

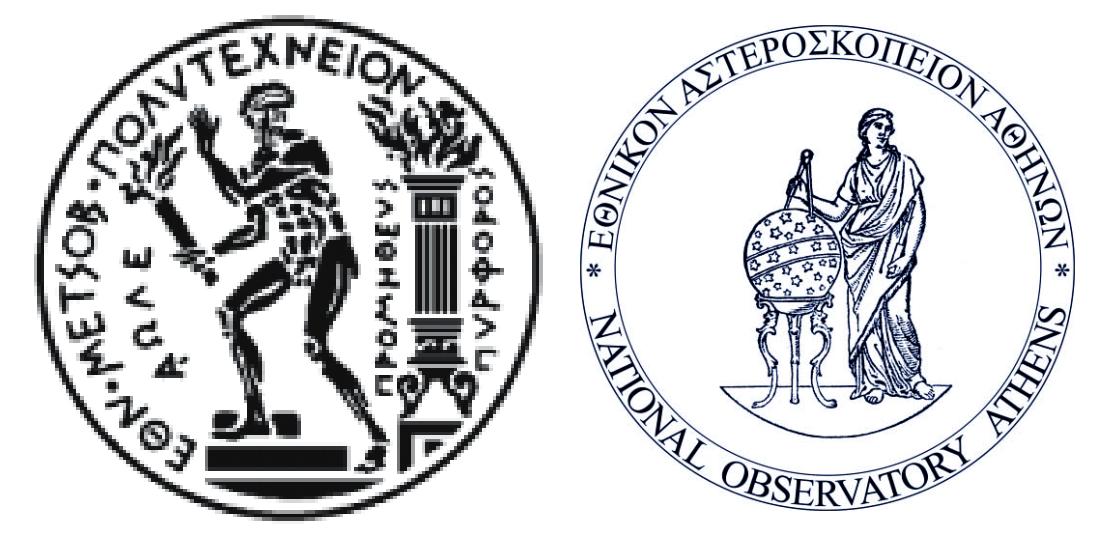
TECTONIC STRAIN DISTRIBUTION OVER EUROPE FROM EPN DATA

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INTRODUCTION

StrainTool is a software package that enables the estimation and visualization of Strain Tensor parameters, given list of data points on the earth's crust along with their respective tectonic velocities. It consists of three basic components:

- a python package (library) `pystrain`,
- a (main) program `StrainTensor.py` and
- a list of (shell) scripts to visualize results

StrainTool was developed in the framework of HELPOS; it is a free and open-source software project, distributed under the MIT License.

A detailed introduction to StrainTool, a how-to guide, usage examples and discussion on the implemented methodologies is available on the web, at <https://dsolab.github.io/StrainTool/>.

STRAIN TOOL

StrainTool is a highly customizable software package; users can configure the estimation process using a list of input options. The basic input is a data file containing station coordinates along with their respective velocity components.

Users can select the estimation of a single Strain Tensor (at the region's barycentre) or estimation of multiple Strain Tensors placed on a (regular) grid within the region limits. Grid formation details are fully customizable by the user.

Estimation of the Strain Tensor parameters follows a Least Squares approach, based either on Veis et al., 1992 or Shen et al., 2015. In the latter case, a sophisticated weighting scheme is used, controlled by the user via a list of command-line-options.

The estimated Strain Tensor parameters along with their corresponding sigma values can be visualized with the distributed shell scripts `gmtstrainplot.sh` and `gmtstatsplot.sh`. Both programs use GMT (Wessel et al., 2013) to plot results, driven by a user-defined configuration file.

