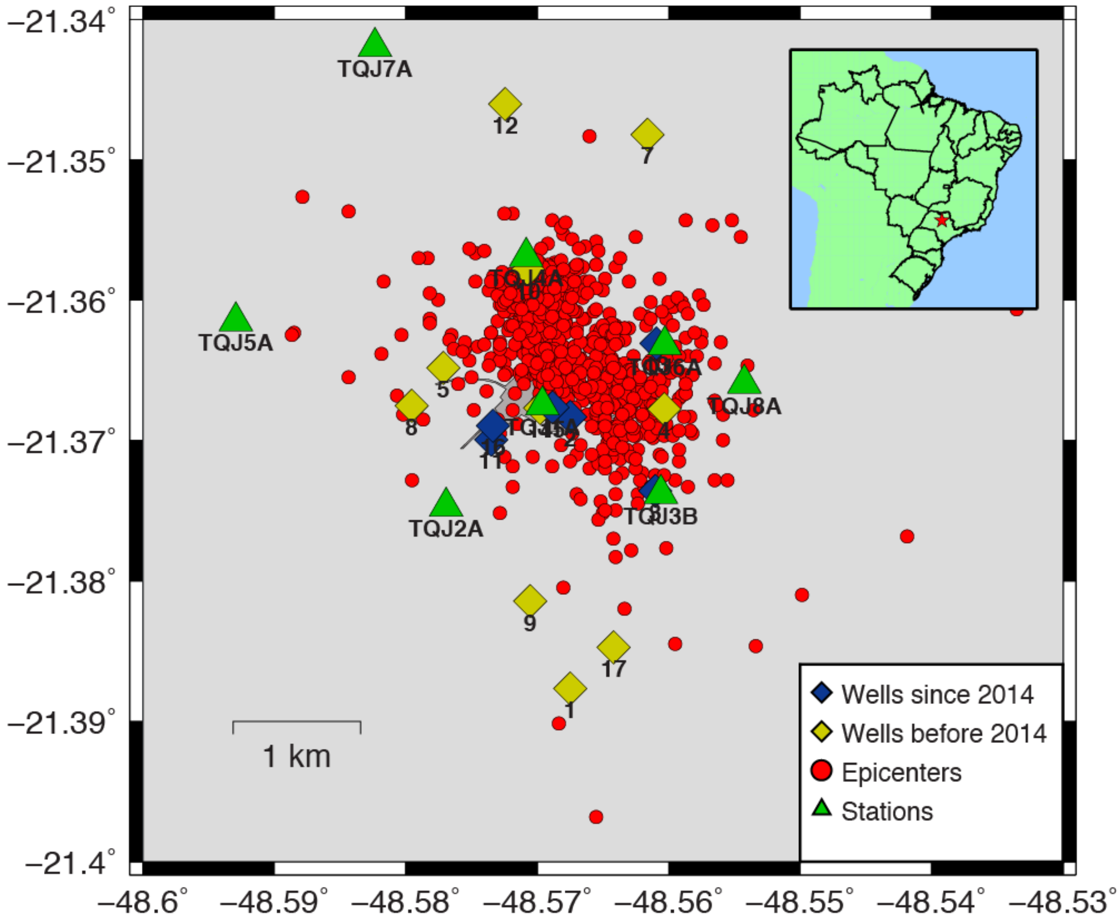
Seismicity – Seasonal Variability



Precipitation (red), and monthly number of seismic events (blue). The instrumented time periods are highlighted in the gray shaded area. There is not only an apparent coincidence of the induced events with the months of higher precipitation was higher. But there is also an evident latency of the onset of seismicity following those months where the rain was highest.

