Strain Rate of South American Lithospheric Plate by SIRGAS-CON Geodetic Observations

Estimativa da Taxa de Deformação da Região Intraplaca Sul Americana por Observações Geodésicas na Rede SIRGAS-COM

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INTRODUCTION

Previous work

There are several works related with the analysis of the terrestrial surface deformation - aiming to understand the dynamic related with the stress applied in the intraplate regions: For example:
Assumption (1992) - contact's forces with the Nazca Plate - can't be the only important contributor to the intraplate region on western South America.

Norabuena *et al.* (1998) and Cretaux *et al.* (1998) - GPS, SLR and DORIS data - crustal shortening occur within the South American Plate, indicating that Andes still in constant formation.

Coblentz & Richardson (1996) - model to describe the stress state of South American Plate - significant changes of the stress field occur in the western part of the Plate in response to the forces associated with the high topography of Andes.

Lima (2000) – Compilation of stress data, numerical models of intraplate stress field and results based on geodetic observations - South American Plate is on horizontal compression and shortening.

INTRODUCTION

Kreemer et al. (2003) model - confirmed correlation between global seismicity rates and tectonic movement rates along subduction zones and continental deformation zones, including the South American Plate.

Ruegg et al. (2009) - accumulation of interseismic stress measured by the GPS in the seismic gap of Chile - surface deformation in the south region comprised by Concepción and Constitución is consistent with elastic loading at the interface of subduction in depth.

In case of forces acting on lithospheric Plates, it is understood that the study of forces and deformation are still a field that needs further research.

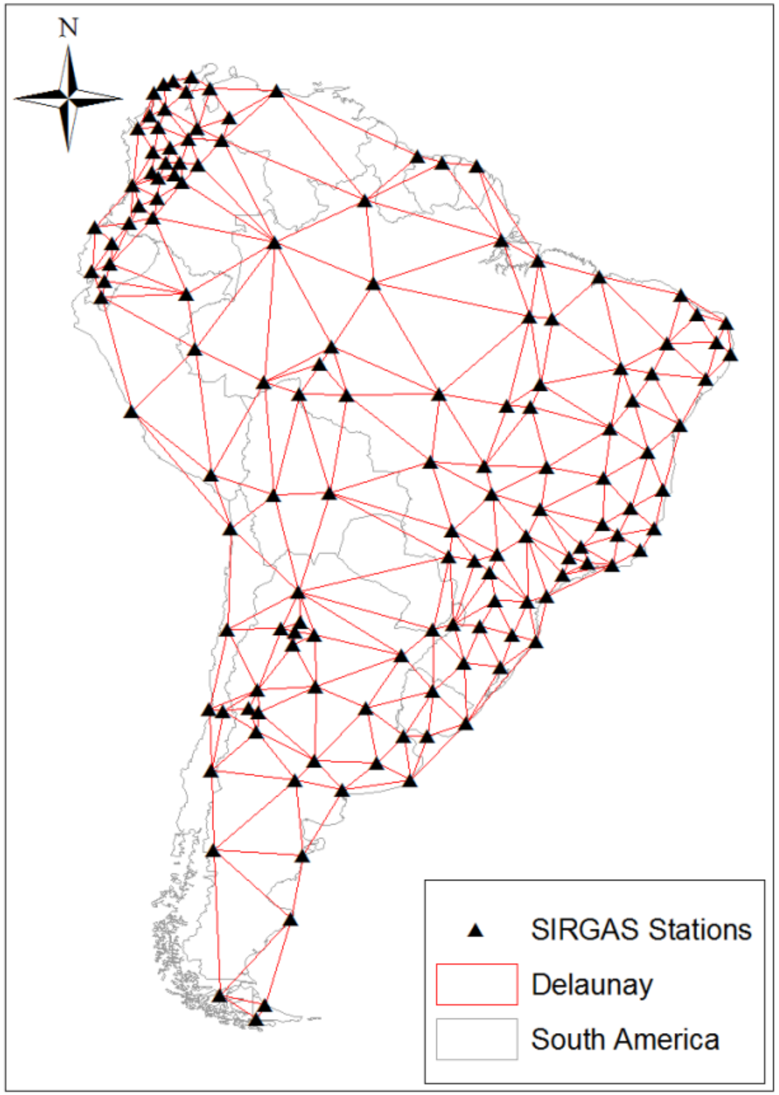
OBJECTIVE

- Estimate the strain rates (taxa de deformação) at surface of South American Plate, by velocity vectors determined by GNSS (Global Navigation Satellite Systems) positioning methods in part of a geodetic network of continuous monitoring, called SIRGAS-CON.

