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Resevoir induced seismicity in Southern Brazil

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Reservoir Induced Seismicity in Southern Brazil

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RESERVOIR CHARACTERISTICS

We set out to study four different cases of reservoir induced seismicity in Southern Brazil (Table 1) The largest recorded earthquakes after impoundment measured 2.5 ML for Itá and Barra Grande, and 1.8 MLv for Machadinho and Campos Novos. Monitoring efforts have been in place continuously since impoundment. This presents a unique opportunity to study tectonic properties in regions where naturally occurring earthquakes are rare and to model the mechanisms triggering the observed seismicity.

Name	Height (m)	Volume (km³)	Impoundment Date	Largest Magnitude (ML)
Itá	130	5.1	1999	2.5
Machadinho	130	3.3	2001	1.8
Barra Grande	190	5.2	2005	2.5
Campos Novos	166	1.5	2005	1.8

Table 1: Reservoir information for the four cases we are currently studying. All dams have water columns of over 100 m. Seismicity has been ongoing at all reservoirs since impoundment (Barros et al. 2018).

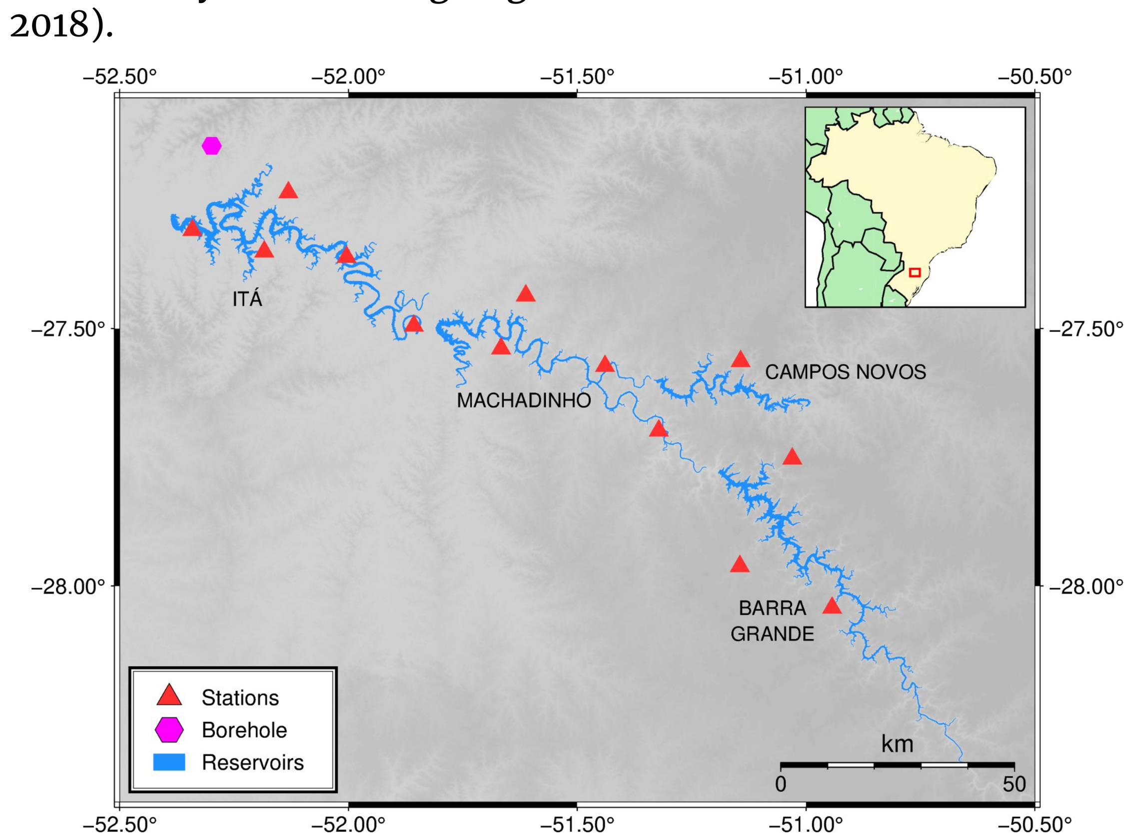

Figure 1: Reservoir locations in southern Brazil. A total of 13 seismic stations (red triangles) operated around the four reservoirs over different time periods. Magenta hexagon is borehole 1-SE-1-SC (SGB-CPRM). Southern Brazil is one of the most aseismic regions in intraplate South America. As such, induced earthquakes can provide valuable geophysical insights.

