



The low Brazilian seismicity, with only three continental earthquakes of magnitude five in the last three decades (Figure 1) and, until recently, the low number of seismic stations, explain why it is difficult to detect events at regional distances that can be classed as Ground True event (GT5).

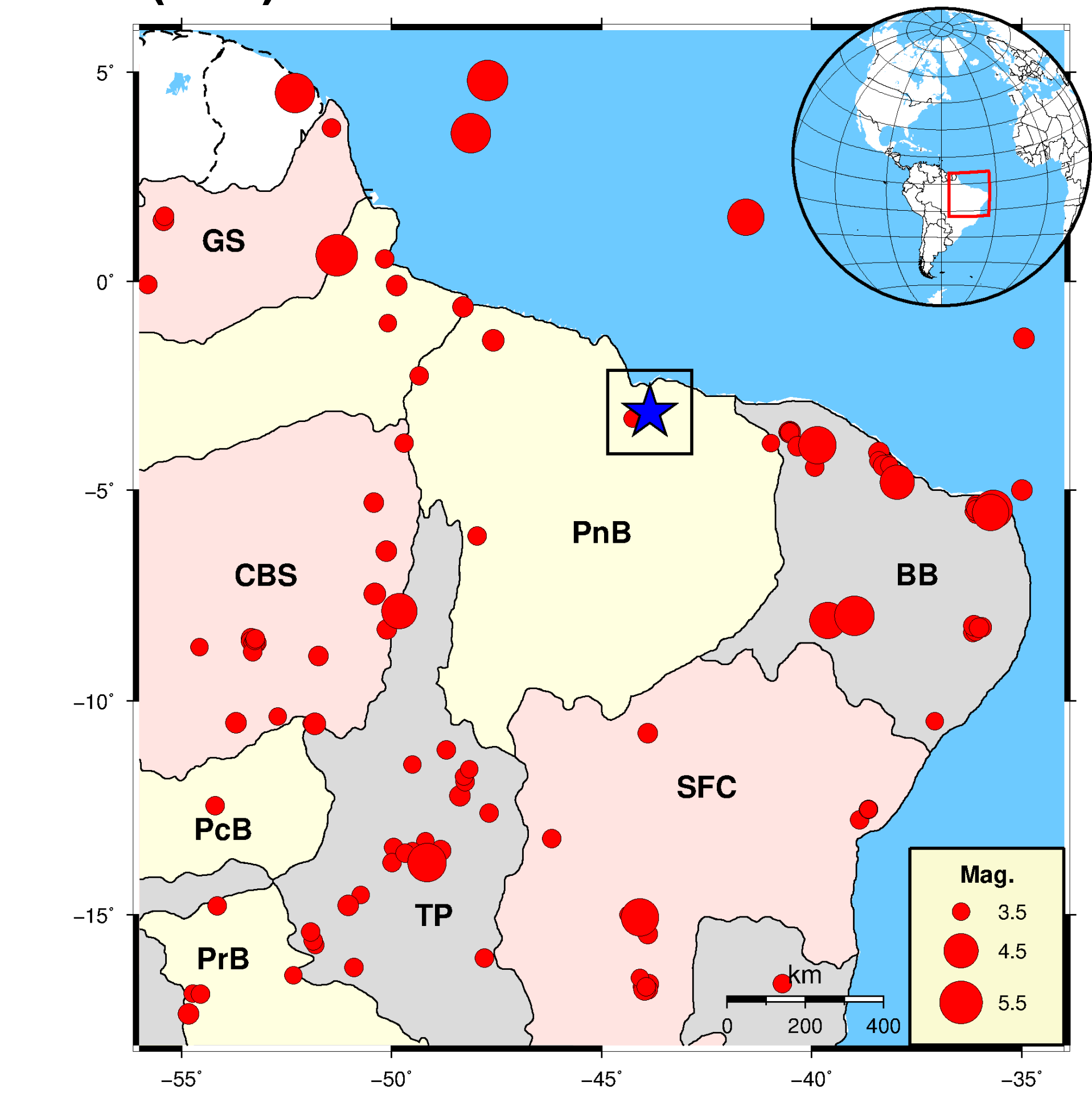
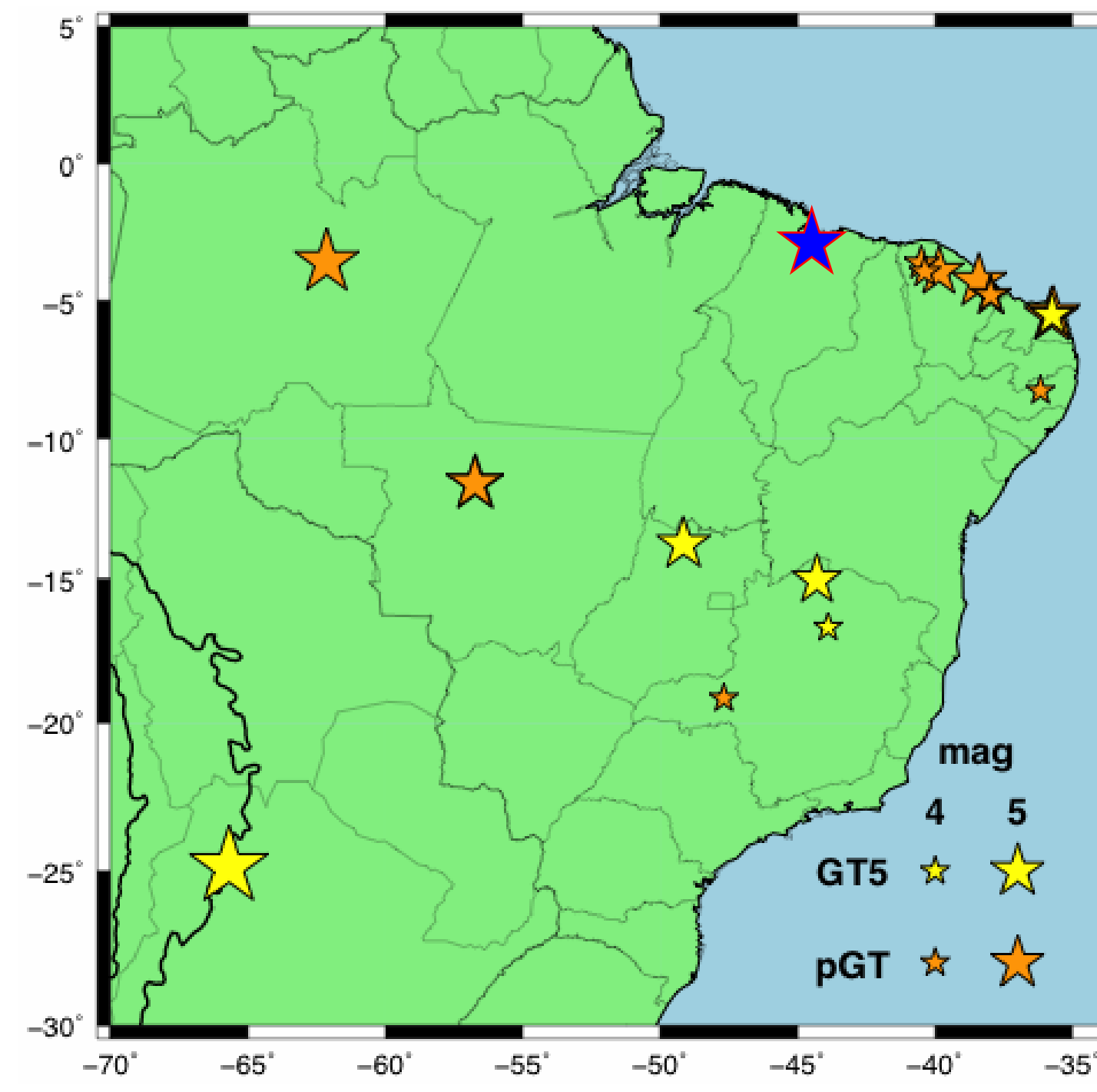


