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APPLICATION OF DEFORMATION ANALYSIS AND ITS NEW POSSIBILITIES

Milan TALICH, and Jan HAVRLANT

Research Institute of Geodesy, Topography and Cartography, Zdiby 98, CZ-250 66, Czech Republic

Abstract: The XML Web Application to on-line calculation of deformations derived from repeated geodetic plane survey using Internet is described in this paper. Parameters of deformation field (strain tensors, total dilatation) in quadratic network, covering the whole result obtained at individual points of the network in question are derived and described. Vectors of displacement from repeated - and in several phases observed - results obtained at individual points of this network are given as input values. The calculation is based on the theory of mechanics of continuum and its basic prerequisite is the homogeneity of the tested territory in question. Using proper calculation method to obtain the right interpretation of results is not the only important thing, but it is the representation form as well. And this fact is also given in this paper. Deformation analysis uses Web Map Services (WMS) as its graphic representation of calculated results in the GIS format. Such services enable forming on-line of defined thematic maps in Internet viewer shown in its viewer from data obtained from servers with WMS by user. Thus no geographic data are needed by user to create GIS of his own. Results may be reproduced and observed on a digital terrain model. This makes better evaluation and analysis possible and takes spatial relation of given terrain in consideration, too. The application includes export of results to a series of formats to further using, e.g. as the KML format to Google Earth programme. Several programmes applied to practical processing of repeated geodetic surveys indicate possibility of reproduction and demonstrate chances of mechanics of continuum to deformation analyses. Such application is at disposal to be registered as on-line calculation using Internet to all interested persons.

1. INTRODUCTION

Deformation analysis of the Earth surface in order to recognize geodynamics of the terrain of interest does not belong to the tasks that geodesists solve every day. In this case usage of **mechanics of continuum** seems to be advantageous for several reasons, which are explained in more details in e.g. (Szostak – Chrzanowski et al., 2006), (Talich, 2008). Homogeneity of the tested territory is the needed assumption. If this assumption is not satisfied, it is necessary to divide the territory into several homogenous parts and make the calculations for each part separately.

In addition, geodesists usually do not have necessary SW tools for the calculation in their disposal. Calculations are rather difficult, as well as required theoretical knowledge. Thus it is

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advisable to use the potentiality and characteristic of web applications for calculations to solve the above mentioned task. The most important advantages are the following:

- users do not need to master detailed theoretical knowledge to solve more difficult calculations, it is sufficient if they understand principals of the solution, real meaning and constraints for the application,
- users do not need to own software for less common or more difficult calculations,
- web application is still up-to-date, the user do not have to bother with either installation, nor updating,
- platform independence – web application may work under any operation system,
- calculations made on-line using the web application guarantee the compliance with given calculation methods and techniques and enables the comparison with calculations made by different SW,
- web applications with XML interface simplify interconnection of applications from different producers. Each application servers may be based on technologies from different companies, but thanks to standardized interface they may communicate together. The necessary condition that must be fulfilled is the existence of XML interface with its description.

This is the way how users get in their disposal a computing tool that assists in solving tasks that may be for them quite unusual.

2. THE CALCULATION METHOD

On the basis of points displacement changes of geodetic network, that are stated by their repeated survey, we first calculate parameters of discretely expressed field of displacements, i.e. displacements interpolated into grid, and further we calculate parameters of discretely expressed field of displacements, characterized by stress tensor (of extension and compression). Theoretical solution and derivation may be found in a number of publications e.g. (Szostak – Chrzanowski et al., 2006), (Altiner, 1999), (Talich, 1994) a (Talich et al., 1993). The whole calculation is based on the theory of mechanics of continuum**.**

Input values for the calculation are at the first place **displacements (movements) of given, or measured points** of the geodetic horizontal network. We take into account the coordinates needed for calculation and graphical displays of results, eventually numbers (labels) of these points. The other input values are different values specifying the way of the grid definition, into which the interpolation will be made and specifying parameters for own implementation of the interpolation of displacements of such points in the field of displacements in the grid.

Output values are besides the interpolated displacements of points in the chosen grid, **parameters of points deformations of the same grid**. We speak about axis of maximum and minimum strain, direction of the axis of maximum strain, total dilatation and total shear.