DATA ARCHEOLOGY

Figure 2: Data retrieval challenges. Machine Learning OCR (Amazon TexTract) had to be used to to extract catalog information. Over 500 pages had to be manually scanned. Old data was stored in CDs, in trigger mode (SEGY format). Over 30 print-only reports had to be thoroughly searched to get information on metadata, GPS, etc.

Vp/Vs RATIOS AND VELOCITY MODELS

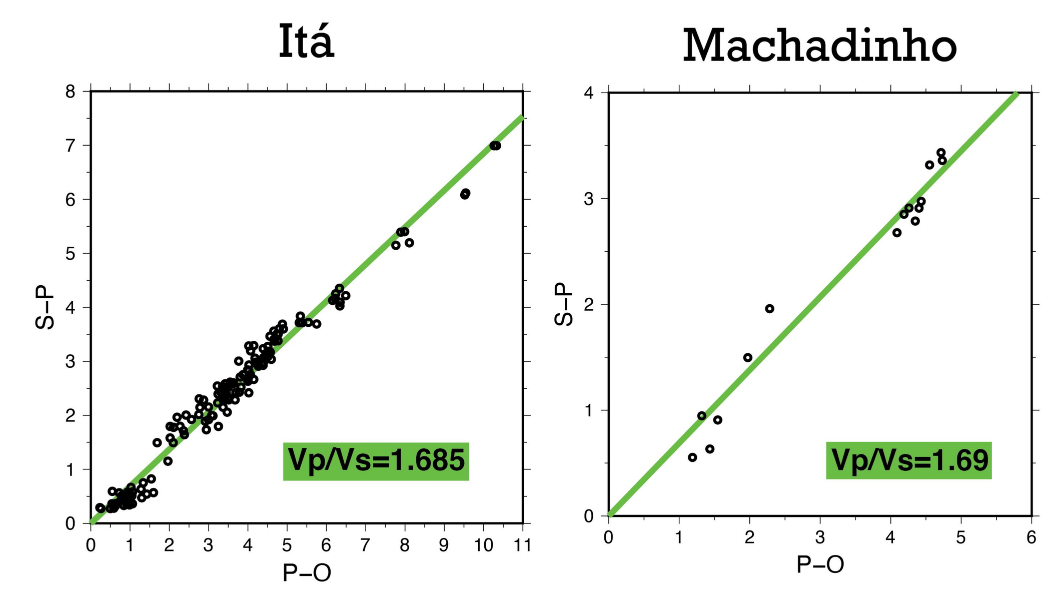

Figure 4: Vp/Vs ratio for Itá (left panel) and Machadinho (right panel). Vp/Vs = 1.685 +- 0.012 at Itá was determined using 61 events and 129 total data, and Vp/Vs = 1.689 +- 0.028 at Machadinho using 6 earthquakes and 19 total data. Both regions are geologically very similar, and this is reflected in the almost identical Vp/Vs found using different event sets at both reservoirs.