Figure 1. – Regional seismicity map. Red circles indicate the seismic events from the Brazilian Seismic Bulletin and the magnitudes as in the legend. The geological provinces are indicated by different colors: dark pink - Precambrian regions - São Francisco craton (SFC), Central Brazil Shield (CBS) and Guiana Shield (GS); light yellow - Phanerozoic regions, Parecis Basin (PcB), Paraná Basin (PrB), Amazon Basin (AmB) and Parnaíba Basin (PnB); mobile shield - light grey.

In the first PTS - CTBTO RSTT meeting (in June of 2012) seismologists from the South America were encouraged to cooperate in identifying GTx events. At that time, Brazil appeared completely empty in the world map of GT events. With the deployment of the Brazilian Seismographic Network (RSBR) (Figure 2) and using aftershock sequences well recorded by local and regional stations as reference events, it was possible to relocate mainshocks suitable for GT5 events

Fig. 2 - Ground Truth events



Maranhão earthquake of January 3, 2017 – 4.6 mb (VI MMI). Detected by 50 stations- 86 phases at distances up to 2500 km.

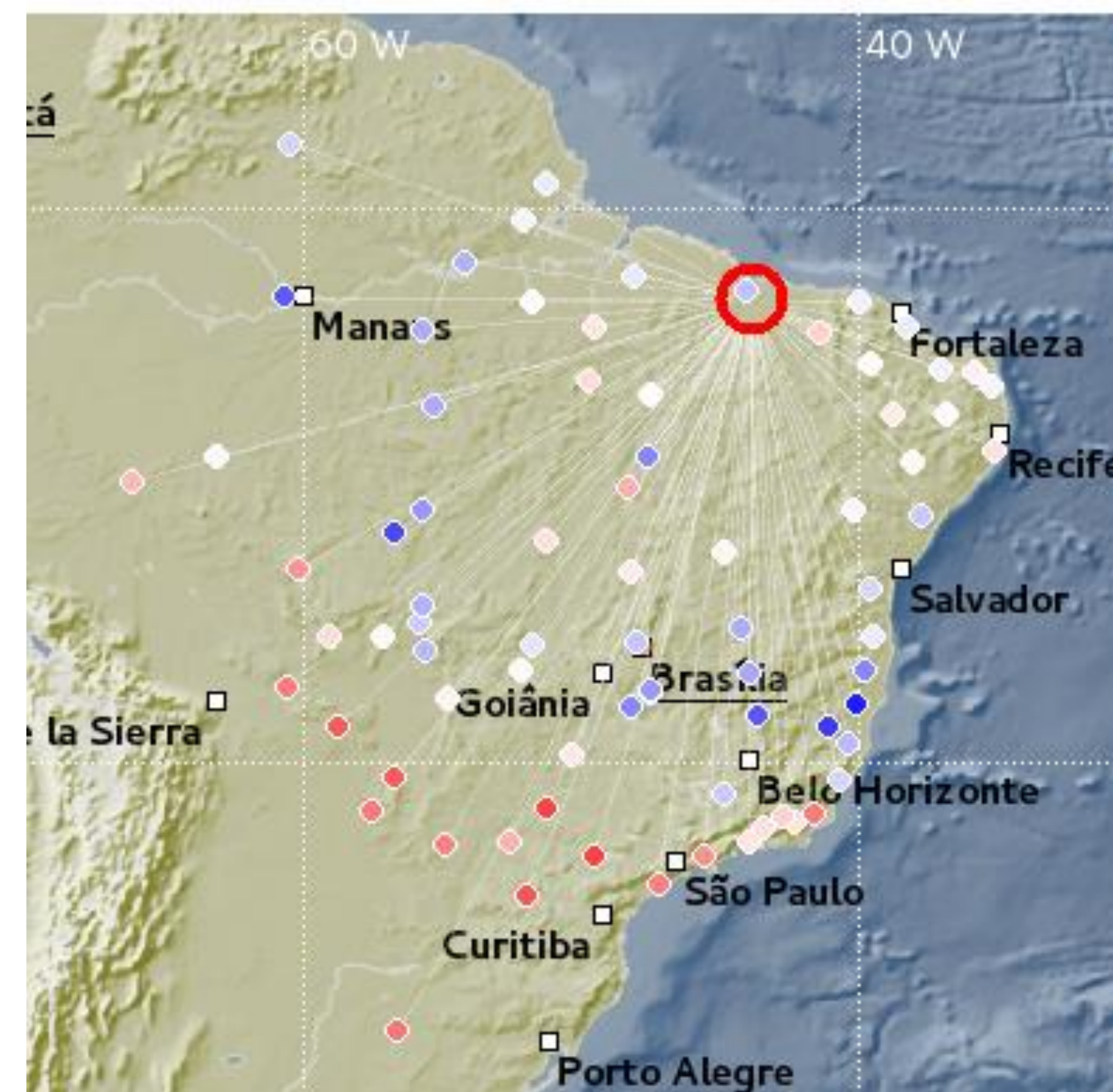


Figure 3. - Maranhão earthquake, 4.6 mb – Maranhão State.