Seismicity - Relocation



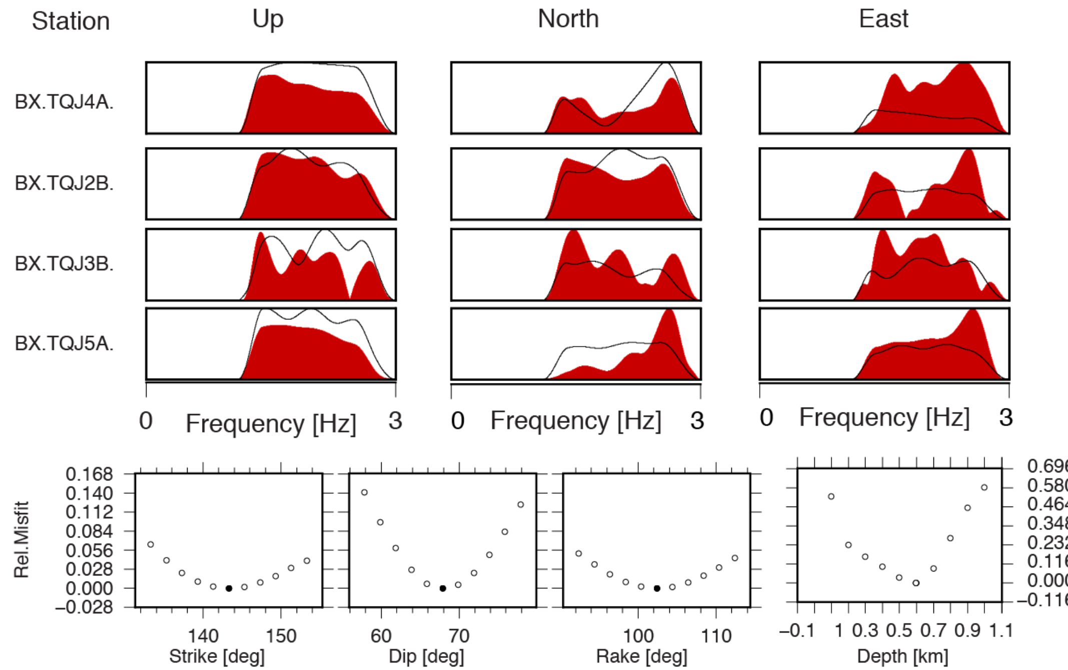


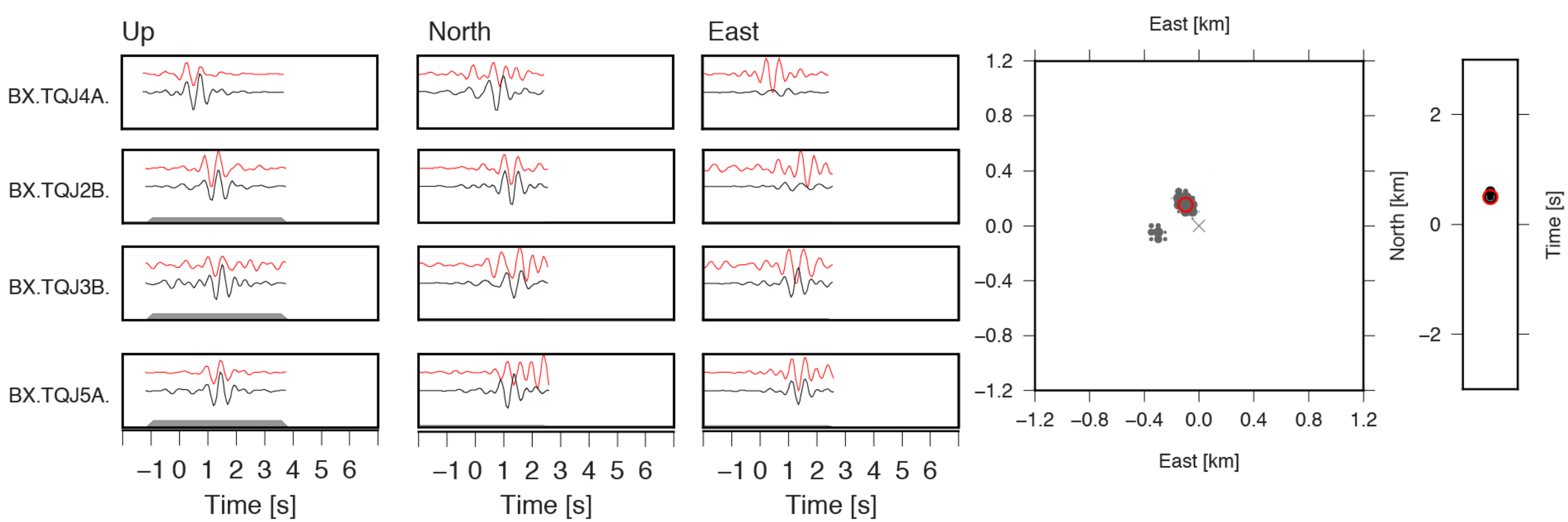
(Left) Velocity model used for relocations and the subsequent moment tensor inversions. (Right) we weighed the phases for relocations based on the confidence with relation to the noise and clearness of the phase arrival, as well as the number of phases available for the relocation.