It is important to note that all displacements depend on the selected coordinate frame. On the other hand, all **parameters of deformation**, except directions, **are independent on the used coordinate frame.** This proves the importance of calculations of parameters of deformation and their application. It is not necessary to consider how to choose conditions for placing the geodetic network in the coordinate frame (to choose the fixed points). In other words, which of the points of the network to consider as stable, and which not. The only thing it is necessary to comply with is the calculation of network adjustment as the free network, i.e. to

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choose only necessary number of conditions for its placement in coordinate frame, and thus do not "deform" the network. They are in the case of horizontal network with stated size (with at least one measured length) three, and in the case of positioning network without stated size four. Different conditions in the case of free network with stated size would mean application of translation and rotation and related to it, the calculation of deformation is independent. Thus using different conditions we get always the same values of parameters deformations. That means that **mistakes from bad** (mistaken, erroneous) **expectations based on stability of selected points**, that we during common calculations of displacements from repeated measurements consider as stable, are totally eliminated. It means that deformations are more objective criterion for disclosure of real relative geodynamic trends in the reviewed terrain. More details about these advantages of using continuum mechanics for deformation analysis are in (Talich, 2008).
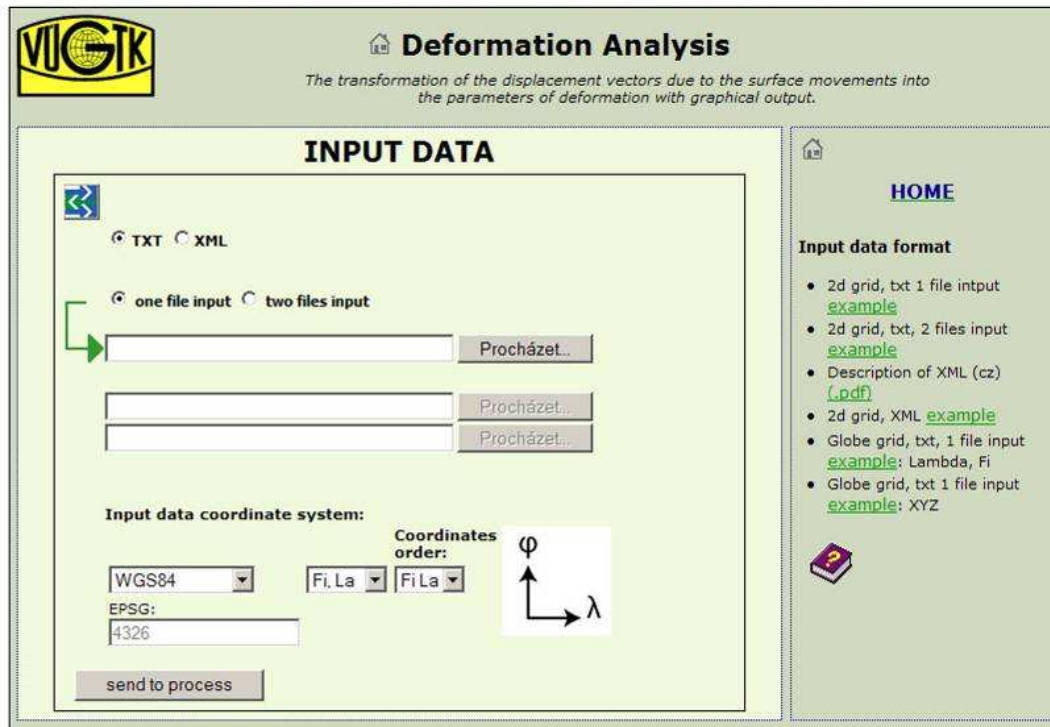
The next advantages of the application of the theory of mechanics of continuum for deformation analysis from repeated geodetic survey have been mentioned in detail in e.g. (Szostak – Chrzanowski et al., 2006). It discusses the development of integrated access to monitoring and analysis of deformation from geodetic survey including physical interpretations. Mechanics of continuum is suggested as a basis for communication in multiprofessional access to geodetic and geotechnical monitoring.

3. DEFORMATION ANALYSIS APPLICATION

The above mentioned calculation is implemented in web application Deformation Analysis. It results from the former off-line application, that served as the basis (Kostelecký, 1986). Web application was supplemented and enlarged by other facilities, that will be described further. Application is still being developed, and especially last year a lot of new functions and improvements were added.

Before you start the application, it is necessary to prepare input data. We may enter displacements of given geodetic points by using 1 or 2 files. If 1 file only is the input file, then it contains approximate coordinate values of given points of the geodetic network and values of displacements (coordinate differences from each measurements). We may also use 2 files as input files, where the application seeks the common points inserted in both files and calculates point displacements from their coordinates.