We studied the aftershock activity after a 4.6 mb mainshock on January 3, 2017. This event was registered by 50 regional stations of the RSBR (Figure 3).

A local seismic network, with 5 stations (Figure 4) permitted the earthquake to be relocated with an accuracy of a GT5 event.

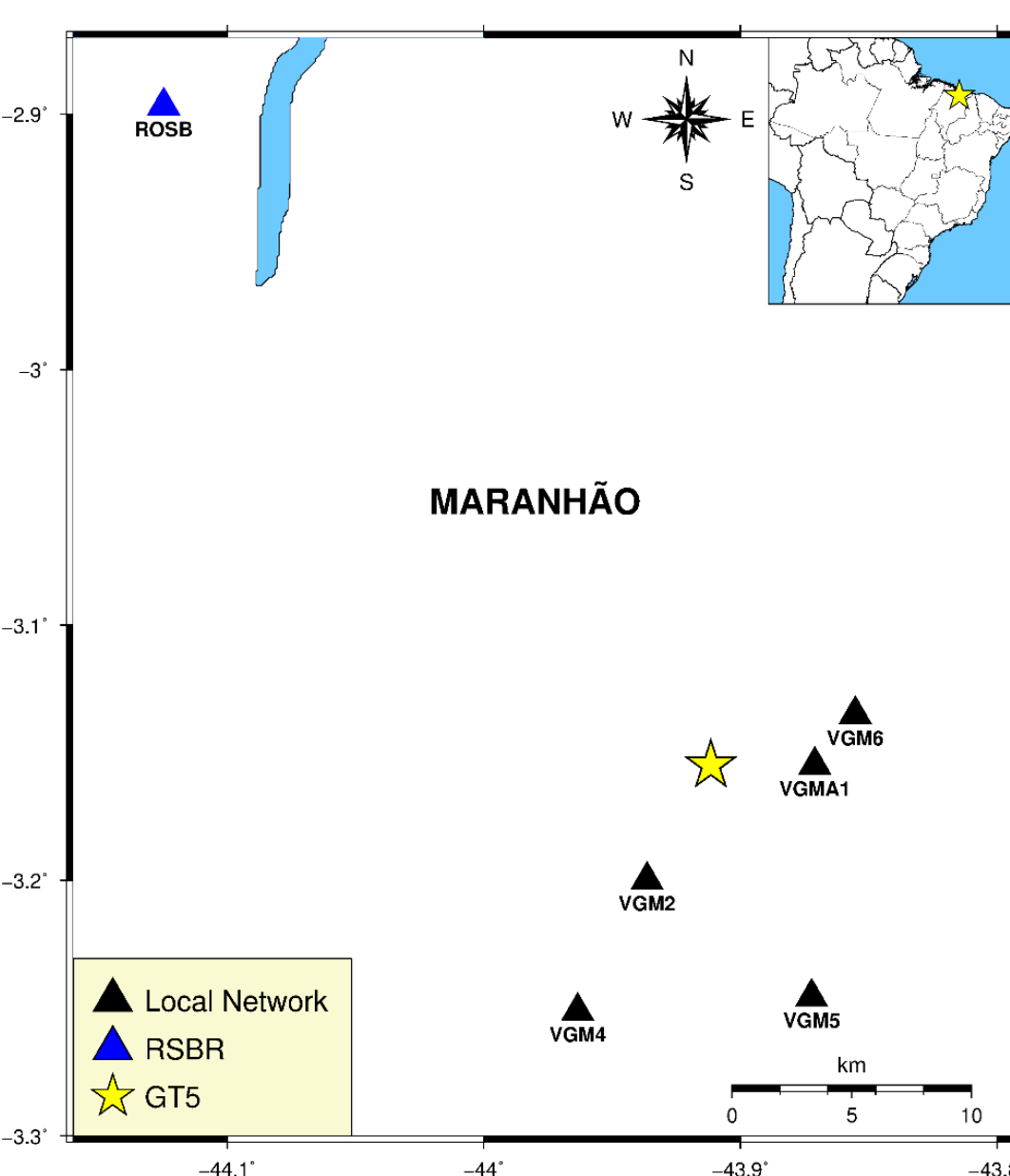


Figure 4. - Local network 6 stations.

For hypocentral location an accurate velocity model was determined using phase conversion, clearly identified on the interface sediment-basement (Figure 5a).

In this work, we present a new GT5 event in order to better define the 3D velocity model for Brazil.