- Try to understand these strain rates by the strress (esforços) that the Plate is submitted.

AREA OF STUDIES

- Region comprised by the network SIRGAS-CON contained in the South America.



We used values of coordinates and velocity vectors estimated and provided by SIRGAS via Sanchez and Seitz (2011) between 2000 and 2012.

Stations selection:

Stations in which time-series of <u>estimated</u> coordinates did not show problems of jumping as those due to earthquakes of great magnitude and changing of antennas of the GNSS stations. (140 stations)

METODOLOGY

- Establishment of networks by Delaunay triangulation.

- Calculation of initial and final coordinates - based on the values of coordinates and velocity of each individual station, with their precisions.

- Transformation of coordinates system: from Cartesian geocentric geodetic system to a local geodetic system (Monico, 2008).

- Model of strain rate – ε:

$$\varepsilon = \frac{S' - S}{\Delta t . S}$$

- Consideration of two-dimensional plane of stress to measure strain rate by finite element method (Turcotte & Schubert, 2002; Deniz & Ozener, 2010):

$$\varepsilon = e_{xx}.\cos^2 Az + e_{xy}.\mathrm{sen}(2.Az) + e_{yy}.\mathrm{sen}^2 Az$$

e_{xx} e_{xy} e_{yy} : deformation parameters

Deniz & Ozener (2010) - This method determines the parameters of deformation independently of the datum, using for this a relation of distance between points of two epochs. Model is free of translations.

METODOLOGY

From the deformation parameters, we calculated for each plane defined by the vectorial components of the coordinates, the principal components of maximal and minimal strain rates, together with its orientation.

$$E_1 = \frac{1}{2}\left[(e_{xx} + e_{yy}) + \sqrt{(e_{xx} - e_{yy})^2 + (2.e_{xy})^2}\right]$$

$$E_2 = \frac{1}{2}\left[(e_{xx} + e_{yy}) - \sqrt{(e_{xx} - e_{yy})^2 + (2.e_{xy})^2}\right]$$

$$\beta = arctan\left(\frac{e_{xy}}{E_1 - e_{xy}}\right)$$

It was also possible to compute the dilation rate (D), which show the regions with tendency to shortening or extension:

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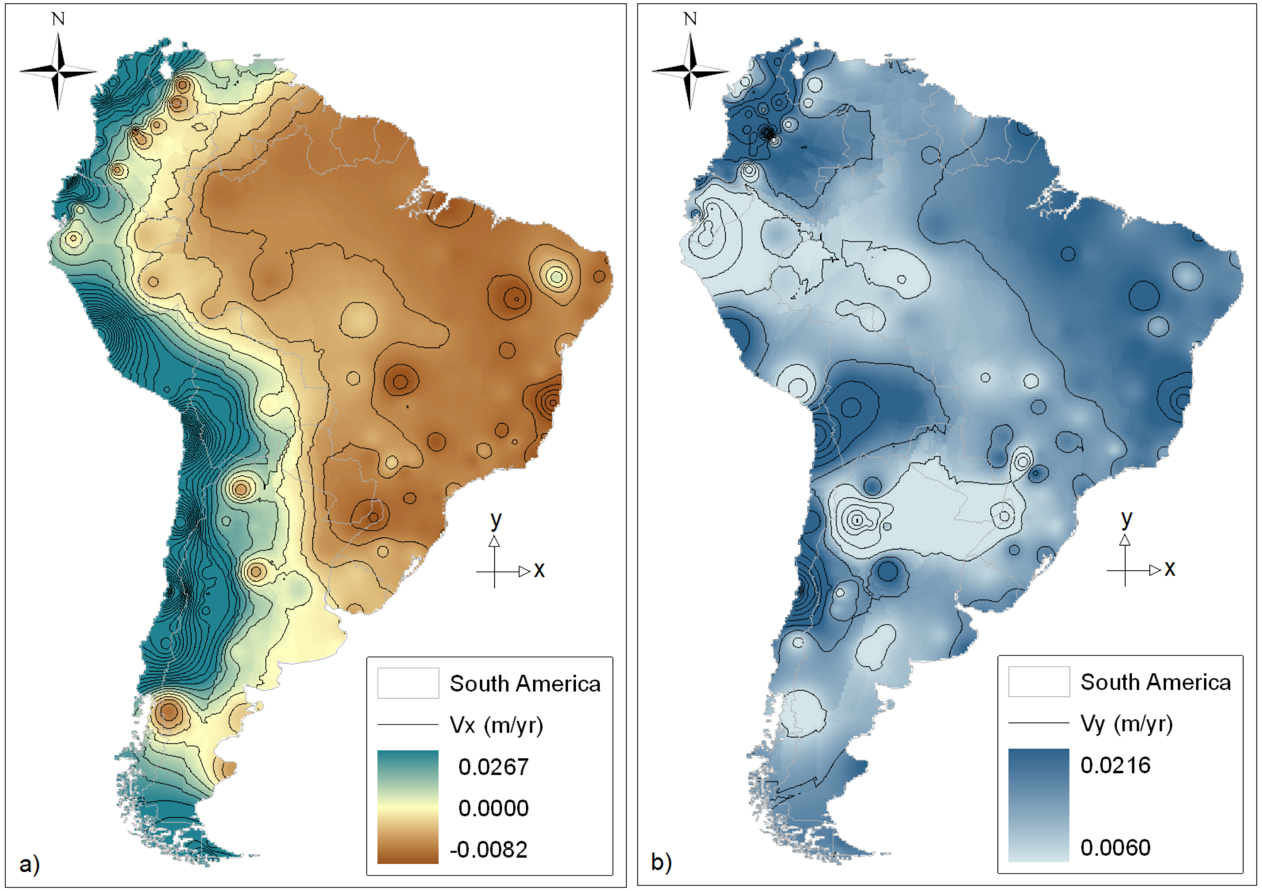
$$D = (e_{xx} + e_{yy})$$

RESULTS and DISCUSSION

Planimetric velocity vectors in the local geodetic system, of each one of the 140 selected geodetic stations, interpolated for whole South America.



Change of direction in the movement of the stations:

Direction (*x*): maximum of 18.5 mm/year. (direction to west and east)
Direction (*y*): maximum of 15.6 mm/year (direction only on north)