Input files may be in the format of simple text files or in its own format XML. The advantage of this format is that it contains other supplementary information necessary for calculation, which in other cases have to be input by hand using the input form. Input form is shown in figure 1.

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Figure 1 - Input form Deformation Analysis Application

When entering the simple text file we must enter in the input form also other parameters, as coordinates system of input points, and further the order of coordinates in the file. The form offers several coordinate systems, but it is also possible to add a coordinate system using code EPSG (European Petroleum Survey Group). EPSG was scientific organization that created worldwide databases of geodetic systems, nowadays used by many applications. Thus if the user knows EPSG code of his coordinate system, he may enter it by hand. The last possibility is to enter local system if the points were measured in the local system. However, in this case it will not be possible to display the resultant deformations together with other map layers.

After input data are entered, another form follows the previous one, where the parameters of the grid for interpolation are chosen. The interpolate form is in two forms, depending on the interpolation being made in the plain or in the sphere. If the user decides to use coordinate system WGS 84, it is required to perform calculations in the sphere to satisfy the condition of deformation calculation in the grid. Interlaced network of points with given grid size in the sphere may be seen in figure 2.

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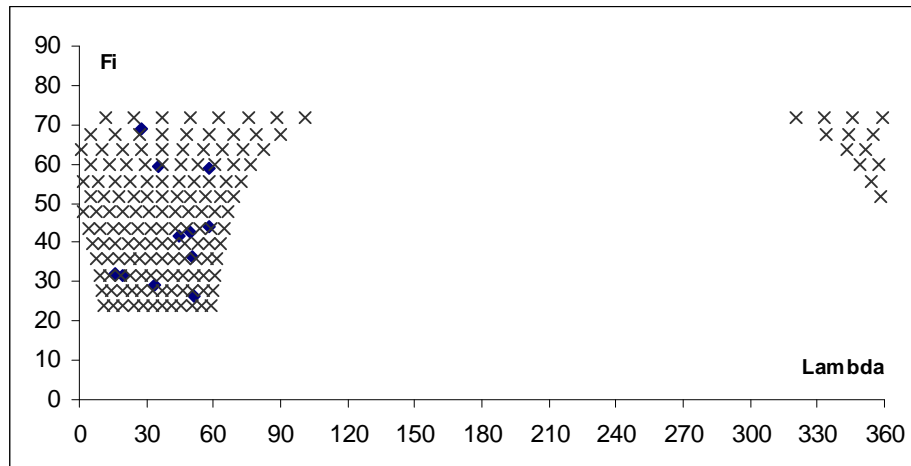
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Figure 2 - Interpolation of points in the sphere

Selection of parameters of the interpolated grid is very important and sometimes it is difficult to select the optimal number of grid rows and columns and it is necessary to repeat the calculation for several times.

Own interpolation of the grid and calculation of deformation tensors will follow. Values of interpolated displacements into grid, and values of deformation field in the same grid are calculated. User then may display protocol on the calculation, where all important information on calculation, the interpolated values of displacements and values of deformation tensors in their numeric form are included. Now it is possible to display the results in graphic form. Before that, it is necessary to enter map projection, in which the results will be displayed. The application offers several possibilities or the user may enter EPSG code by hand.

To display the results freeware (Open Source license) Map Server from the University of Minesotta, USA (http://mapserver.gis.umn.edu/) is used. It is very effective application that provides a number of functions for map designing in the Internet. It enables to display map layers offered by other map servers using the service WMS (Web map service) according to specifications OGC (Open Geospatial Consortium).

This is very advantageous. The user does not have to have needed map data on his computer. There are many map servers on the Internet, that using WMS offer their content and their number is getting larger.

In our application for deformation analysis service WMS is used for entering topographic underground into graphic display of results of deformation calculations. The user gets well-arranged output, from which it is obvious where is the exact geodynamic activity located in the reviewed terrain. In figure 3 an example, when the client creates on-line his own map with deformations and uses information from different servers from Internet is shown.

In map server for graphic display, the results of deformation calculations are divided in the following layers:

- Points of the measurement (given points of the geodetic network)
- Numbers (labels) of the points of the measurement
- Displacements in the points of the measurement

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- Displacements interpolated in the grid
- Deformation – axis of maximum and minimum strain in the grid

These layers may the user independently switch on or off together with other map layers, which leads to required display of results.