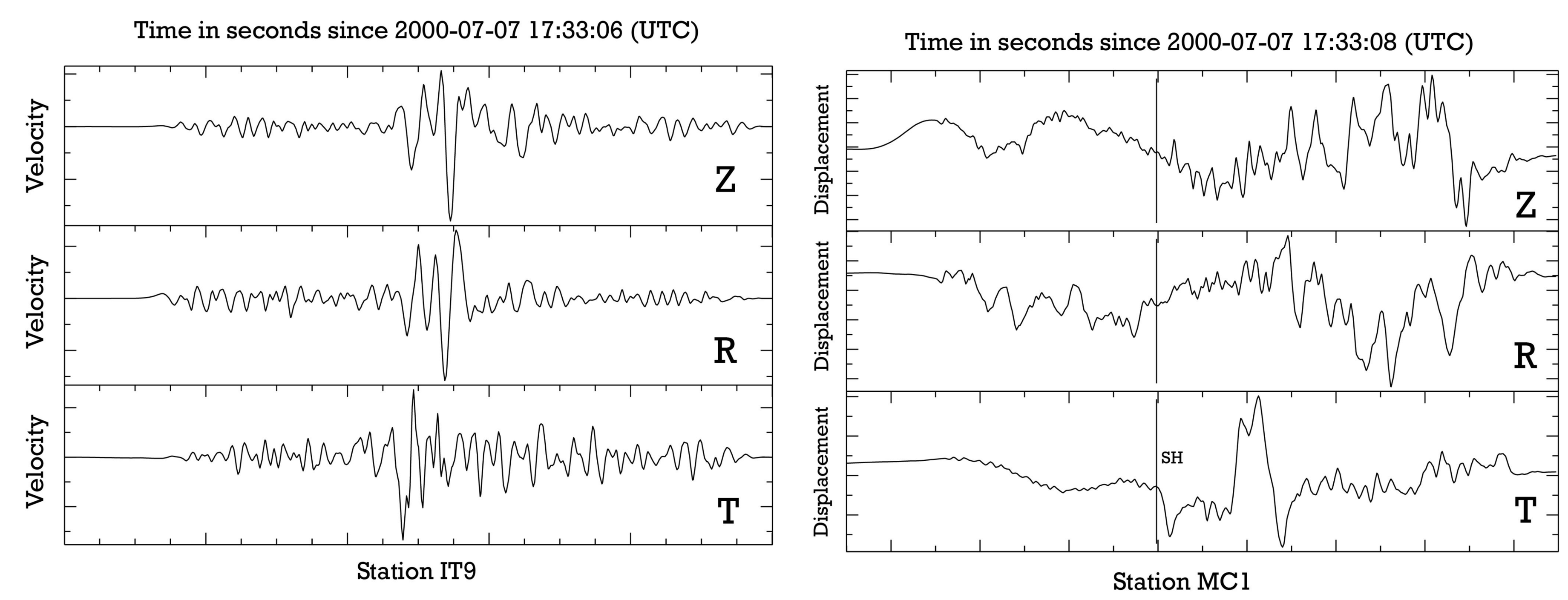

Figure 5: Seismogram for the largest event at Itá reservoir registered at stations IT9 (left, velocity) and MC1 (right, displacement). The SH arrival reading is shown at MC1. The many velocity inversions and complex geology upon which the reservoir sits make the reading of S arrivals particularly challenging for this region of Brazil. P arrivals also tend to be emergent for all but the closest stations depending on epicentral location.