- Local velocity model -Components Z, R and T in VM2, VM4 and VM6.
- Sp e Ps are phases converted in the basement interface x sediments.
- Ps - P = S - Sp, proportional to the thickness of the sediment package

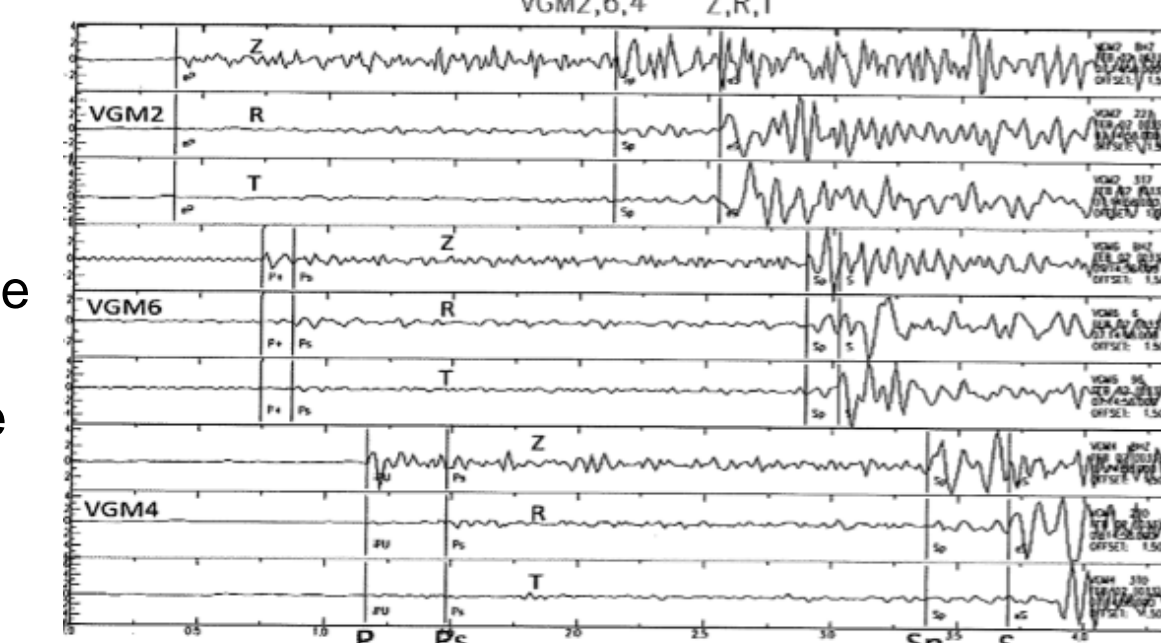


Figure 5a. – Local network Waveform (Ps – P = S – Sp).