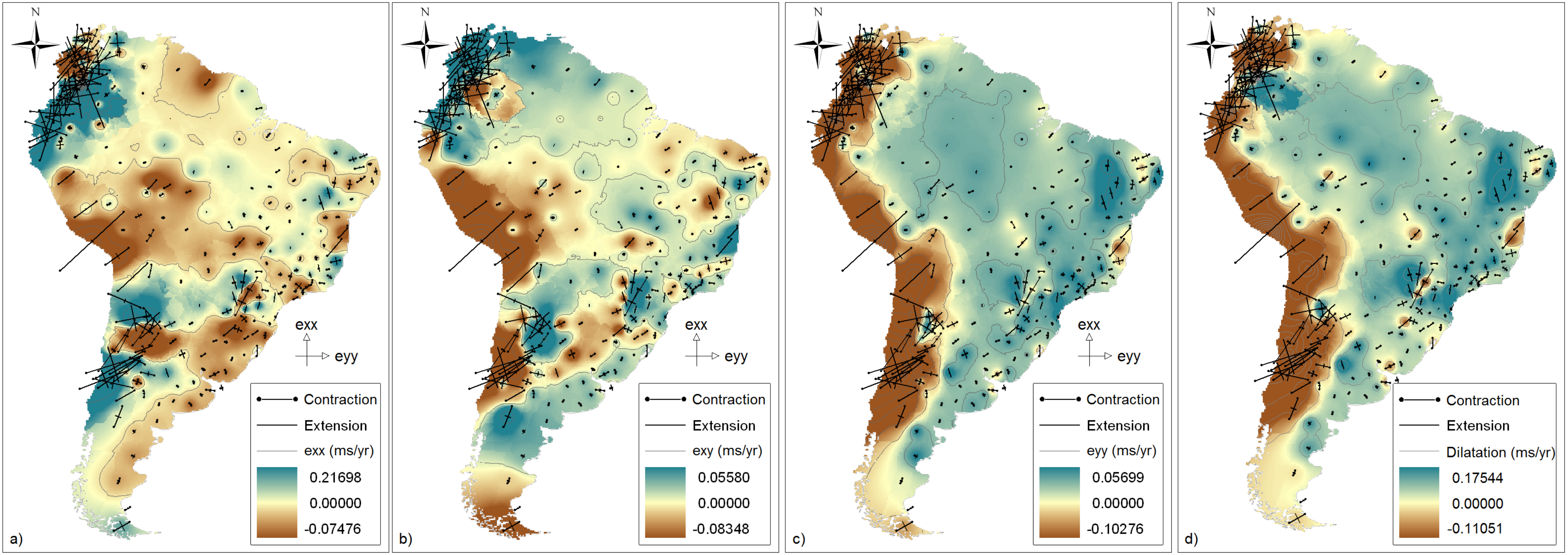
We suggest that a large influence comes from the interaction of stress applied by the subduction of the Nazca under the South American Plate.