In addition, application offers map display with deformations in 3D (figure 4). For this purpose the application uses the program extension Java3D that enables to work in programming language Java with 3D graphics. The advantage of this solution is that the user does not have to install any other program, it is sufficient to use common internet viewer supporting Java. Program uses the cut of the map with layers, that are switched on in the map server. In 3D display it is also possible to adjust the basic setup, as height distortion or setup of the model lightening. Moreover, it enables output to a printer or to a file.

If the user is not satisfied with this simple 3D view, the map application enables also export of results in format KML and their further display in program Google Earth. Other possibilities of export are in format XML (GML, SVG), or ESRI Shapefile.
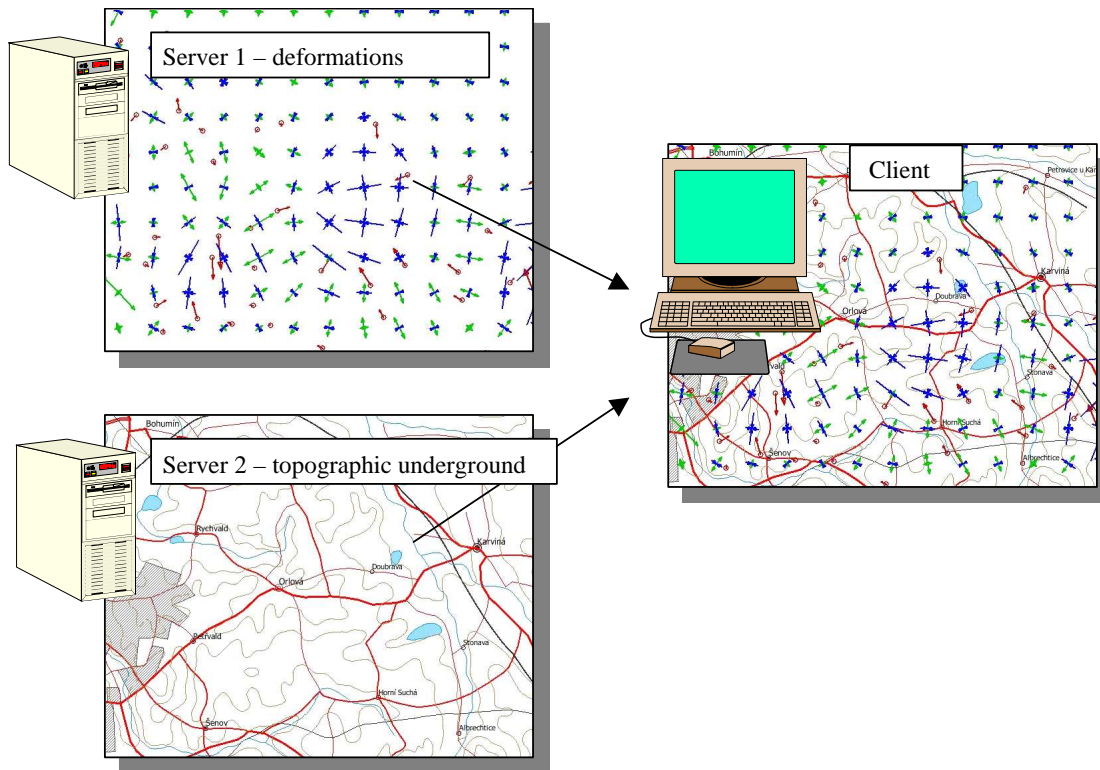