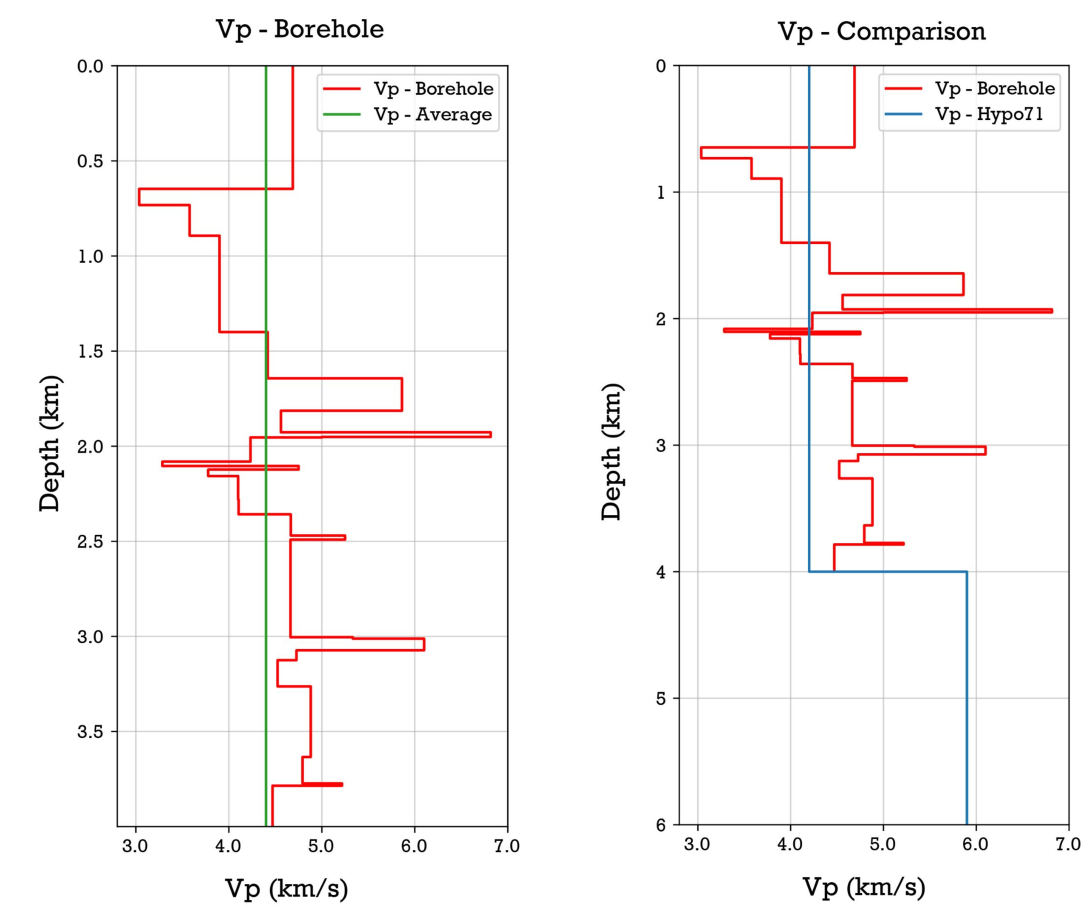

Figure 6: Velocity models for the reservoir region from borehole 1-SE-1-SC sonic logging data (SBG -CPRM). Left panel: Velocities for the topmost 4 km down to the basement. The red line shows the sonic log derived velocity curve, and green line shows the average velocity for the entire layer (4.4 km/s). Right panel: Comparison of the borehole model and the model used for locations at both Itá and Machadinho. The best velocity model for epicentral locations using HYPO71 71 is a two layer model with Vp = 4.2 km/s and 5.9 km/s in the top and bottom layers, respectively. The basement interface is located at roughly 4 km depth.

