WSM WORLD STRESS MAP

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The next phase of the WSM Project

by the WSM Team

Since 1986, the World Stress Map (WSM) project has systematically compiled the orientation of maximum horizontal stress SHmax of the contemporary crustal stress state. For the 30th anniversary of the project, the WSM database release 2016 was compiled and put online in December 2016. In comparison to the 2008 release we doubled the amount of data records due to our intensive international collaborations and full integration of new or updated national stress compilations from e.g. Australia, Canada, China, Germany, Iceland, Italy, New Zealand and Switzerland. This release marked the end of the third phase of the WSM project (2009-2016) and the key findings of this new global compilation are now published in an invited review paper in the journal Tectonophysics (see article on the second page of this newsletter).

The key activity during the current WSM phase (2017-2025) is to extend the database with stress magnitude data. This extension of the database is the consequent step to further increase our knowledge of the stress state. Stress magnitude data are essential for estimation of stability and criticality of rock volumes such as performed by calibrated geomechanical-numerical models that describe the contemporary 3-D in-situ stress state (see article by Moritz Ziegler on FAST Calibration tool on page four). However, we will also continue and intensify the compilation of stress orientation information to further resolve regional and local S_{Hmax} rotations. These rotations will also provide key information to study the relative impact of far-field and regional to local stress sources (see article by Abdelkader Soumaya on the new stress map of the Maghreb region in North Africa on page three). Furthermore, there are still large regions where very little or even no data are available. Bridging these gaps in data and also in particular the database extension by stress magnitudes can only be accomplished with a joint effort of the international scientific community, governmental institutions and industry partners. Please get in touch with the WSM-Team if you are willing to participate in accomplishing this ambitious goal.

On a technical level we will change our database release policy. Instead of compiling a new database every 6-8 years, we will update the WSM at least once per year to account for the steady and increasing influx of new stress data that we experienced in the past few years. We will describe these new releases in the WSM technical report series and announce the updates on the WSM homepage and in the WSM newsletter.

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The World Stress Map database release 2016: Crustal stress pattern across scales

by Oliver Heidbach
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The journal Tectonophysics invited us to contribute a review paper on the new World Stress Map database release (Heidbach et al., 2018). The paper opens with a short review on the basics of the stress tensor and the project history followed by the presentation of details on the new WSM database release 2016 (Heidbach et al., 2016a). The paper also presents the results of a global and regional analysis of the stress pattern to revisit the question whether the direction of absolute plate motion is sub-parallel to the long wave-length pattern of the orientation of maximum horizontal stress S_{Hmax}. In contrast to earlier approaches we use for this comparison a mean S_{Hmax} orientation on a global 1° grid that is smoothed with a fixed search radius of 500 km using a data quality and distance weight. This smoothed stress field is also published as a supplement and ready for download on different grids (2°, 1°, 0.5° and 0.2°) using two different smoothing approaches from Heidbach and Ziegler, (2018). It turns out that only in North and South America the sub-parallel orientation of S_{Hmax} is still dominant, but even in these plates large deviations are now detected on regional and local scale. Two examples in the south-central US and in the southwestern region of Australia prominently display such stress pattern variability. With the significantly higher data density in the WSM database release 2016, we resolve in these regions 40°-60° S_{Hmax} rotations within 70 km and a recent new publication by Lund-Snee and Zoback (2018), with even more data for Texas and New Mexico, confirms these findings. These rotations can be used as proxies to better understand the relative importance of plate boundary forces that control the long wave-length pattern in comparison to regional and local controls of the crustal stress state.