With the phase quality and number of phases restriction, we are left with about 800 events overall. As expected this reduced the number of epicenters, but it is beneficial for our confidence on the focal mechanism inversions.

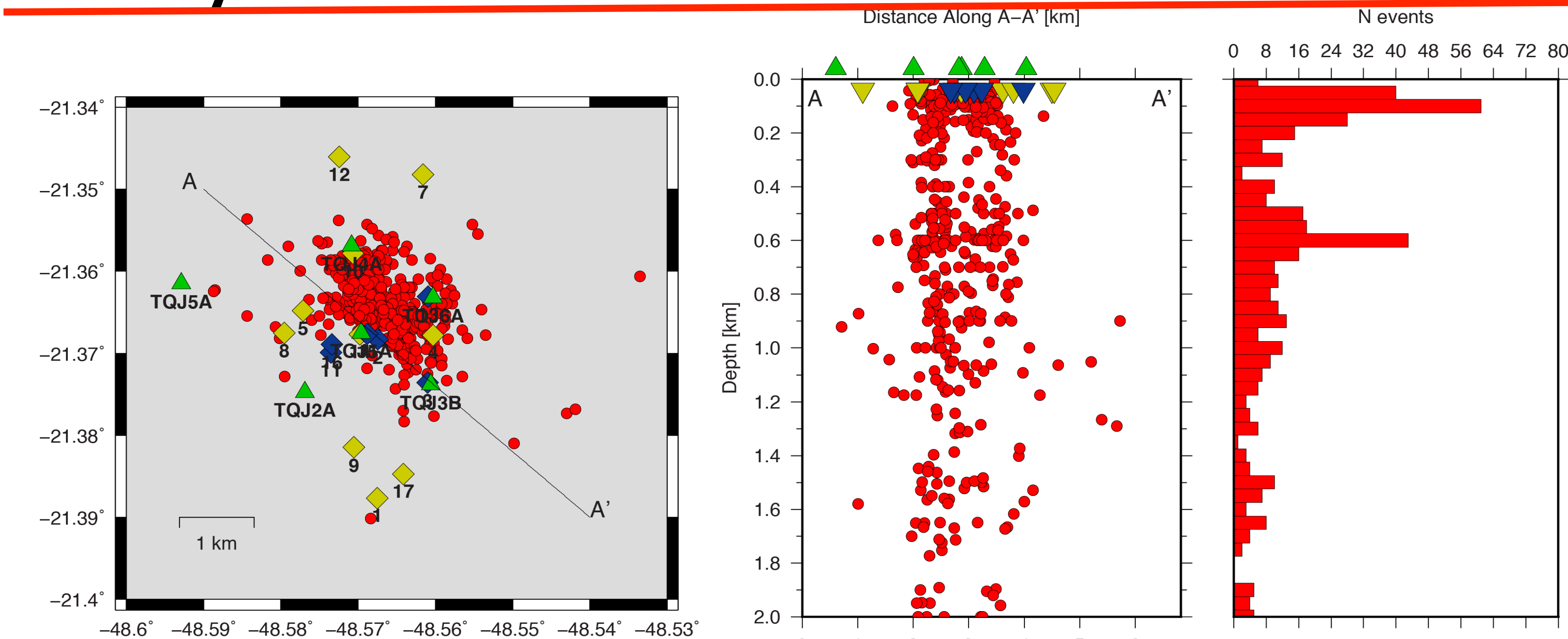
Moment Tensor

example of KIWI-rapidinv (Cesca et. al., 2010). MT inversion stages: Step 1 [right] the amplitude spectra is used to solve for nodal planes and hypocentral depth.
Step 2 [lower right] fits the waveforms in the time domain to solve polarity and with the possibility (if needed), to solve for a lateral variation of the hypocenter as well the hypocentral time.
This method allowed us to easily discriminate any particular component of one station if needed, if it has noisy or not working properly.