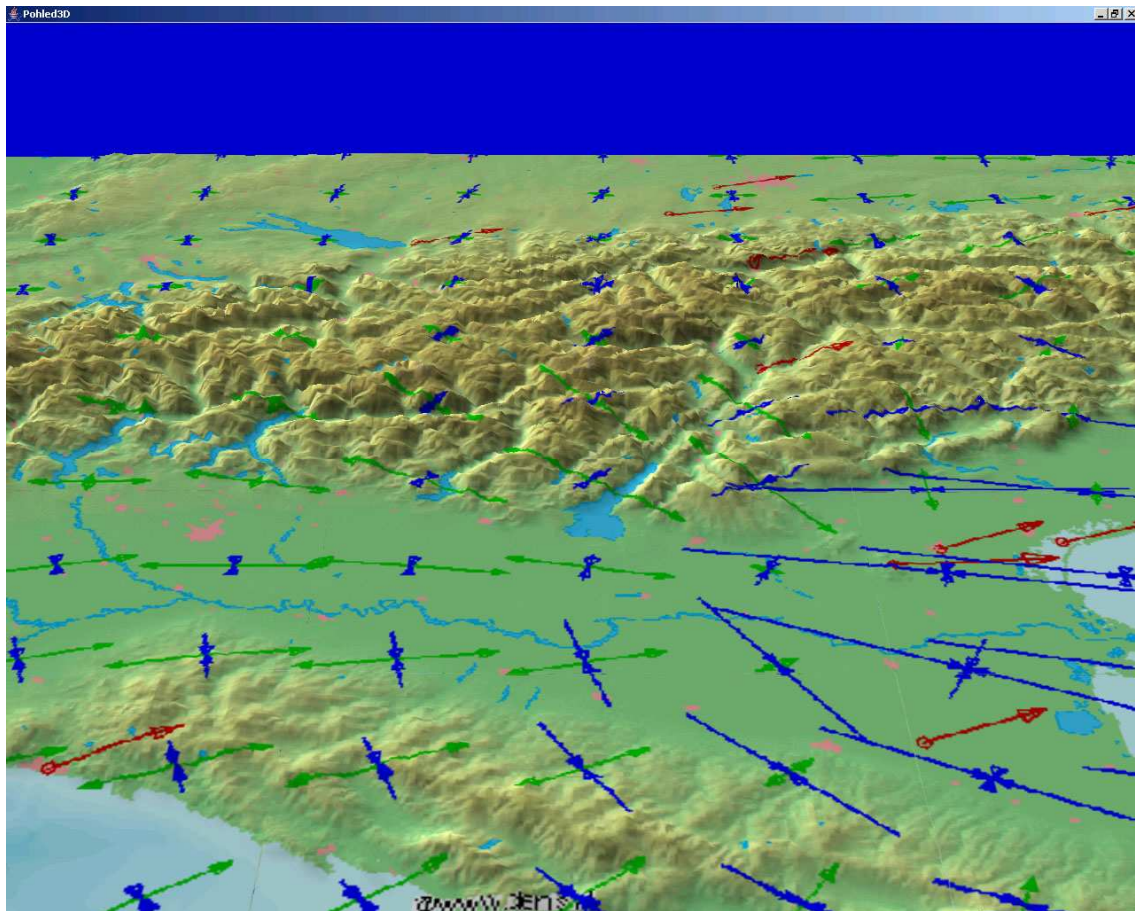Figure 3 - Example of deformation display with topographic underground

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Figure 4 - Deformation display in 3D

4. EXAMPLES OF THE USAGE

As an illustration of the usage of Deformation Analysis application we used a file of 154 points of system ITRF2000 in epoch 1997.0 in Europe (Boucher et al.). Annual velocities of these points were assumed from IERS Technical Note No.31. Please take into consideration that not every point included into these processing is suitable for geodynamic purposes. So these examples are only for demonstration of capability of Deformation Analysis application.

In figure 5 you can find displacements in points, that show that almost whole Europe is being moved to North-East. Red arrows indicate displacements on measured points and blue arrows on points of interpolated grid. Figure 6 displays axis of maximum and minimum strain in the same grid. On the most of the territory the size of the deformations is minimal. Only in some of the areas as South East Europe are deformations significant.

Figures 7 and 8 displays place, where deformations are displayed the most, and that is in South East Europe. Maximum calculated deformation is here 0.16 mm/km/year.

Figure 9 and 10 displays stated deformations in the Alps. Maximum calculated deformation is here 0.12 mm/km/year. This terrain can be seen in figure 4 in 3D.

