RECENT PLATE KINEMATICS IN ROMANIA

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SUMMARY

The paper gives some final results of the subproject "Three Dimensional Plate Kinematics in Romania" of the CRC 461 "Strong Earthquakes", funded by the German Research Foundation at the Universität Karlsruhe in the years 1996 to 2007. The reprocessing of the data of 14 GPS campaigns performed from 1995 to 2006 in the deformation network, covering the middle and eastern part of Romania, using the Bernese Software (version 5.0) is discussed, including the analysis of multipath effects and antenna calibrations. From the daily coordinate solutions station velocities were derived using the kinematic model of deformation analysis. Based on these station velocities a three dimensinal velocity field was estimated using the technique of multilevel B-spline approximation, followed by the calculation of strain components. Especially the results of the height deformations could help to support the geophysical modelling of the Vrancea earthquakes.

1. INTRODUCTION

In the Vrancea region in the SE-Carpathian arc in Romania strong earthquakes occur at intermediate depths (70-180 km) in a laterally small volume, while the crust shows low seismicity. In this region Miocene subduction of oceanic crust of the Tethian Ocean was accompanied by rollback of the subduction zone and slab steepening in its final phase after continental collision. The whole subduction zone extended laterally from the northwestern to the southeastern Carpathians (Fig. 1). More and detailed information can be found for example in Wortel and Spakman (2000), Sperner et al. (2001), Sperner et al. (2005) and Heidbach et al. (2007). Obviously the nearly vertical hanging slab segment in Vrancea is currently breaking off. The current interpretation of the behaviour of the slab is a "soft" coupling with the crust as indicated in fig. 2.

The tectonic situation in Romania is represented by three main units, the East European platform in northeast – sometimes called Ukrainian shield -, the Tisia-Dacia block with Pannonian and Transylvanian basin in the centre of the country and the Moesian platform in the south. South of the Danube delta between the East European and the Moesian platform there is a sytem of disturbance zones with the Trotus fault, the Peceneaga-Camena system and the Intramoesian disturbance in the south (Fig. 3).

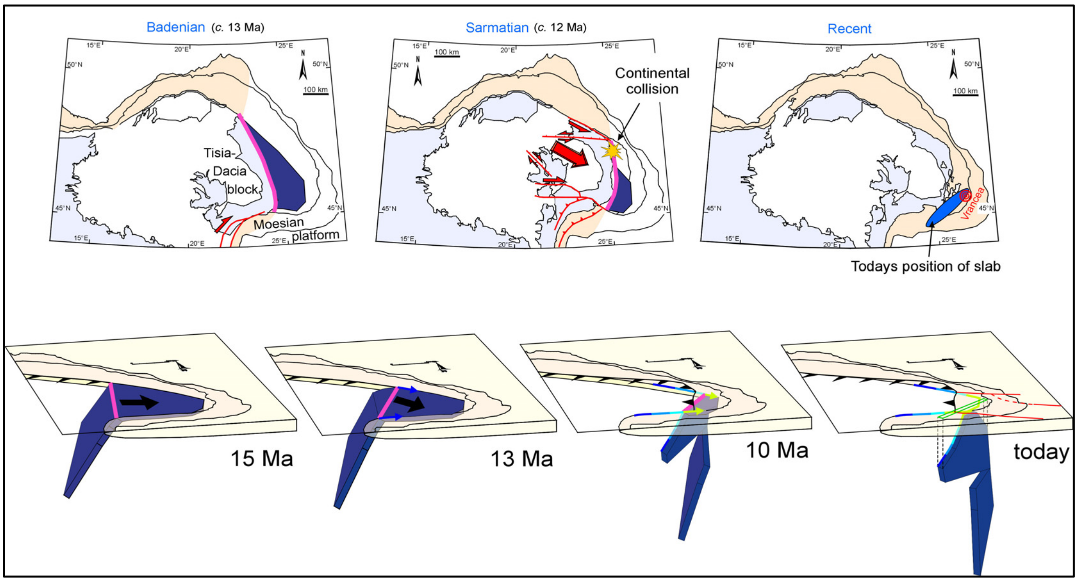

Fig. 1. Tectonic evolution of the SE-Carpathians.