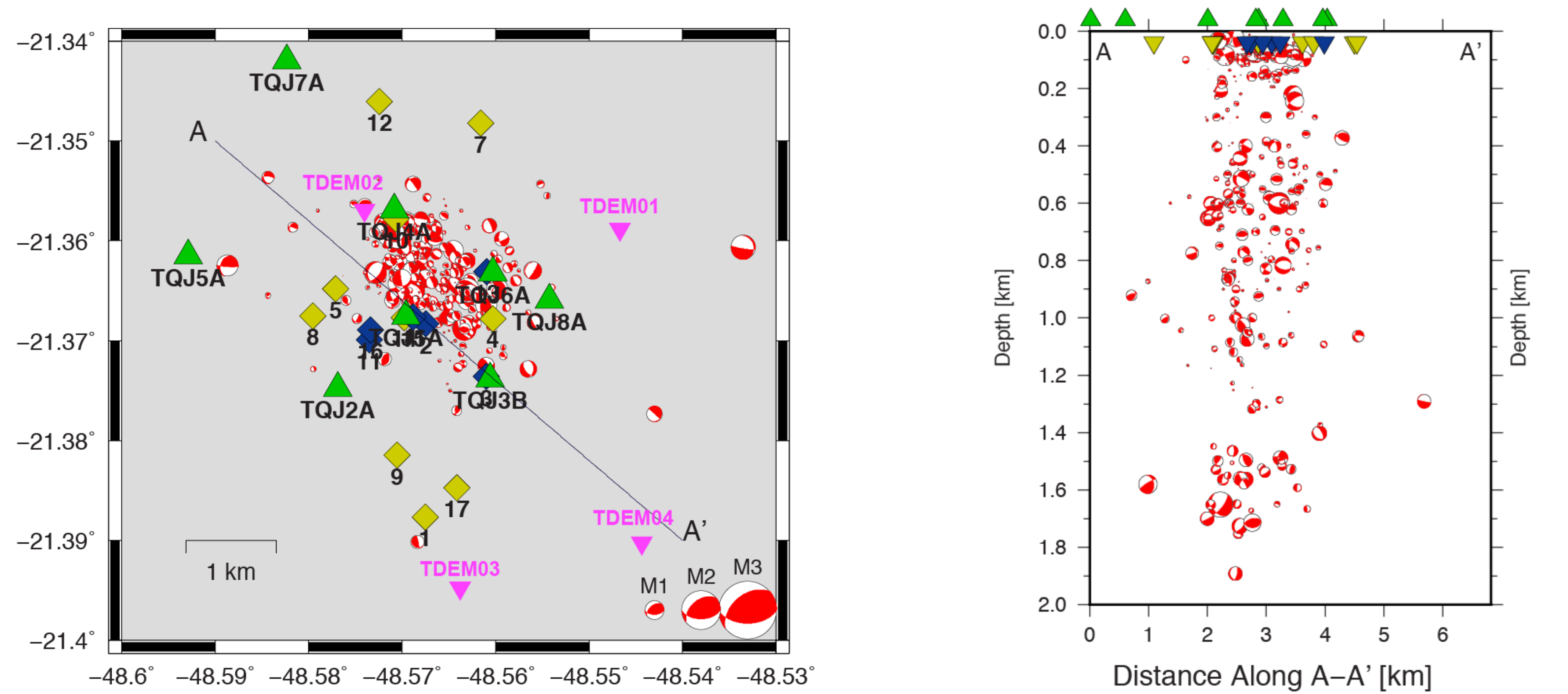


Analysis



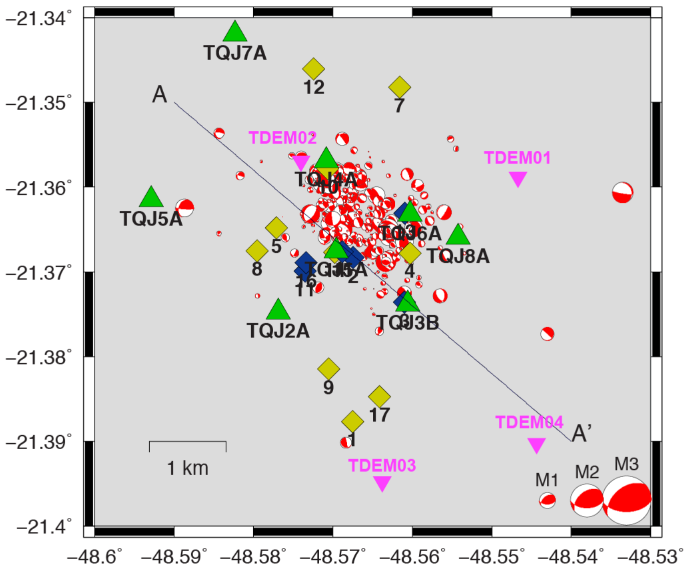
[Left] Distribution of relocated events in Jurupema from may 2016 to the end of 2019. [Middle] Projected depth cross-section along A-A' and (Right) depth distribution of the events in the middle panel in this time period, where most of the events are indeed very shallow (from 100 m to 200 m), and at the depth of 600 m. It is worth to note, that not all the events depicted here are suitable for focal mechanism analysis, due to quality of waveforms with acceptable quality for a moment tensor inversion. Additionally, the events that are deeper than about 1 km appear to have the largest errors, so for the moment we will focus on those above 1km