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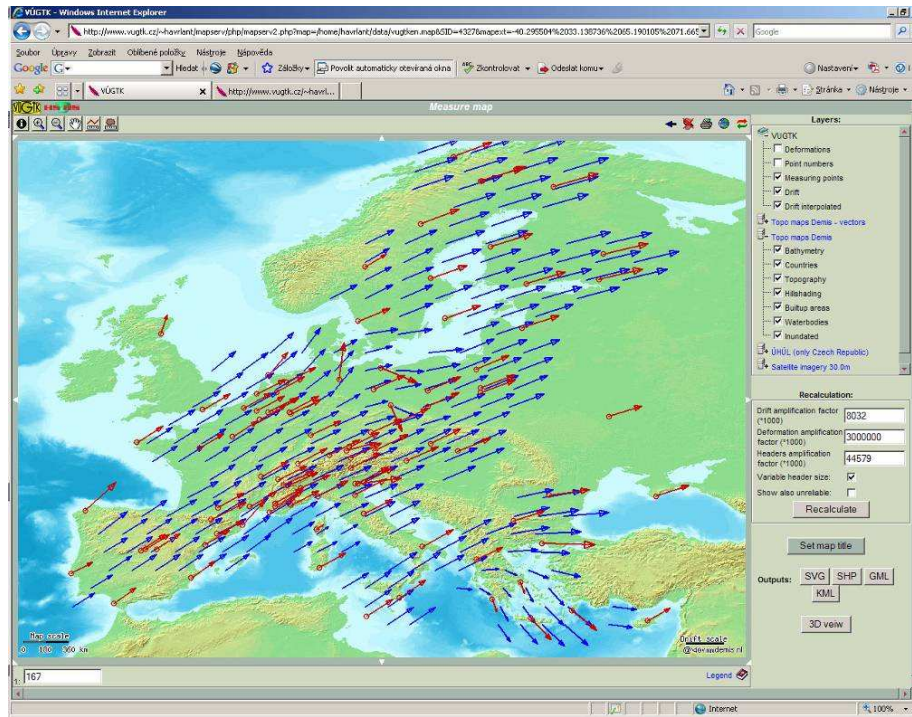
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Figure 5 - Interpolated displacements on points of network ITRF2000 in epoch 1997.0
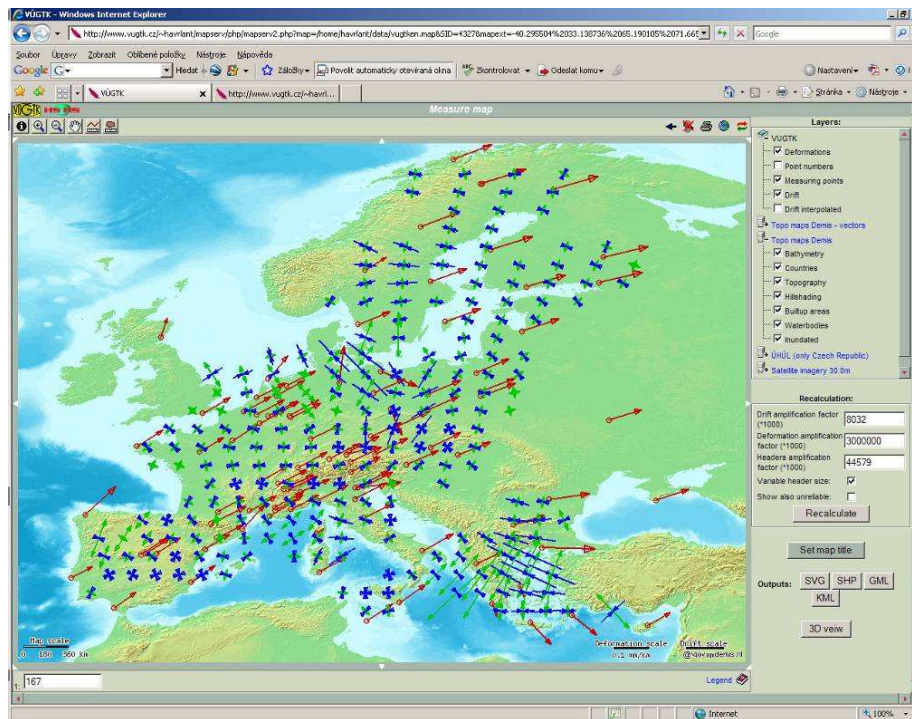
Figure 6 - Given displacements and stated deformations on points of network ITRF2000 in epoch 1997.0
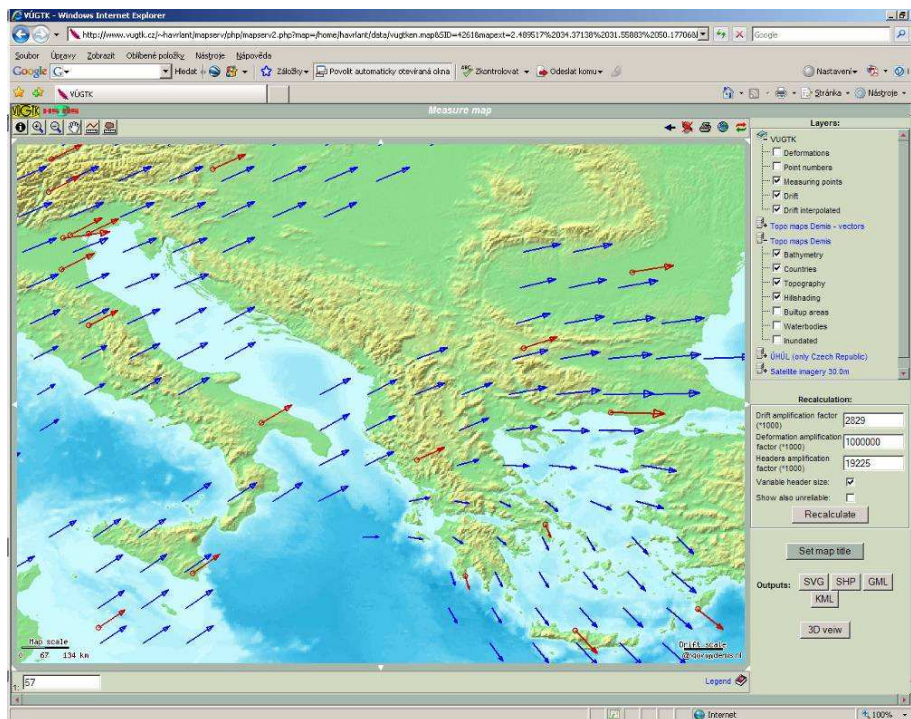