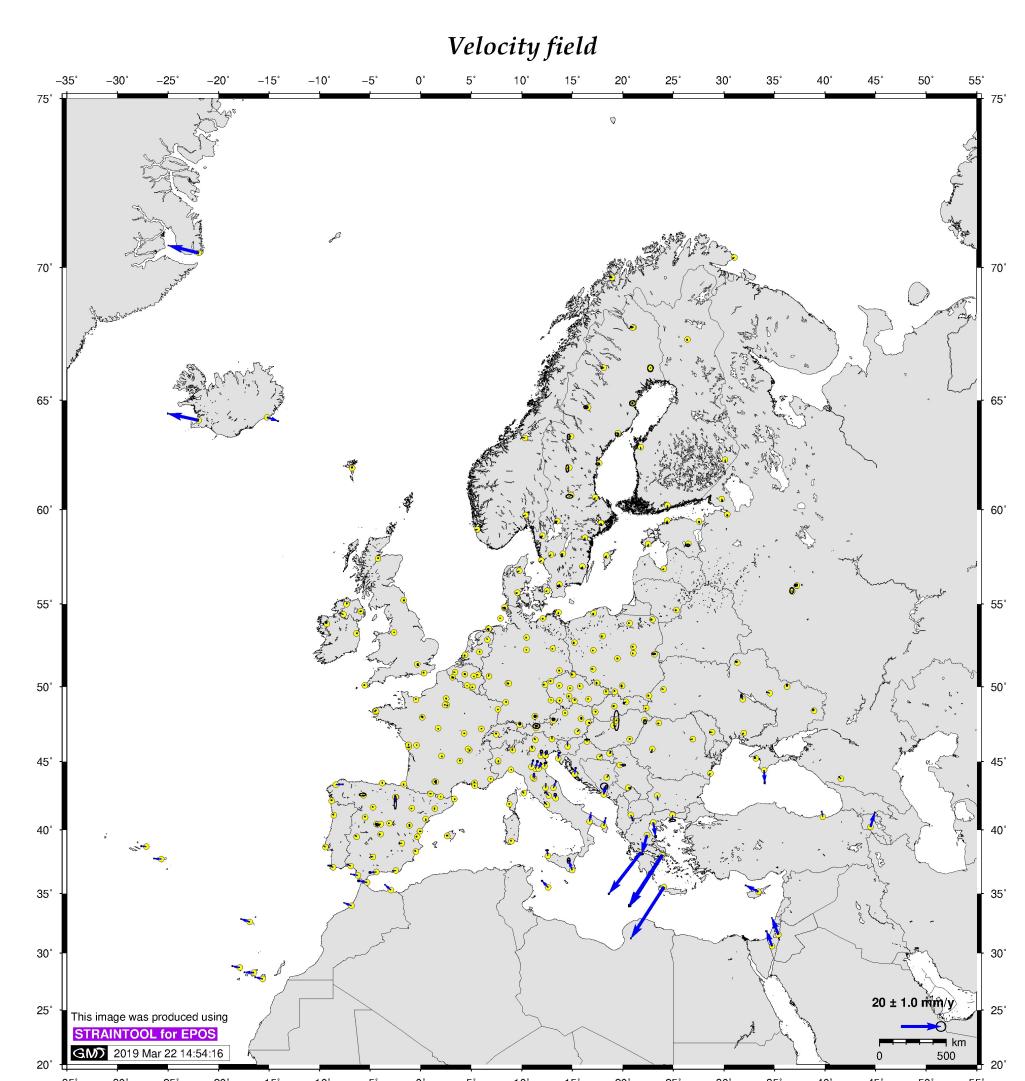
ALGORITHMS

Given a set of stations (aka point on earth's surface) with their corresponding east and north velocities, we can estimate (or compute) strain tensor parameters, by solving for the system

$$\begin{bmatrix} V_{x,S_1} \\ V_{y,S_1} \\ \dots \\ V_{x,S_n} \\ V_{y,S_n} \end{bmatrix} = \begin{bmatrix} 1 & 0 & \Delta_{y_1} & \Delta_{x_1} & \Delta_{y_1} & 0 \\ 0 & 1 & -\Delta_{x_1} & 0 & \Delta_{x_1} & \Delta_{y_1} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ 1 & 0 & \Delta_{y_n} & \Delta_{x_n} & \Delta_{y_n} & 0 \\ 0 & 1 & -\Delta_{x_n} & 0 & \Delta_{x_n} & \Delta_{y_n} \end{bmatrix} \begin{bmatrix} U_x \\ U_y \\ \omega \\ \tau_x \\ \tau_{xy} \\ \tau_y \end{bmatrix}$$

at any given location R ; Δ_{x_i} and Δ_{y_i} are the displacement components between station i and the point R . A minimum of 3 stations is required to compute the parameters; if more than 3 stations are used, then the parameters are estimated using a least squares approach. Assuming that we have variance information for the station velocities (and a Gaussian distribution), we can add the covariance matrix C of the velocity data in the system. In the simplest case, C is a diagonal matrix, with the velocity component standard deviations as its elements. Shen et al., 2015, propose a more elaborate approach, reconstructing the covariance matrix by multiplying a weighting function to each of its diagonal terms. The weighting function $G_i = L_i \cdot Z_i$, in which L_i and Z_i are functions of distance and spatial coverage dependent, respectively. The final covariance matrix becomes then, $C = C \cdot G^{-1}$ or, since its diagonal, $C_i = C_i \cdot G_i^{-1}$.