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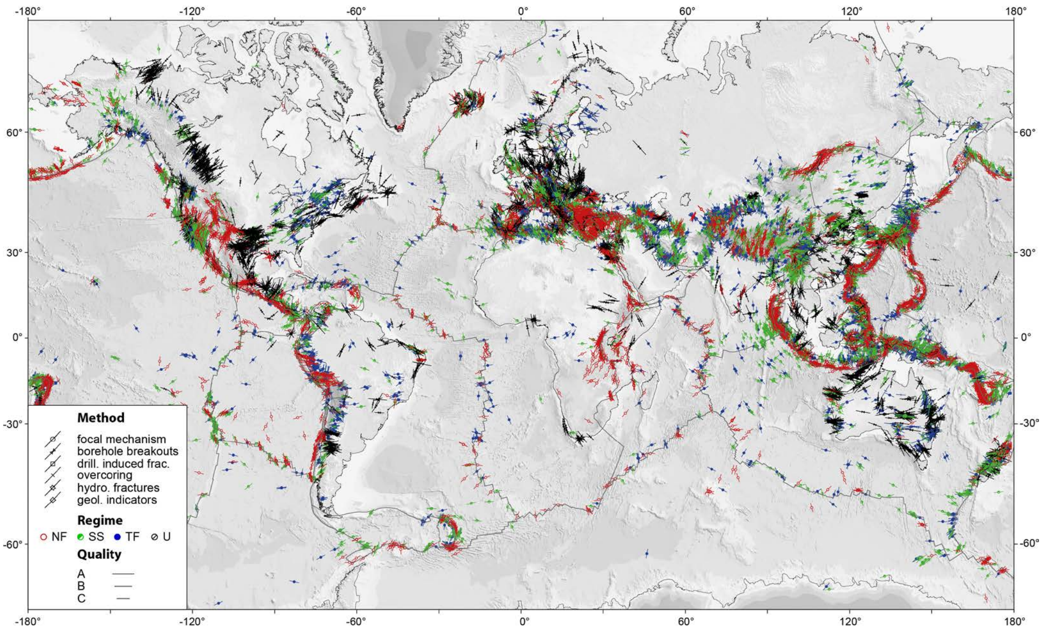
Figure Caption



The WSM 2016 (Heidbach et al., 2016b) displays the orientation of maximum horizontal stress S_{Hmax} in the upper 40 km based on the WSM database release 2016 (Heidbach et al., 2016a). Symbol and line colours indicate stress regime with red for normal faulting, green for strike-slip, blue for thrust faulting and black for unknown stress regime. This map can be downloaded in high resolution at **http://doi.org/10.5880/WSM.2016.002**

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State of stress and active strike-slip fault system along the Maghreb region (North Africa)

by Abdelkader Soumaya
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The Maghreb region (from Tunisia to Gibraltar) is a key area in the Western Mediterranean to study the active tectonics and stress pattern across the Africa-Eurasia convergent plate boundary. The stress field and active tectonic style within the Maghreb region are more heterogeneously distributed than commonly considered. New and already published data records were compiled into a comprehensive dataset of well-constrained crustal stress indicators. Formal stress inversion of earthquake focal mechanisms shows a first-order transpression-compatible stress field and a second-order spatial variation of the present-day tectonic regime across the Maghreb region with clockwise rotation of S_{Hmax} from east to west and a stress axes permutation. The mean S_{Hmax} is oriented NW-SE, suggesting that plate-driving forces, related to the Africa-Eurasia convergence, provide the major role on the regional stress pattern.

From this dataset, it appears that strike-slip fault geometry (the distribution of discontinuities such as bends, fault termination, conjugate fractures) plays an important role in shaping the different Maghreb tectonic zones and controlling the active stress regime variations. We evidence a change in the current tectonic regime from transpressional to compressional in the Tell and Atlas areas, to strike-slip/transtensional in the Alboran/Rif block, with a slight clockwise rotation of S_{Hmax} orientations from the intraplate Saharan-Tunisian Atlas domain to the Tell domain. From East to West, the S_{Hmax} orientations remain stable if we consider inversion results of the largest magnitude earthquakes, but significant rotations are observed between the different magnitudes classes in the Alboran-Rif. The neotectonic and smoothed present-day stress map reveals that plate boundary forces control the long wavelength of the stress field pattern. The current tectonic deformations and the upper crustal stress field in the Maghreb are governed by the interplay of the oblique plate convergence (i.e. Africa-Eurasia), lithosphere-mantle interaction and preexisting tectonic weakness zones. The results of this study have been recently published as an invited review paper in Tectonics (Soumaya et al., 2018).