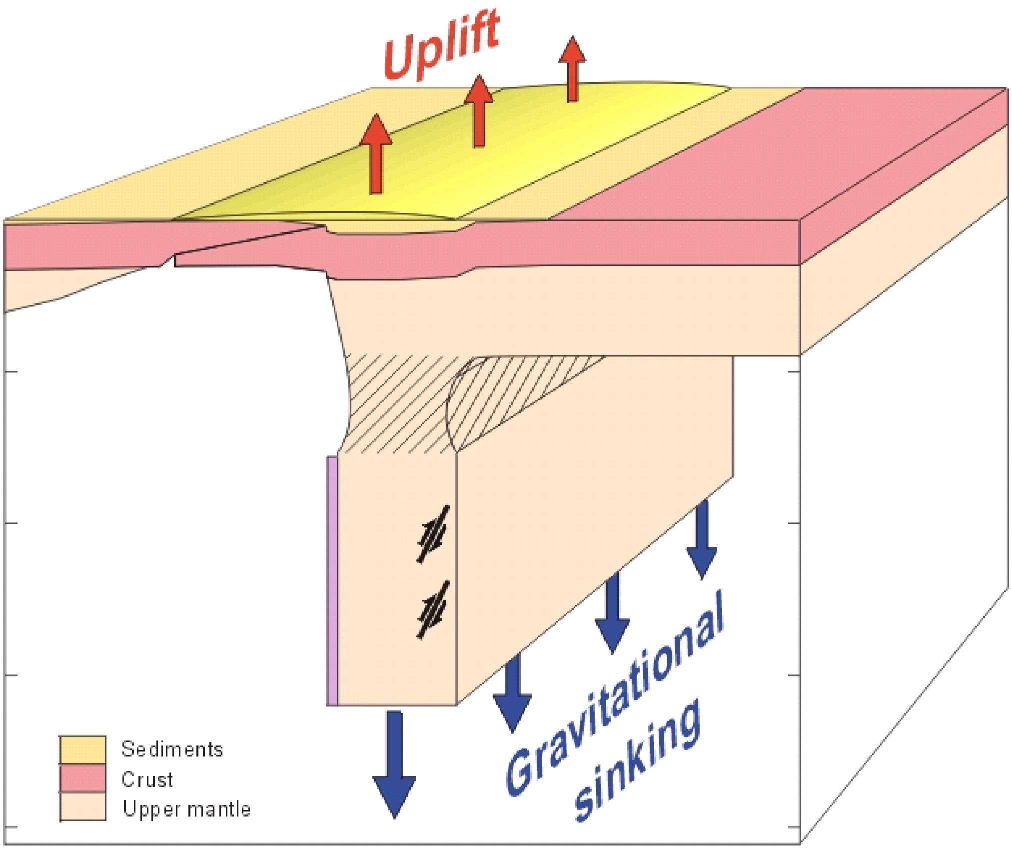

Fig. 2. Soft coupling model of the slab.