VELOCITY FIELD - ETRF14



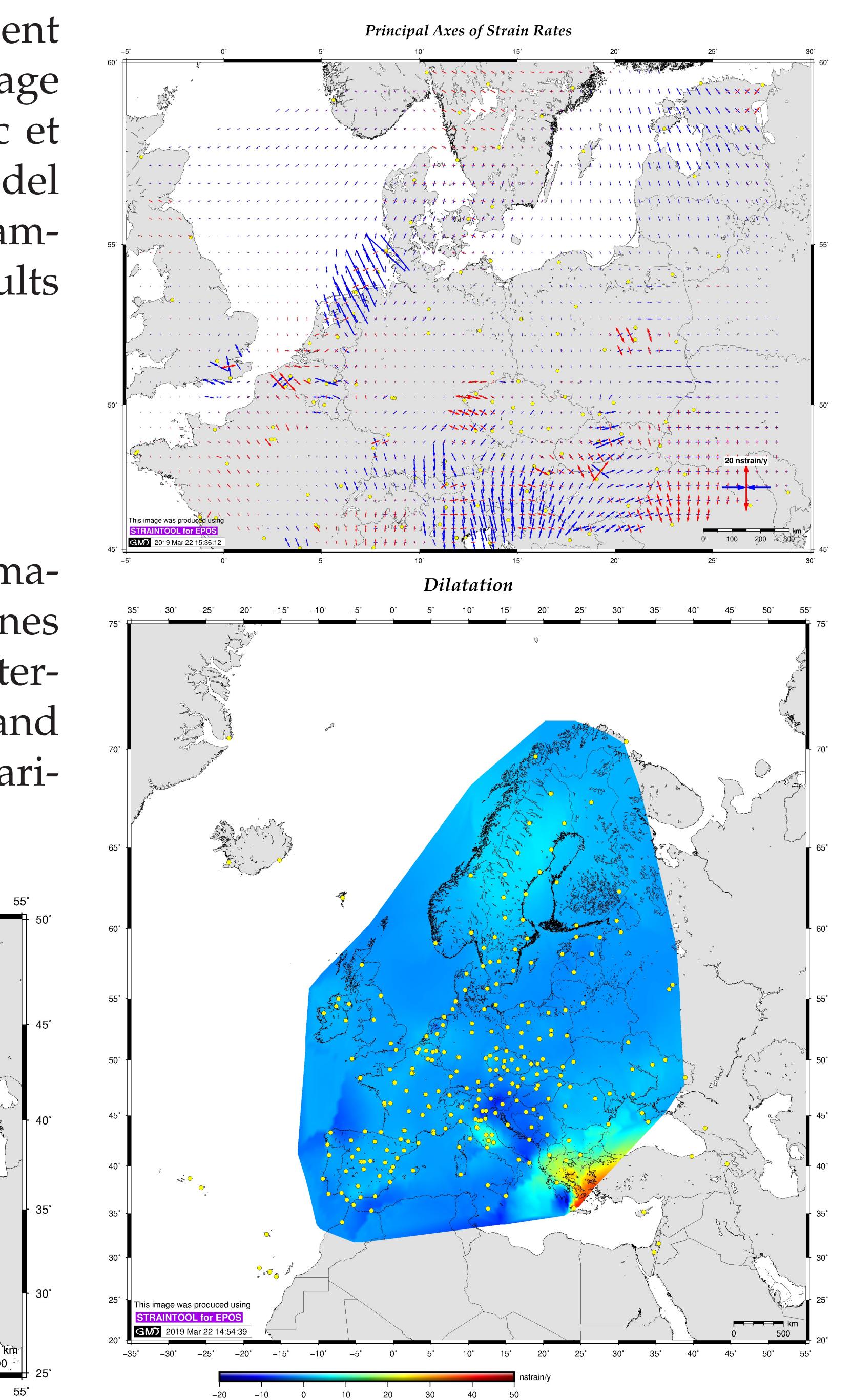
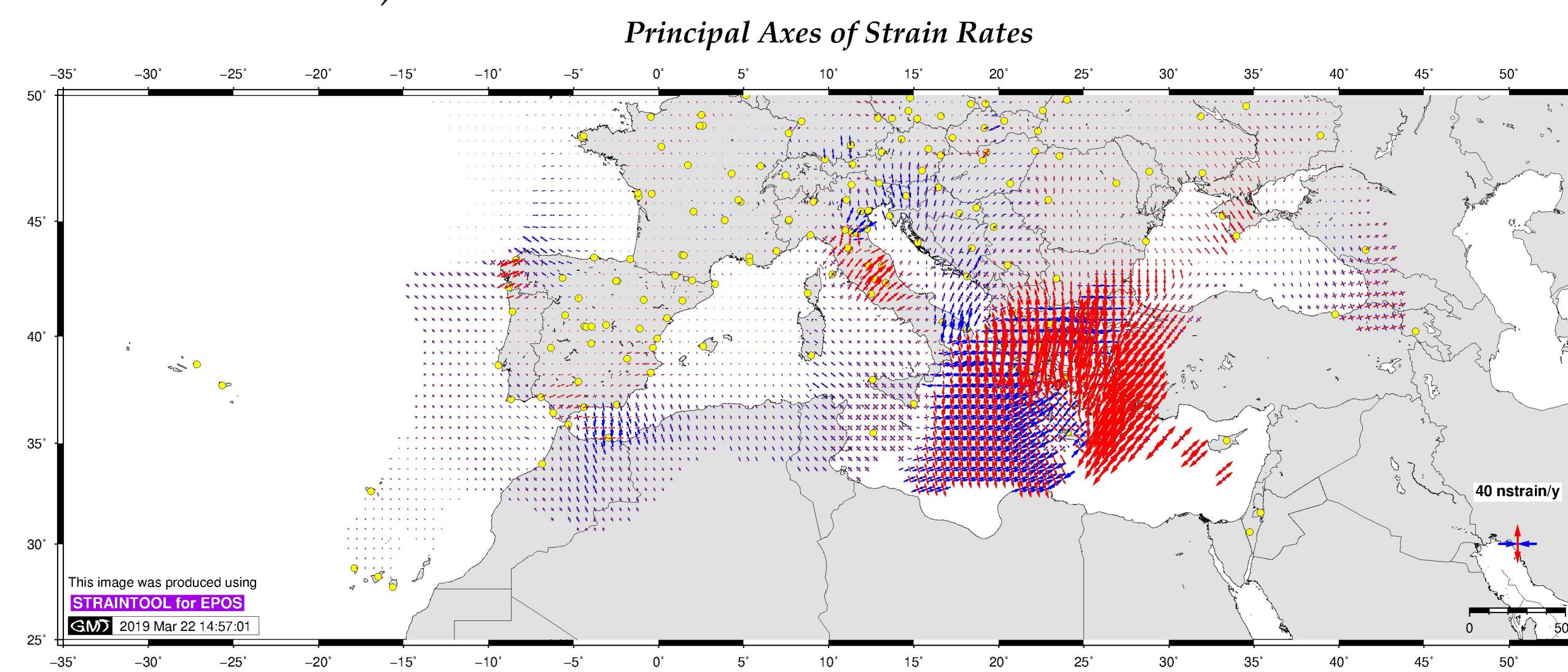
A total number of 302 GNSS stations of EUREF Permanent Network (EPN) were selected on the base of the following criteria: a) station have observations time period longer than 3 years, b) one velocity per station and c) stations with large velocity changes excluded. The stations positions are computed with several geodetic software packages and then we used CATREF to estimate multi-year positions and velocity solution. The available dataset comprises the velocity field extracted from the C2010 EPN solution. Reference frame of the velocity field is ETRF014 which is the realization of ETRS89 corresponding to ITRF14. According to EUREF Technical Report 1, the ETRS89 is fixed to the stable part of Eurasia tectonic plate. For the transformation from ITRF2014 to ETRF2014 the three translation components are set to zero and the rotational rates (Eurasia angular velocity components) are taken from Altamimi et al. 2017.