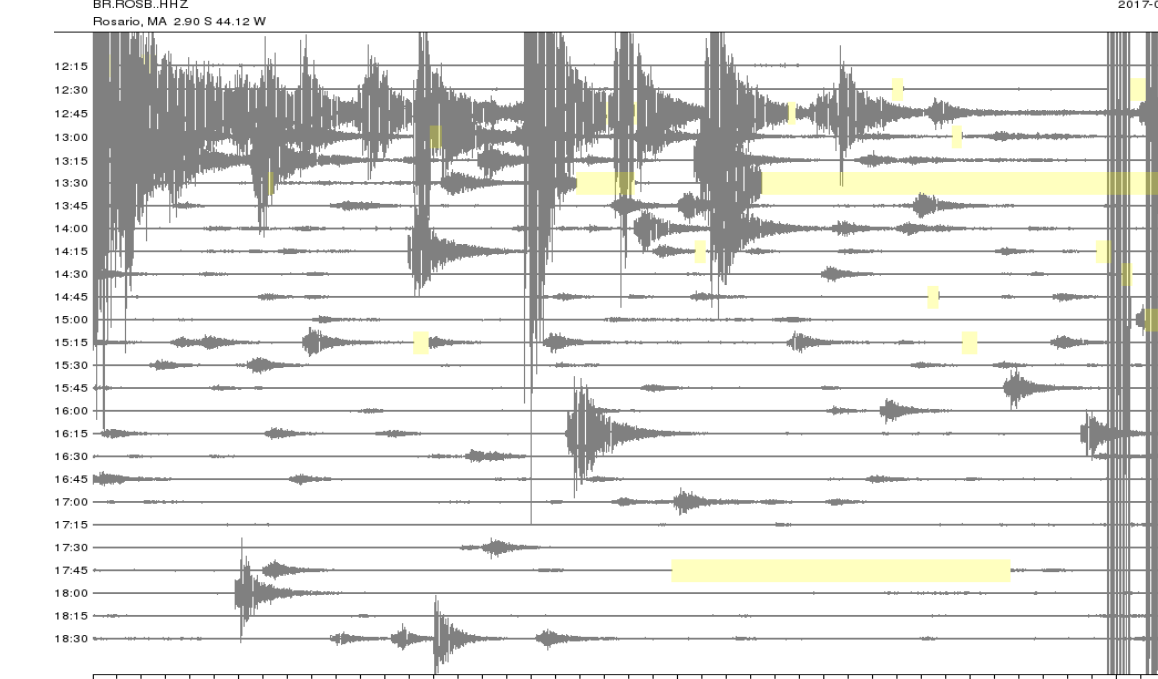


Figure 5b. – Six hours seismogram (ROSB) showing the main event and the aftershock activity with more than 100 events.

1D Velocity model

3.60	0.00
6.20	0.50
6.40	10.00
8.00	40.00
Hi = 5km	Vp/Vs = 1.73

How to get a Ground-Truth event

Ground truth (GTx) - 'x' designates accuracy in km. The true epicenter lies within 'x' km of the estimated epicentre. Possible GTs: GT0, GT1, GT2, GT5, GT10

criteria based on network geometry.

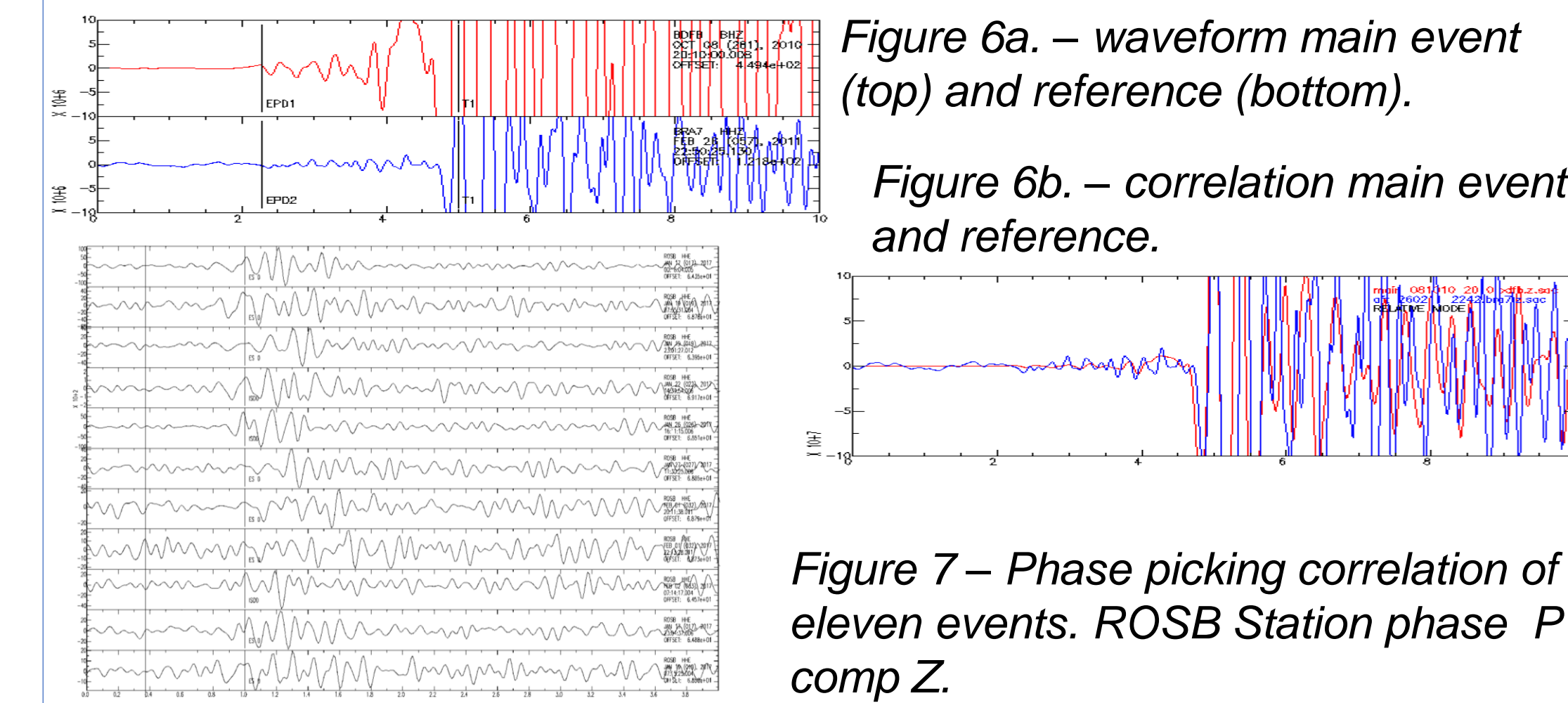
- The selection criteria identify GT5 candidate events at the 95% confidence level if they are located:
- (1) with at least 10 stations, all within 250 km;
 - (2) with an azimuthal gap of less than 110°;
 - (3) with a secondary azimuthal gap of less than 160°;
 - (4) with at least one station within 30 km from the epicentre.