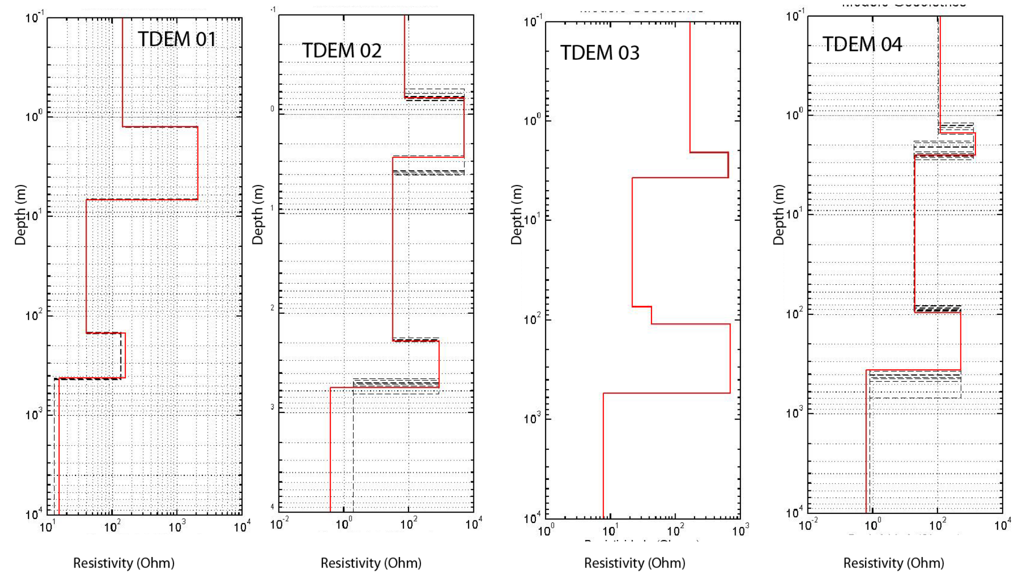
Analysis

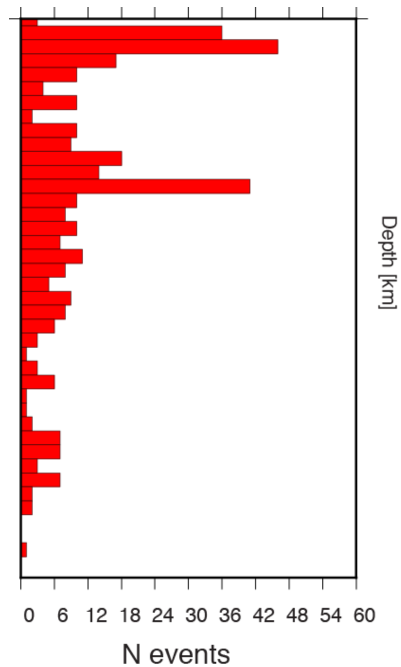


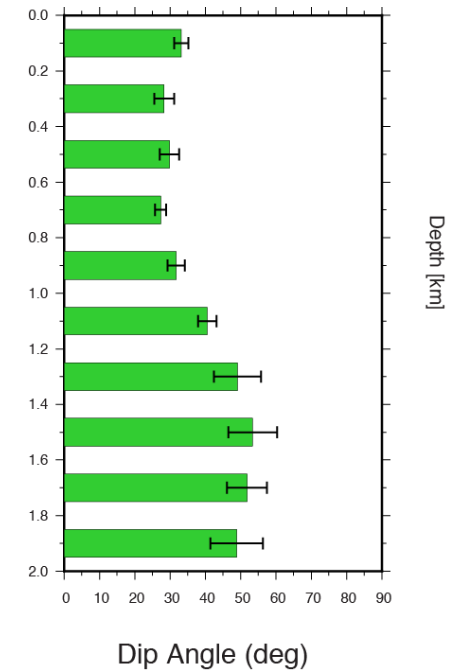
[Left] Distribution of Focal mechanisms in Jurupema from 2016 to 2019. The focal mechanisms of these events have been inverted using the methodology of Cesca et al. (2010). [Right] Projection of the cross section of