We suggest influence predominantly tectonic with some variation that may be attributable to local effects.

RESULTS and DISCUSSION

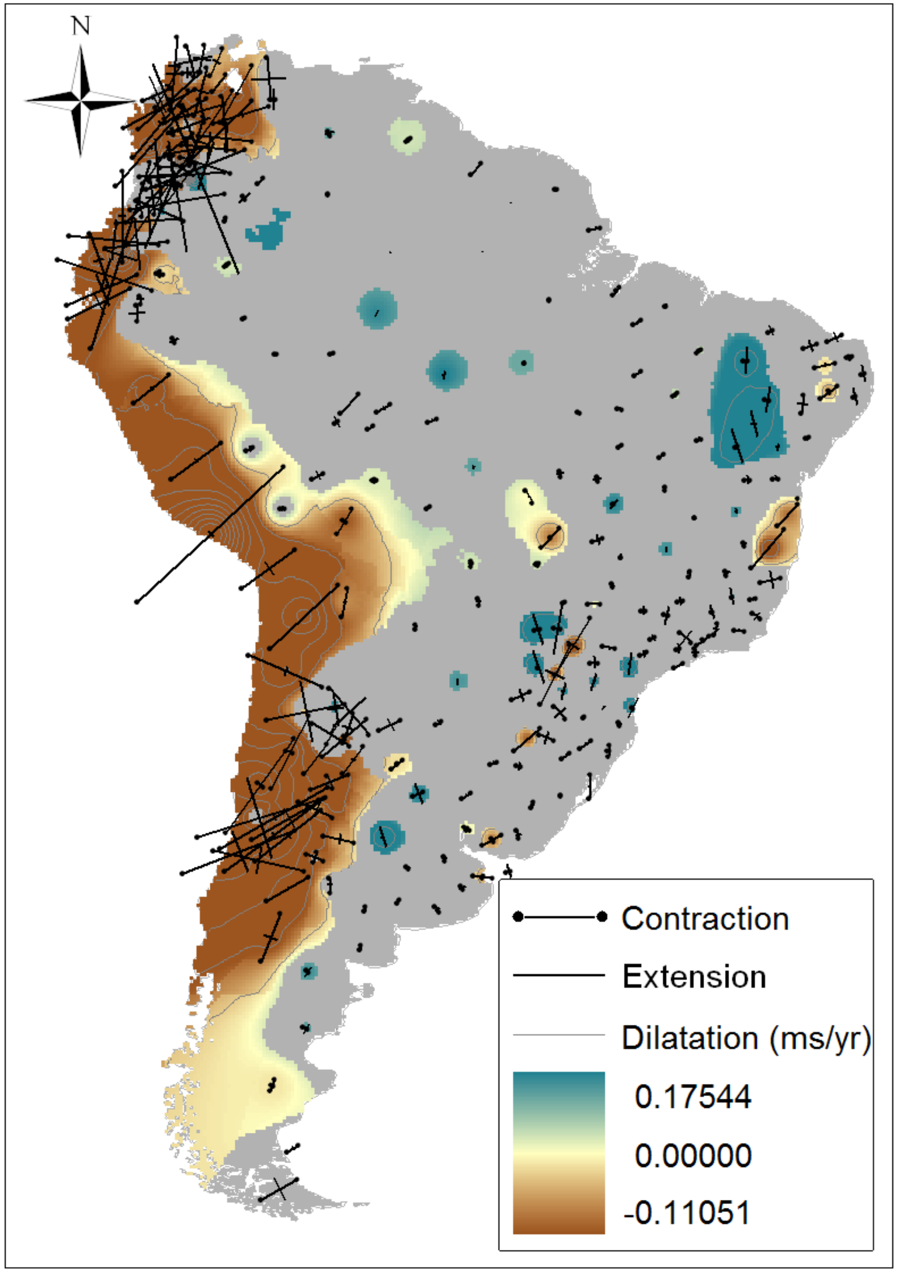
Values of strain rates, dilation and principal component vectors.