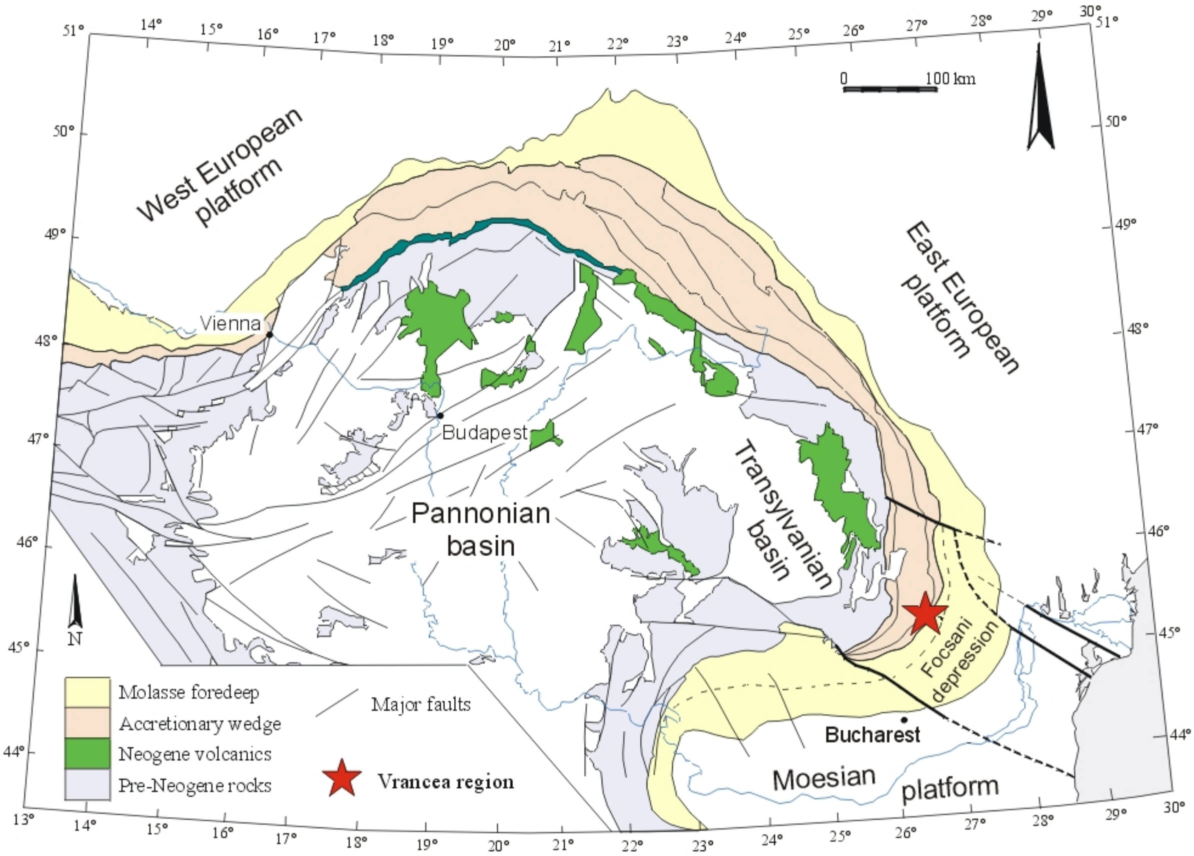

Fig. 3. Tectonic map of the Carpathians with geological units.

The Collaborative Research Center (CRC) 461 "Strong Earthquakes: A Challenge for Geosciences and Civil Engineering" at the University of Karlsruhe has been funded by the Deutsche Forschungsgemeinschaft (German Research Foundation) from 1996 to 2007. One of the main objectives of the geoscientific partners was the development of a Vrancea earthquake model with the following constitutive parts: the earthquake source process, the propagation of waves to the earth's surface and site effects and soil/structure interaction followed by engineering components such as measures for damage reduction and rescue technologies.

2. GEODETIC WORKS

The aim of the geodetic subproject B1 "Three Dimensional Plate Kinematics" of the Geodetic Institute of the Universität Karlsruhe in the CRC was the determination of three dimensional plate movements for Romania with a special focus on the Vrancea area as support for the development and the evaluation of the earthquake model. Our partners have been the Faculty of Geodesy of the Technical University of Civil Engineering Bucharest, the Faculty of Geology and Geophysics of Bucharest University and the Department of Earth Observation and Space Systems of the TU Delft (DEOS), the latter within the Dutch research program ISES (Integrated Solid Earth Sciences).

2.1. GPS Network

Three dimensional movements of the earth's surface can be determined by regional GPS networks. Beginning with 26 CRC stations in 1997 the network (Fig. 4) could be extended up to roughly 60 stations, including 5 permanent stations installed by DEOS (van der Hoeven, 2004).