the focal mechanisms along a vertical plane from A to A’. Note that the beach balls are also projected onto the vertical plane.

Analysis





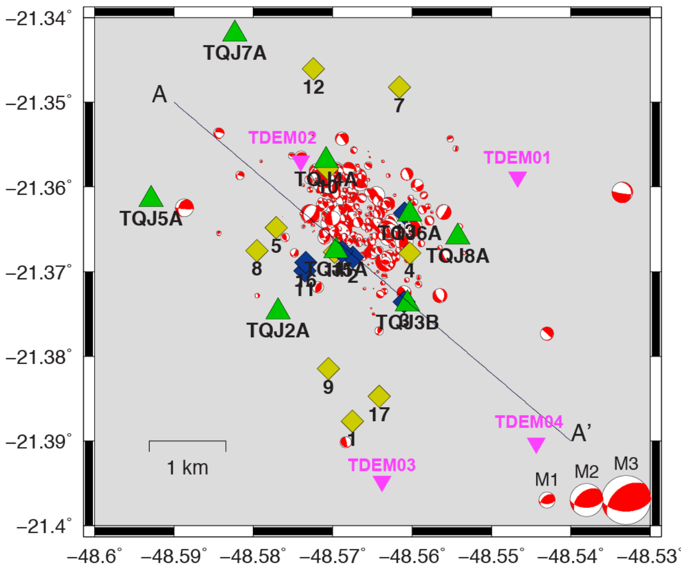




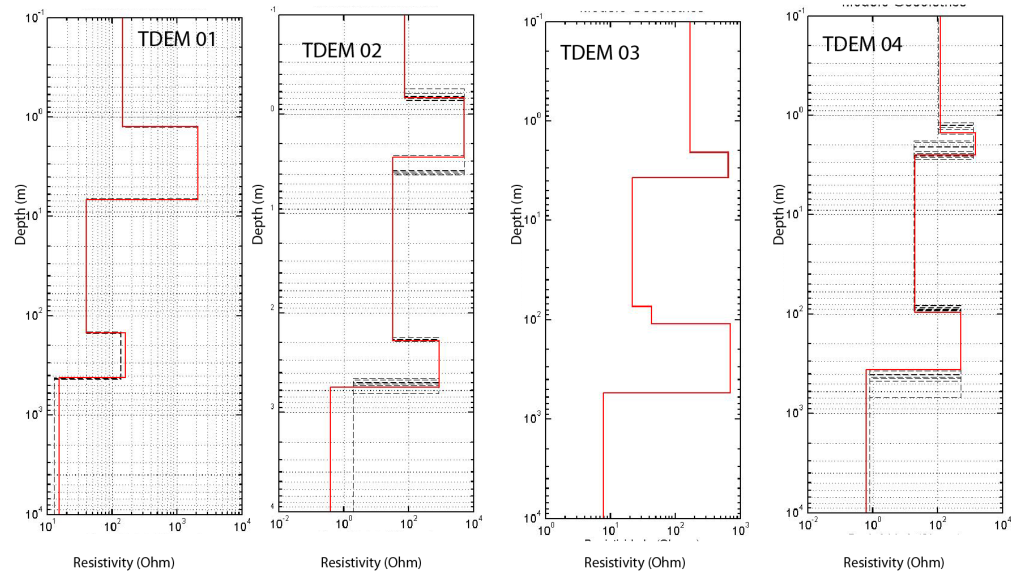
TDEM profiles [upper right], number of events registered (and inverted for) and distribution of dip angles [lower right]