- Influence of stress in the continental crust, on the surface of South American Plate.



- Largest values of strain rate found in the west-east
- Largest contrast between compression and extension displayed in south-north direction.

RESULTS and DISCUSSION



<u>Values of the dilation and principal component vectors rates</u>.

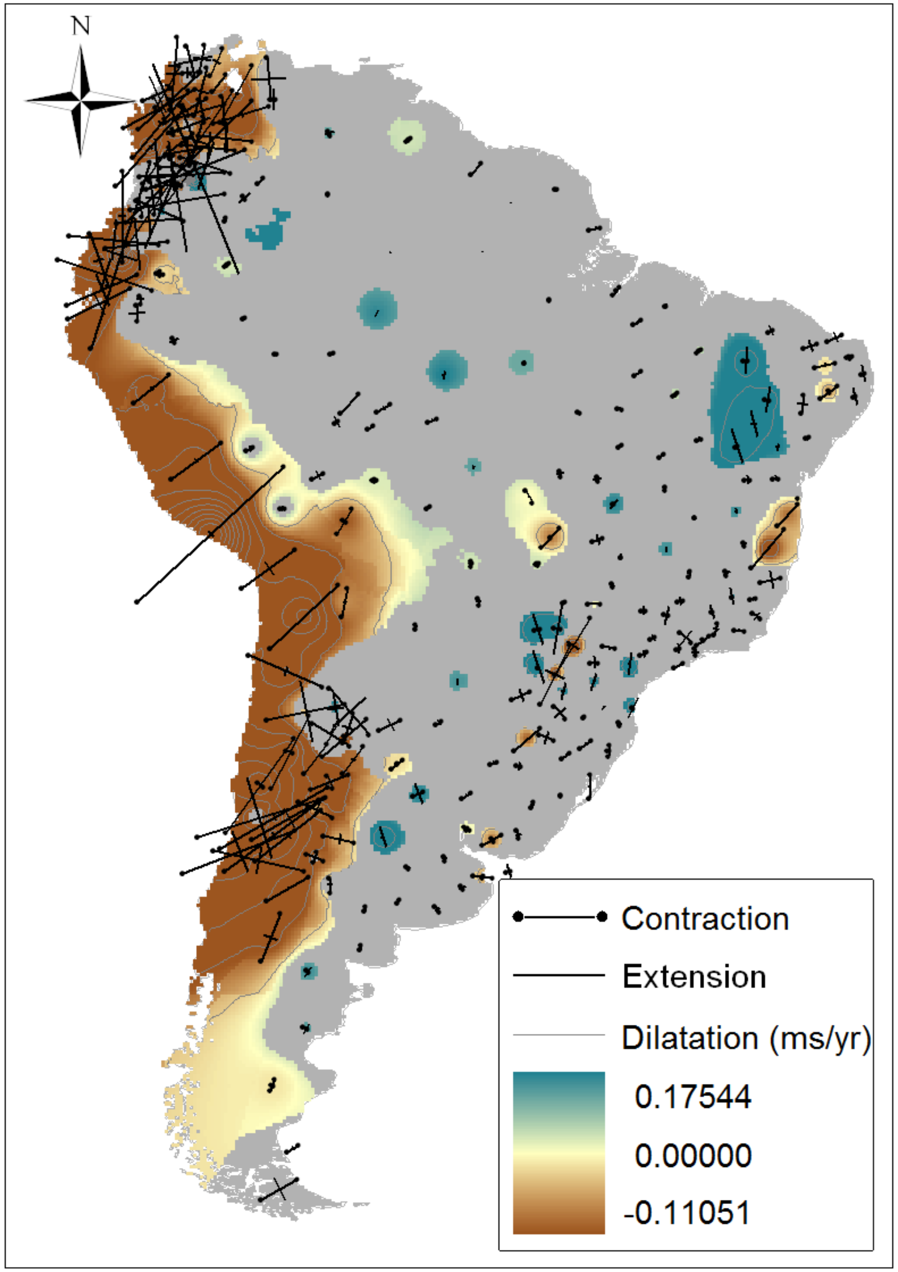
- 99% confidence level.