EPICENTERS AND FOCAL MECHANISM

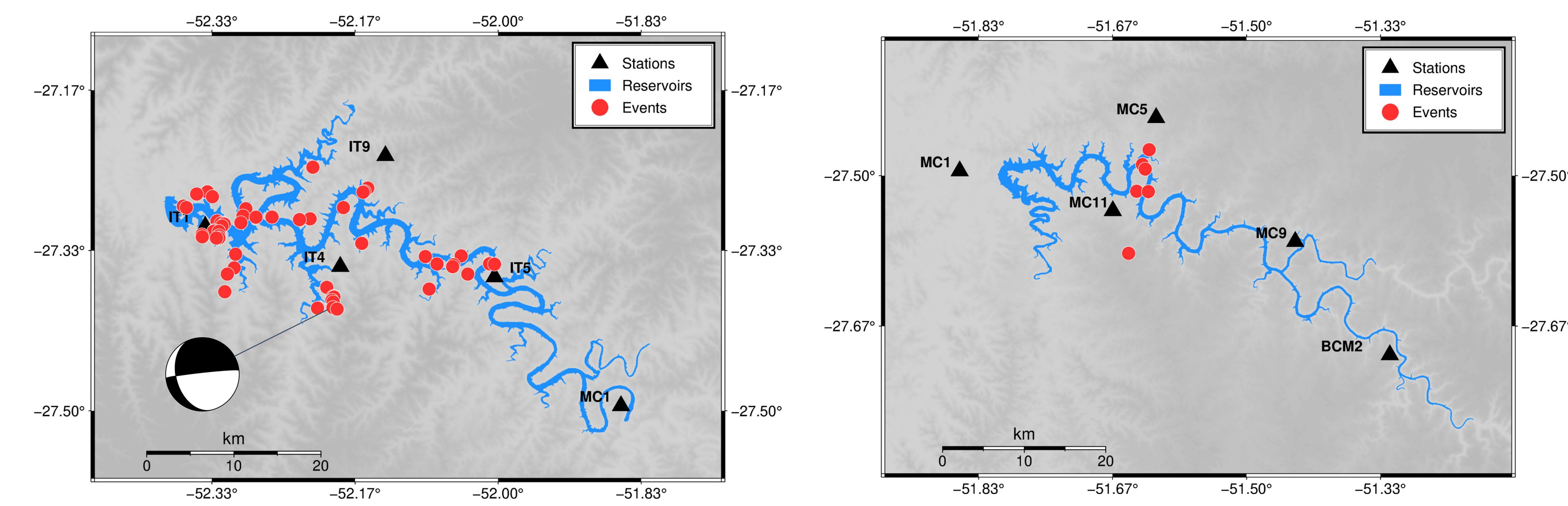

Figure 7: Best epicentral locations for Itá (left) and Machadinho (right) using HYPO71 and travel time residual minimization. Epicenters shown were obtained using the velocity model in Figure 5. RMS at both reservoirs is RMS = 0.085-. At Itá, epicentral alignments can be observed in different parts of the reservoir. At Machadinho, a tentative NS alignment across the reservoir seems visible, although more event locations are needed to confirm this trend. At Itá, the focal mechanism shown is the best solution obtained for the largest event at the reservoir.

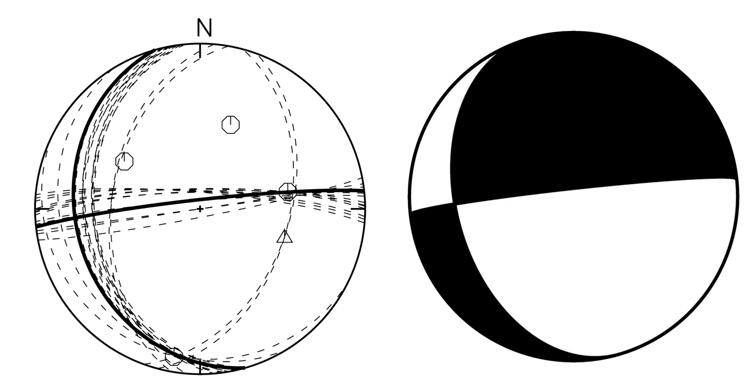

Figure 8: Left: All possible solutions for the focal mechanism of the largest event at Itá (2.5ML) obtained from P and SH polarities and SH/P amplitude ratios. 5 P polarities, 4 SH polarities and 1 SH/P amplitude ratios were used. Right: Best solution out of all 16 possible ones.