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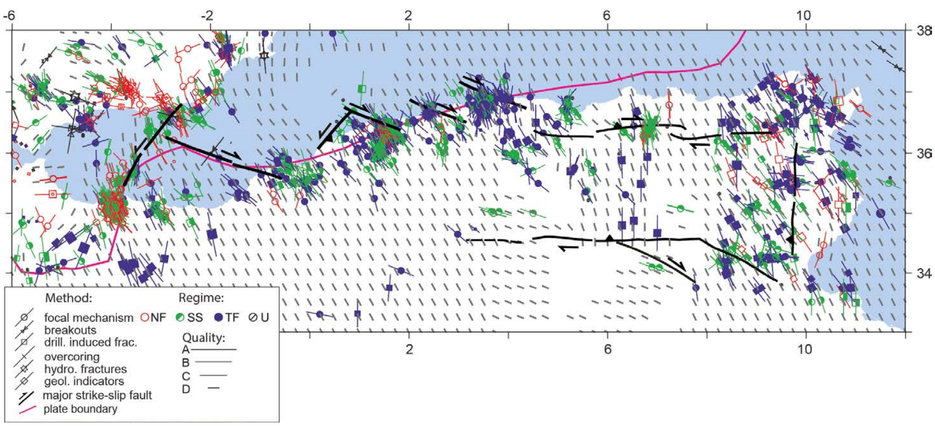

Figure Caption

Stress map and smoothed stress pattern of the Maghreb Region based on the WSM 2016 (Heidbach et al., 2018) and new stress data from Soumaya et al. (2018). Lines show the orientation of maximum horizontal stress S_{Hmax} with line length according to data quality. Different colors show various tectonic stress regimes (red for normal, green for strike-slip and blue for thrust). Grey lines on the regular grid are mean S_{Hmax} orientation.

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Fast Automatic Stress Tensor Calibration (FAST Calibration) of geomechanical models

by Moritz Ziegler (GFZ German Research Centre for Geosciences)

The detailed in-situ crustal stress state in areas of interest with few available data records is commonly predicted by 3-D geomechanical-numerical models. Such a model requires stress data at reference locations within the model area to initialize the stress state. The stress state is created by the application of displacement boundary conditions (Hergert et al., 2015). The comparison of the modelled with the observed stress state allows the adaptation of displacement boundary conditions that eventually provides a best fit stress state in the entire model region (Reiter and Heidbach, 2014). This process of fine-tuning the model by changing the displacement boundary conditions is referred to as calibration. Depending on the amount of available information and the complexity of the model, the calibration is a lengthy trial-and-error process of modelling, analysis, and adaptation of boundary conditions.

The tool Fast Automatic Stress Tensor (FAST) Calibration (Ziegler 2018a,b) facilitates and speeds up this calibration process. Provided that the rheology is linear elastic, it requires only three simulations with different arbitrary boundary conditions. The modelled stress states from these are compared to the observed stress data. The linear relation between the boundary conditions and the stress response is then used to calculate the displacement boundary conditions that are required to achieve the best fit stress state. The tool is a Matlab® script that contains the relevant processes and calculations and guides through the calibration (Ziegler, 2018a,b). The influence of the individual observed stress information on the resulting stress state can be weighted. The script assists both the calibration of a single geomechanical-numerical model and also a multistage approach according to Ziegler et al. (2016).

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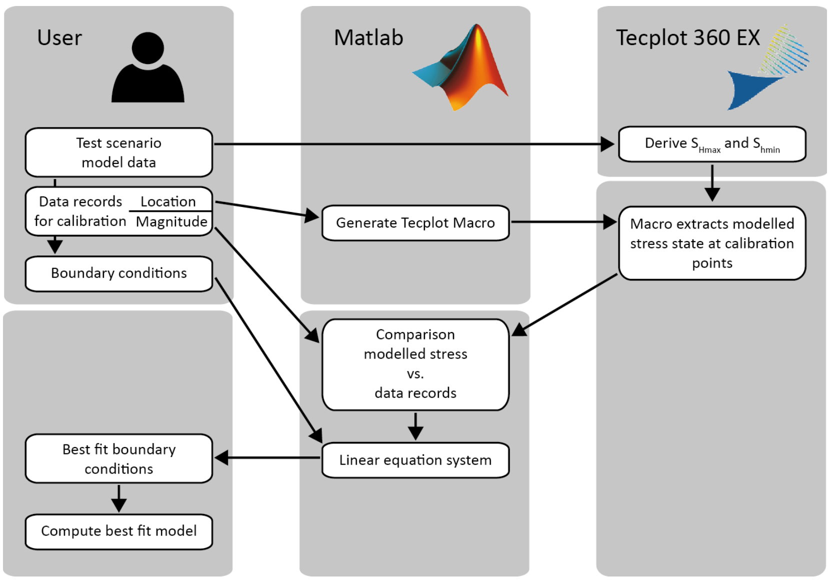
Figure Caption

Sketch of the general workflow of the Matlab script FAST Calibration



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