- Largest amount of contraction near to the meet of plates at the west and of extension in some intraplate regions at the east.

- Strain rates predominantly of contraction with directions southwest-northeast.

- In the region of large contraction at west are concentrated the large earthquakes and these are caused by great tectonic activities in the South American Plate.

RESULTS and DISCUSSION



<u>Values of the dilation and principal component vectors rates</u>.

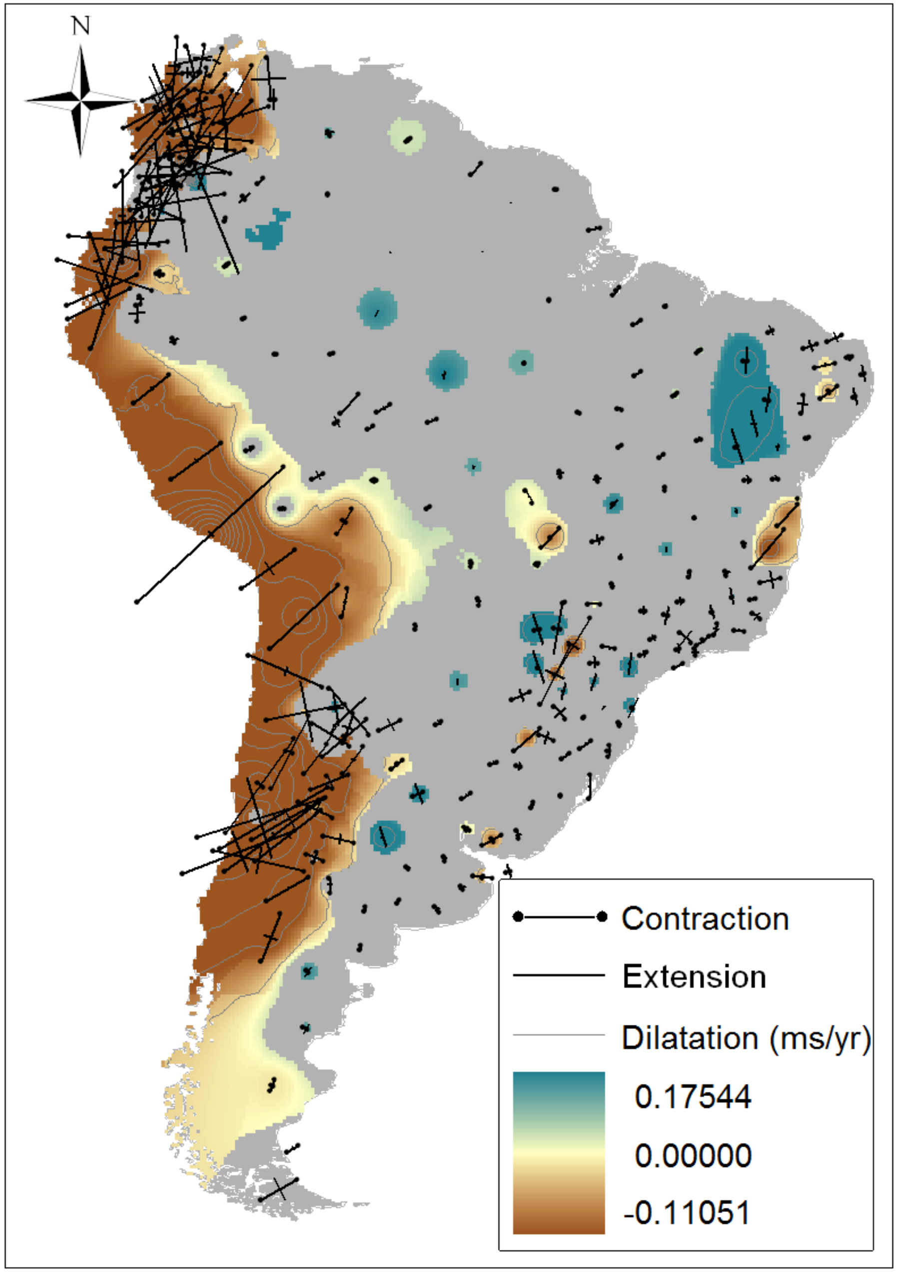
- Some intraplate regions at the east have significant values of contraction at the northeast-southwest direction.