RESULTS AND DISCUSSION

Strain-rate results from 302 permanent European GNSS stations present in these maps. The vertical velocity component is ignored in this stage and other sources of deformation (GIA, hydrological, anthropogenic et al.) are not considered in the preliminary interpretation. Different model setups (variable grid-size, destance from cell-center, smoothing parameters etc.) were used for estimation of strain rates. We present results estimated using the following model:

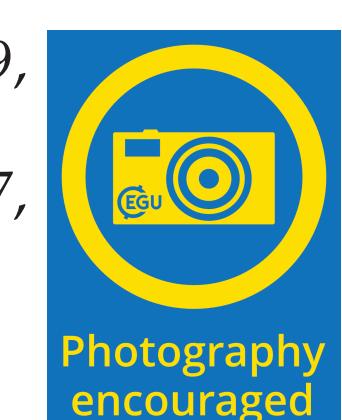
grid-size	ltype	dmin	dmax	Wt
0.5°x0.5°	gaussian	1 km	500 km	6 and 12

Overall, our first results reproduce the gross features of tectonic deformation in Southern Europe, such as NE-SW extension across the Apennines (Italy), NNW-SSE compression across the Alboran Sea (western Mediterranean) and N-S extension in mainland Greece. Large areas of central and Northern Europe show small strain rates (less than 10 ns/yr; 2nd invariant of the tensor).



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FUTURE RESEARCH

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slglsgf

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