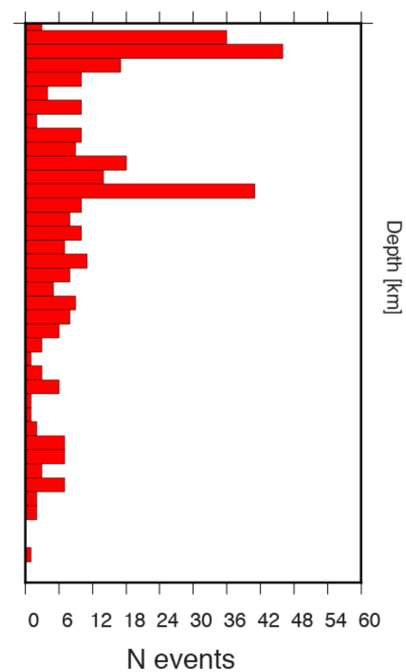
(Location of the TDEM profiles is on the upper-left map)

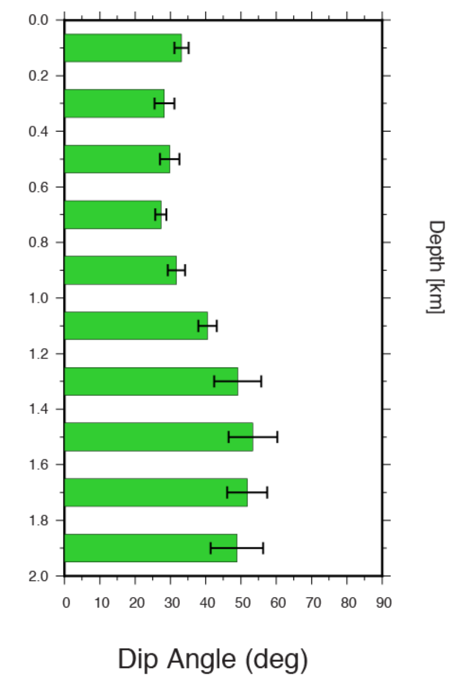
Analysis



the resistivity profiles point to two zones where the rock could be highly fractured: around 100 - 200 m and from about 500 – 700 m depth.