Requirements hard-to-reach with space networks and low seismicity as it is the case of Brazil.

Reference event registered locally and regionally

The P and S waveforms of the reference events and the main event are correlated to determine the arrivals in a consistent way (Figure 6a).

Weak phases in the references events are read using the strong mainshock signal filtered in the same frequency band to compensate for differences in magnitudes. The cross-correlation used to identify common phases in both signals (Figure 6b).



Aftershocks hypocentral location of 7 events with three stations: VGM2, VGM4 and ROSB) and two events located with the addition of VGM5 and VGM6 (Figure 8).

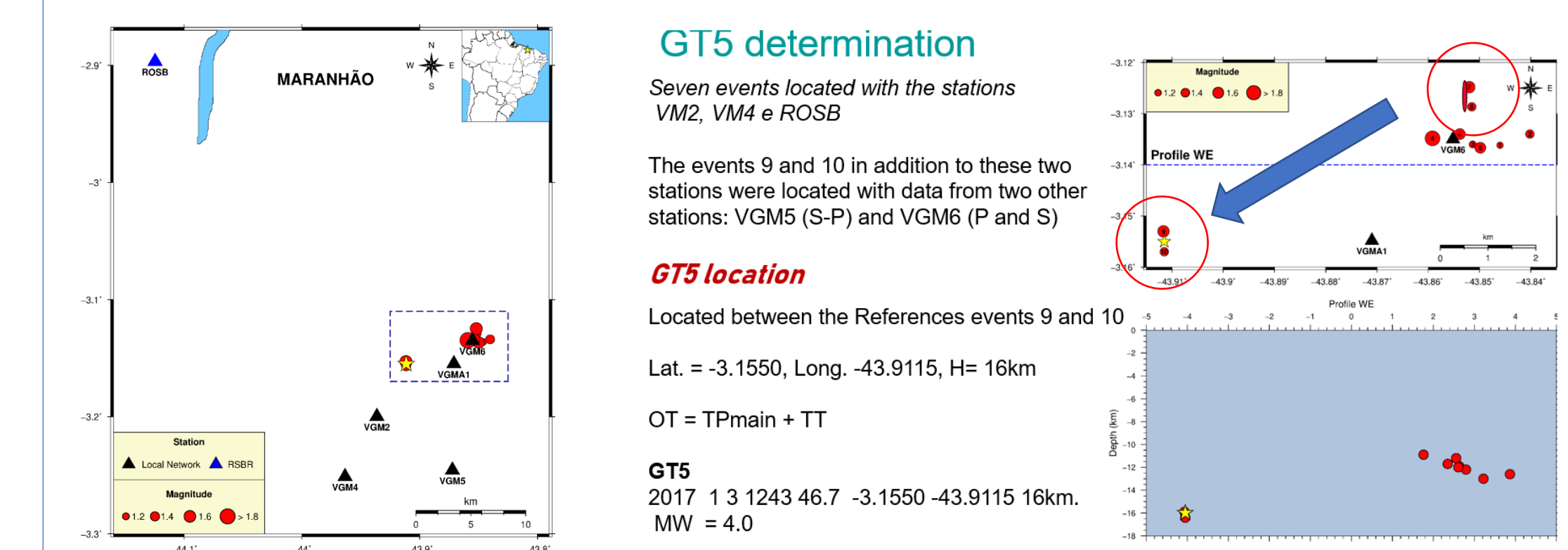