- Such regions don’t show seismic activities.

- Such regions are close to areas that have seismic activities of medium and small magnitude and are located close to big rivers and reservatories and in areas with presence of faults and fractures which results in big lineaments.

- We suggest interaction of stress with local geological features. (Lineament of Pernambuco)

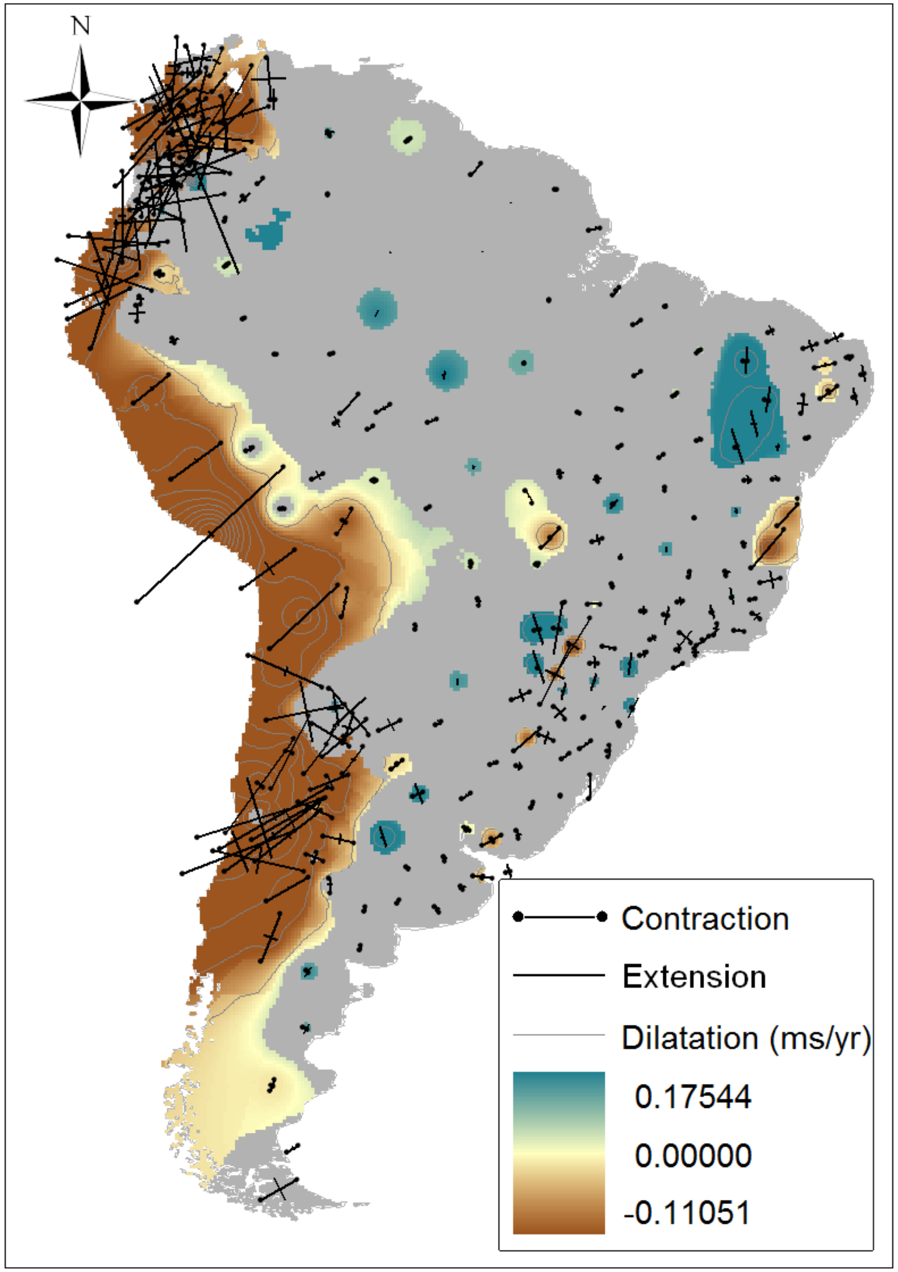
RESULTS and DISCUSSION



- Calais *et al.* (2006) suggest that as significant earthquakes in intraplate regions are infrequent and that the strain rates are very low, the rates and patterns of intraplate deformation are not very limited and these mechanisms are not responsible for accumulation of tension and release in crashes inner plates.

-Ou seja: não vimos correlação com eventos sísmicos. O que quer dizer que a deformação nestas regiões não é fator principal para acumulação e liberação de tensão em falhas, que se traduz na ocorrência de terremotos.

RESULTS and DISCUSSION



- By the principal component vectors of deformation, it can be seen that the behavior of the contractions and extensions is similar to those found by Assumpção (1992) and published by the World Stress Map for Heidbach *et al.* (2008);

-It suggests susceptibility of the GNSS network to detect stress not only from subduction zone at west, but also at the divergent zone of the dorsal Meso-Atlantic.

CONCLUSIONS AND FINAL COMMENTS

- Delaunay Triangulation and Finite Element Method - possible to estimate the strain rates of geodetic network located in the South American Plate and associate them to the stress applied by the dynamics of Plates.

- At the west of South American Plate, by the differences presented for Lay & Kanamori (1981) and Lay et al. (1982) and to the spatial distribution of velocity values shown, it is concluded that:

  -The large surface movements occur in regions with more heterogeneous geological structures and multiple event of rupture.

  -The great earthquakes, arising from the large tectonic activity on the South American Plate, are concentrated in areas with strain rates of contraction predominantly oriented towards southwest-northeast.

- The change of direction in the movement of geodesic points demonstrates influence predominantly tectonic with some variations that could be attributed to the interaction forces with local geological features. <u>To better understand the distinction between local and regional effects, the densification of the geodesic network is necessary to improve the analysis.</u>

CONCLUSION AND FINAL COMMENTS

- The behavior of contractions and extensions are presented similar to that found by Assumption (1992) and by the World Stress Map published by Heidbach et al. (2008). This, in consonance with Calais et al. (2006), confirm the sensibility of the network to detect stress not only from subduction zone at the west, but also divergent zone of the dorsal Meso-Atlantic at the east.

- The detection of strain rates values in some regions of South American Plate leads to suggest that the distribution of forces applied arising by the terrestrial dynamics, whether local, regional or global, affects the geodetic network investigated by several forms and so this can be used as a complement to intraplate tectonic studies.

-With **SIRGAS Repro** future results, further investigation may be carried out on this subject

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