GEOMECHANICAL MODELING

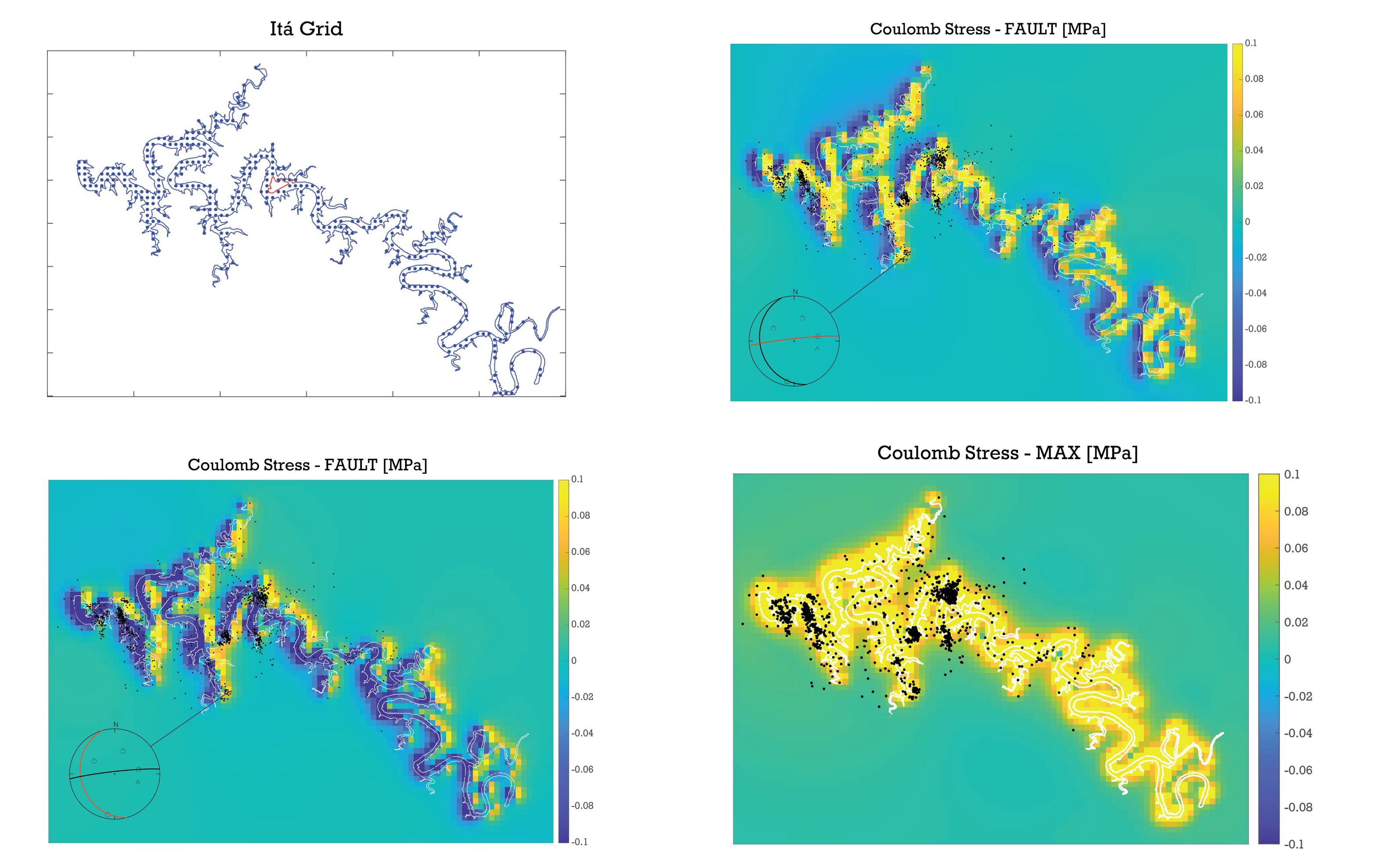

Figure 9: Top Left: Grid used to model stress changes caused by reservoir loading and poroelastic effects. Bottom left: Coulomb stress changes arising from reservoir loading for the (roughly) NS striking fault of the focal mechanism shown in Figure 8. Top Right: Same as top right but for the second possible fault plane (EW). Bottom right: Maximum Coulomb stress for any fault orientation. Yellow areas indicate Coulomb stresses favouring slip. Coulomb stress changes favour slip for both fault orientations.

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References: ***Barros, L. V., Assumpção, M., Ribotta, L. C., Ferreira, V. M., de Carvalho, J. M., Bowen, B. M., & Albuquerque, D. F. (2018). Reservoir-triggered seismicity in Brazil: Statistical characteristics in a midplate environment. Bulletin of the Seismological Society of America, 108(5B), 3046-3061.***

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