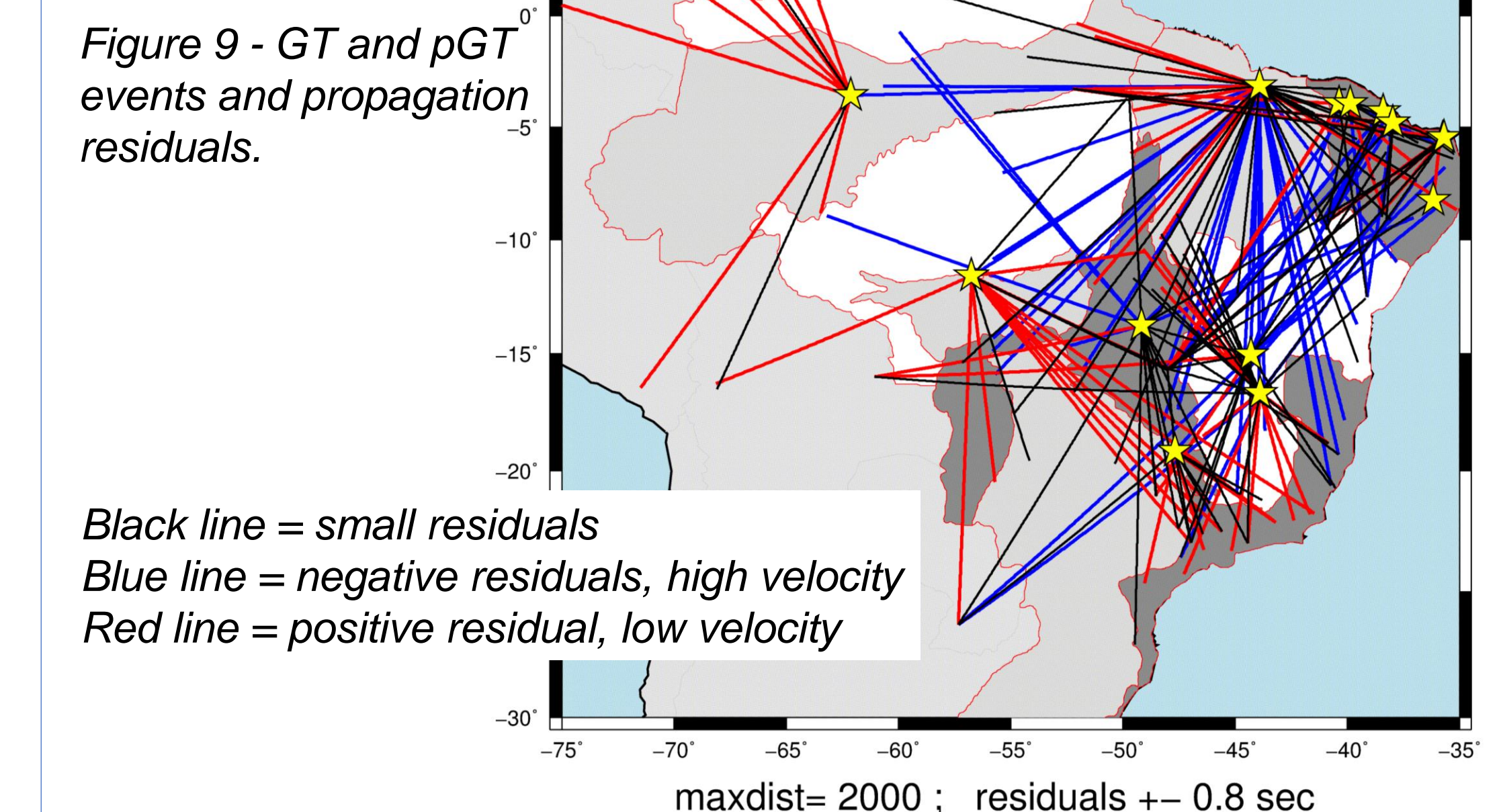


Figure 8 – seven events located with 3 stations and two with 5 stations.



Discussion and conclusions

1. The determination of GT5 events in Brazil resulted from joint studies with local and regional networks (RSBR).
2. GT events allow the determination of more precise models. In Brazil, errors of epicentral location of the order of 10-30km are possible due to the variations of velocities of P and S in the upper mantle, caused by structural variations not compensated by 1D models. This is reflected negatively in seismic risk studies currently carried out in Brazil.
3. This event is an important (GT5) because it occurred in a completely aseismic region – (PNB).