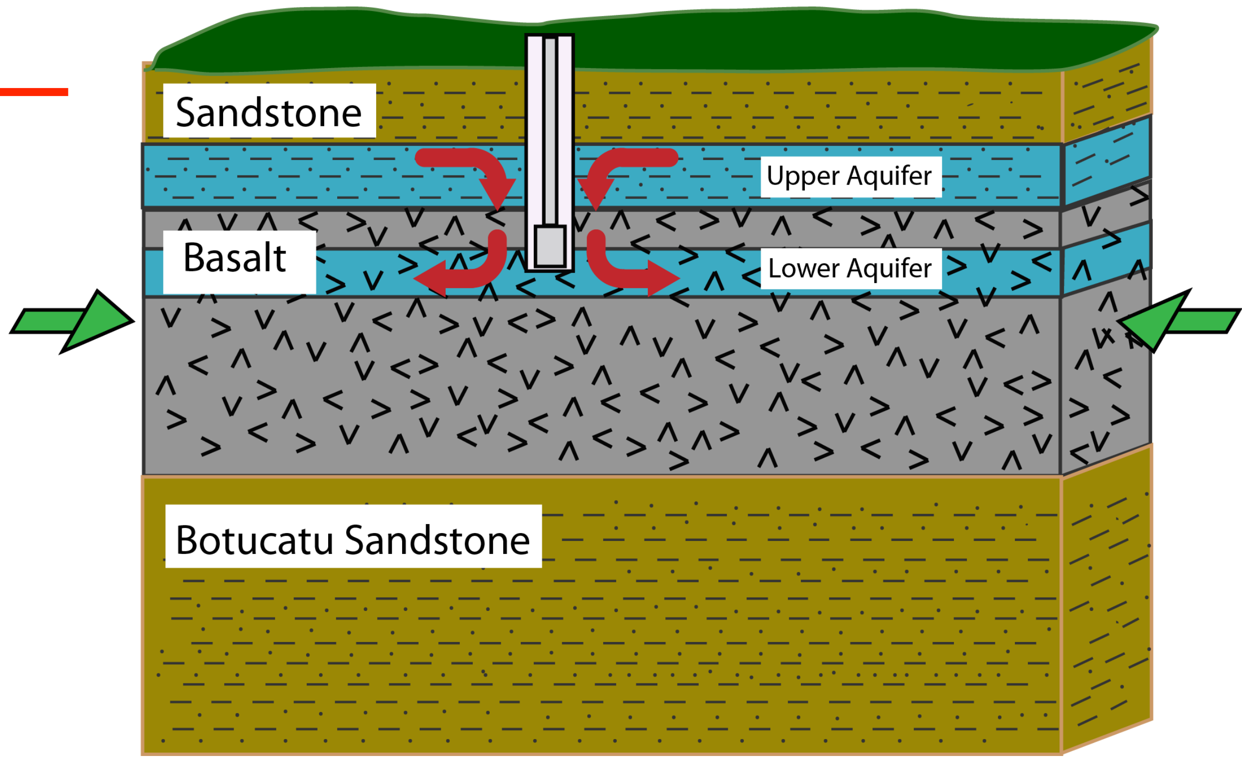






Analysis

[Right] Schematic representation of the rock formation and aquifer process in Jurupema.



The fractured basalt hosts the confined aquifer layers, and the well drilling without a proper casing seems to facilitate the infiltration of water from the upper aquifer into the lower aquifers

The wells that were drilled recently (>2014) do not seem to have casing in the borehole. This facilitates not only the flow of rainwater to the bottom of the upper aquifer, it also allows for the infiltration of water going from the upper aquifer to the lower aquifers.
This appears to facilitate the seasonal seismic events, occurring inside the basaltic rock layers that host the lower aquifers.

Analysis

The two main sections where most seismic events appear to occur are the ~100m and the ~600m depths, where, resistivity profiles most likely point to highly fractured basalt.

While the dip angle itself will not tell the full story of the specific mechanism, it is likely that the lower dip angles at those depths are representing events happening mostly at the base of the aquifers.

The seasonality seems to show that a heavy rain period is needed for the aquifer water flow to modify the pore pressure more effectively. However, as we do not have full reliable information about the flow rate of the water wells, and the extrapolation of precipitation data, it is difficult to obtain a more quantitative idea of the amount of rain and it relation for the water well flow rate (the precipitation is obtained by averaging weather stations around the town, but none of these stations is closer than 20km).

While there doesn't seem to be a high contrast of recent precipitation trends compared to previous years, there is an apparent decrease in seismic activity in the last year.

This decrease in events during 2019 could signify that either wells have placed casing, closed, of that the aquifer system is reaching an equilibrium. However, due to the many unknowns in out area and lack of reliable well data, it is hard to pinpoint on a single suspect.

Thank you

(please feel free to contact me for questions)

-Jaime

Acknowledgements

This study is part of the thematic project Pantanal-Chaco-Paraná Basins project 2013/24215-6.

Jaime Convers was supported by the Brazilian FAPESP grant 2016/13297-0.

Precipitation data is maintained by The National Institute of Meteorology of Brazil (INMET).

Water well data was collected thanks to the people of Jurupema-SP.

Station Installation, Maintenance, and data collection: Jose R. Barbosa, Cleusa Barbosa.

Seismic data quality control: Emilia Brasilio.