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Figure 7 - Cut out – interpolated displacements
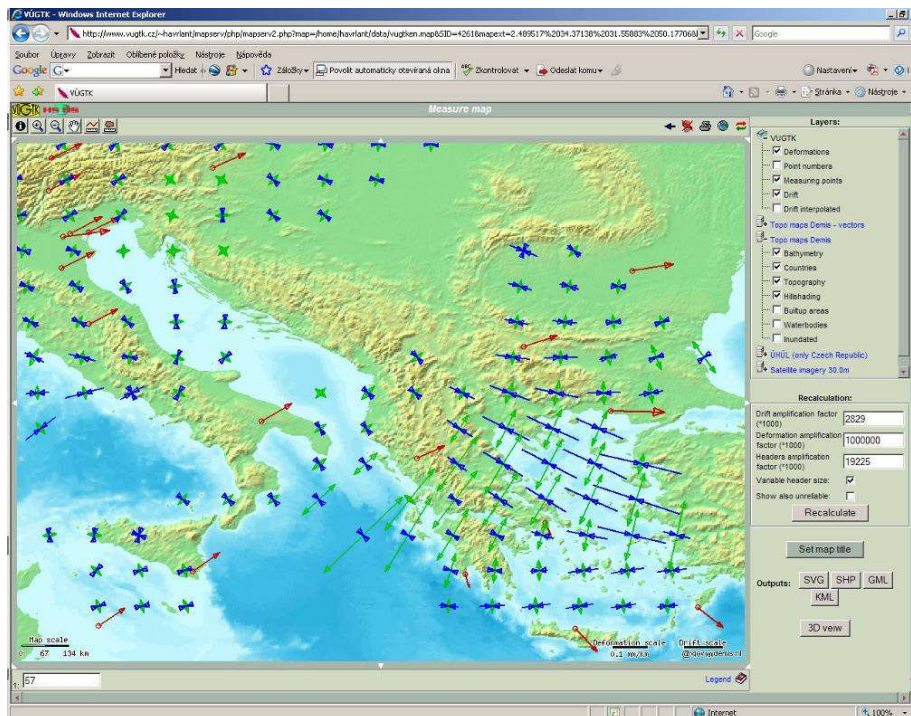
Figure 8 - Cut out – given displacements and stated deformations

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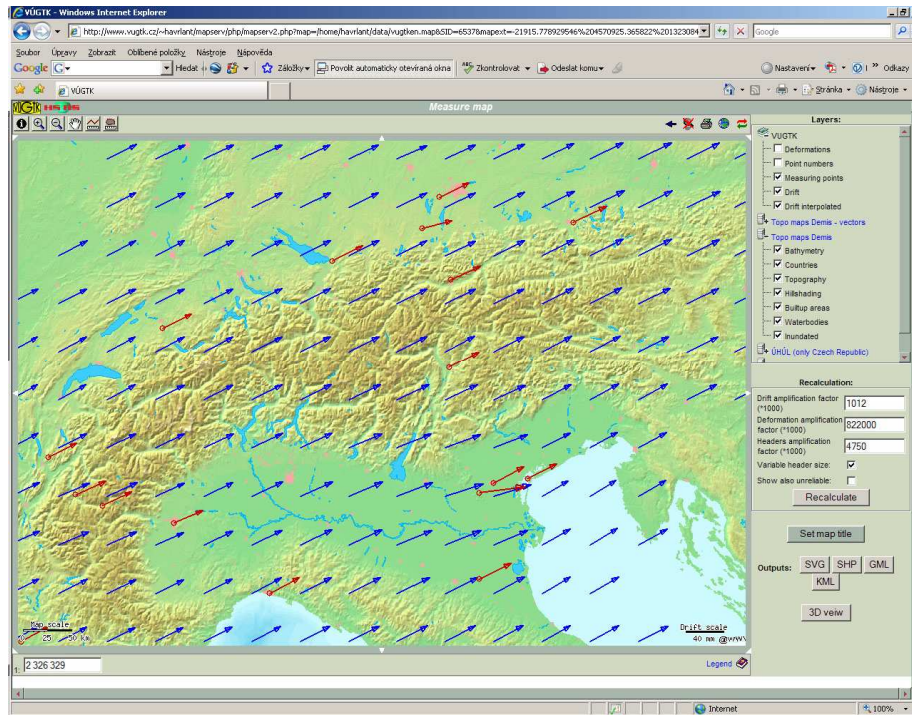Figure 9 - the Alps – interpolated displacements
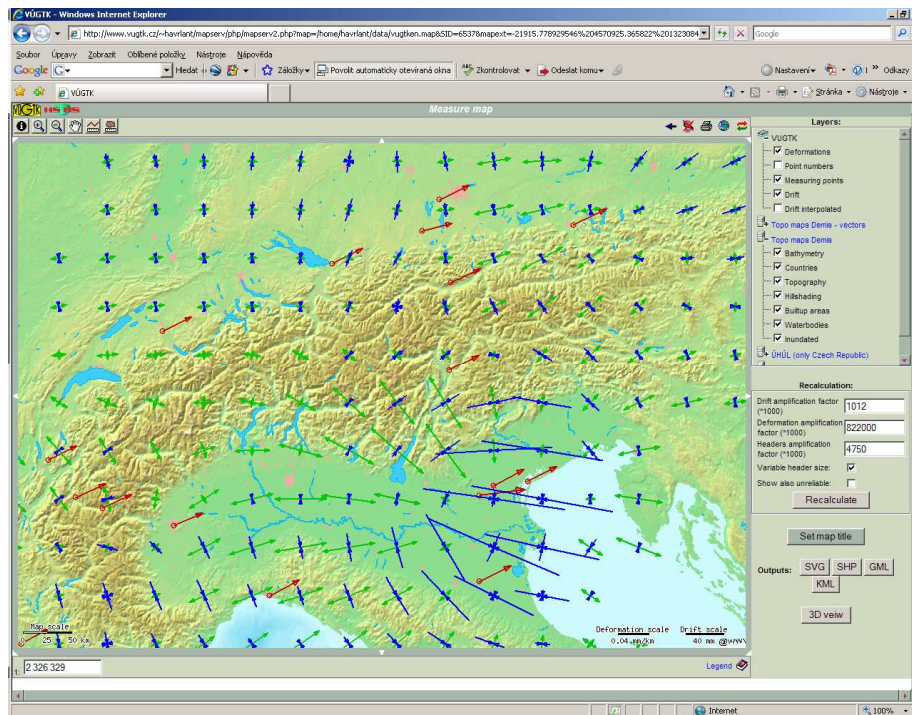
Figure 10 - the Alps – given displacements and stated deformations

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5. CONCLUSION

The aim of this article is, above all, to present web application Deformation Analysis for on-line calculations of deformation analysis from repeated geodetic measurements, which uses the theory of mechanics of continuum and thus, enables the user to use all advantages of this theory. This application can be found at URL: **http://www.vugtk.cz/~deformace/** and is at the disposal for everyone who is interested. Therefore common user does not have to have either detailed theoretical knowledge on calculation of the deformation analysis, or needed SW tool. The calculations are done on-line on the server, the user only input path to his data, and on the other hand, receives the protocol on the calculation including graphic display of the results. Optionally, he may include topographic underground into the graphic results display using the service WMS, which will make easy the interpretation.

The application is still being developed and its functionality is being extended, e.g. to display results in 3D or export in format KML. The examples also demonstrate application of work with different sources of data, that should enable users from all around the world to calculate deformation values.

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Corresponding author contacts
Milan TALICH
  Milan.Talich@vugtk.cz
  Research Institute of Geodesy, Topography and Cartography
  Zdiby 98
  CZ-250 66
  Czech Republic