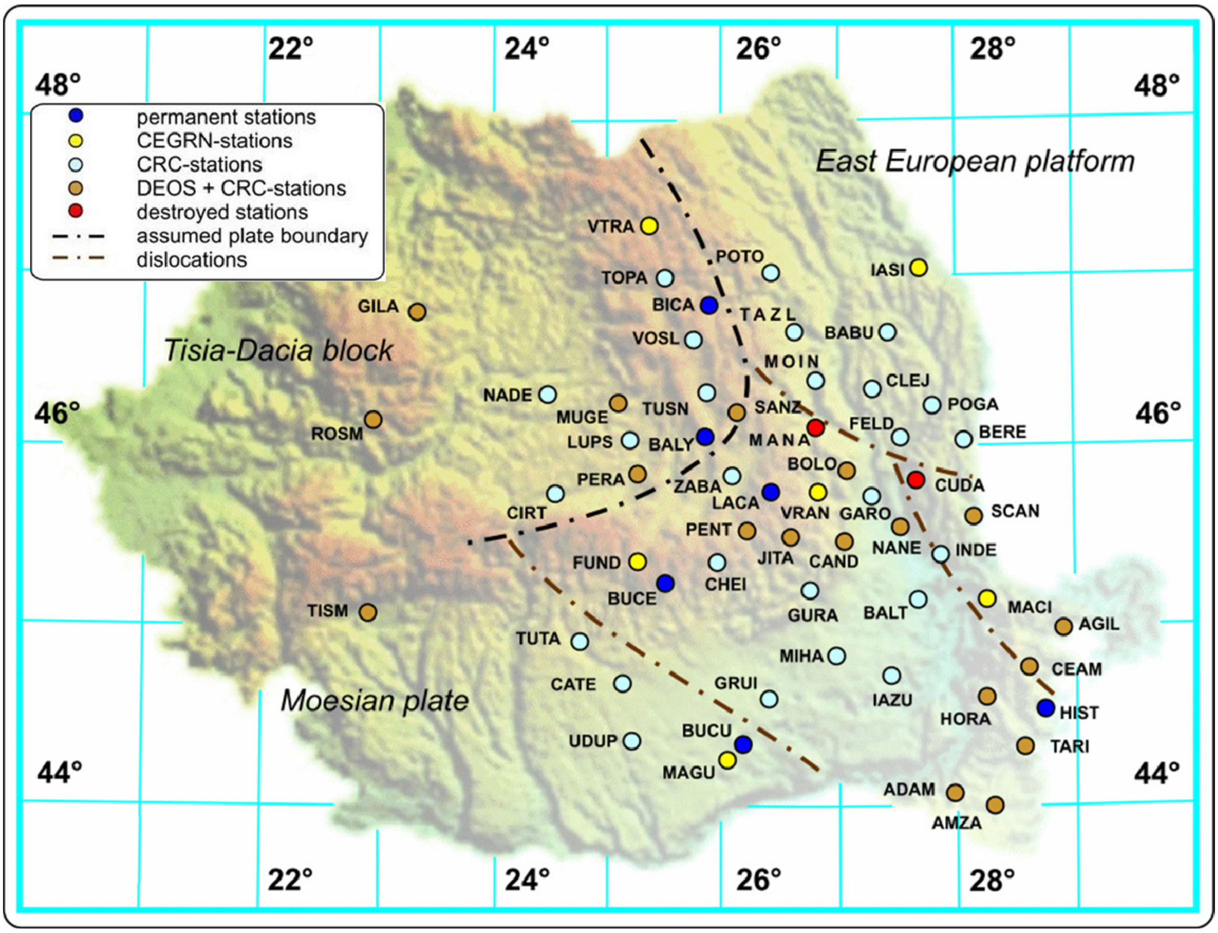

Fig. 4. GPS network used in CRC 461.

Details about marking of the sites, backup bolts, offset-measurements and special antenna adapters are reported in Schmitt et al. (2007). Final station velocities were estimated using observations of 14 GPS field campaigns between 1995 and 2006 (Table 1).

2.2. GPS Data Processing

After the last measurement campaign in 2006 all available data have been reprocessed using the Bernese GPS Software version 5.0 with the same settings for all campaigns. In order to process all campaigns in the same way, a so called Bernese Processing Engine (BPE) was created. Within this part of the software all important settings could be stored and the processing could run in a kind of batch-mode, including the 4 steps: data preparation, baseline definition and preprocessing, float solution and ambiguity fixed solution. As reference frame ITRF2000 was used; final IGS orbits, earth rotation parameters and ionosperic data from the internet were included in the processing.

Special attention was directed to antenna calibration and multipath effects (Knöpfler et al., 2007). For further details we refer to Schmitt et al. (2007) and Schmitt et al. (2008).

Table 1: GPS campaigns

Year	Institution	GPS-Days	Number of Stations	Occupation Time
1995	CEGRN	148-154	6	24 h
1996	CEGRN	162-167	6	24 h
1997	CEGRN	155-161	6	24 h
	CRC	270-275	26	7 h
1998	CRC	232-239	27	7 h
1999	CEGRN	165-170	6	24 h
	NATO	184-195	11	24 h
2000	CRC	232-240	34	8 h
2001	NATO	130-138	12	24 h
2002	DEOS	184-207, 250-268	50	24 h
2003	CRC	224-234	63	24 h
2004	CRC+DEOS	221-231	58	24 h
2005	DEOS	184-198	32	24 h
2006	CRC+DEOS	226-236	51	24 h

CEGRN for Central European GPS Geodynamic Reference Network

2.3. Velocity Estimation

The velocity field was derived from the daily coordinate solutuions of the GPS network. In the first step a kinematical model was used to estimate the station velocities, afterwords a continous velocity field was generated using B-spline techniques (Nuckelt, 2007). The station velocities were calculated relatively to the movement of the European continent. Severe difficulties came up in the analysis of the height coordinates, caused obviously by the use of different receiver equipments in the different epochs, leading to different sensitivity for multipath signals and to height offsets. In most cases the offsets could be estimated in the analysis of the corresponding time series (Schmitt et al., 2007).

As usual the GPS stations are located very scattered. For analysing the movement and deformation of the investigation area it is necessary to determine a regular grid or continuous surface using approximation techniques. The methods of freeform surfaces and scattered data interpolation provide both lots of possibilities for the estimation of approximation surfaces. The multilevel B-spline approximation unifies both methods and provides the possibility to include a computation of strain rates. Due to application of the law of propagation of variances to the approximation algorithm standard deviations can be obtained for the velocity field.

Fig. 5 shows the horizontal velocity field in the grid with the corresponding significance ellipses. The Moesian platform moves direction southwest. In the northern part there is a significant movement in direction west. The Transylvanian Basin inside the Carpathian arc performs a shift to the west. The biggest velocities (up to 5 mm/year) are shown for the south-eastern part of the Carpathian arc.

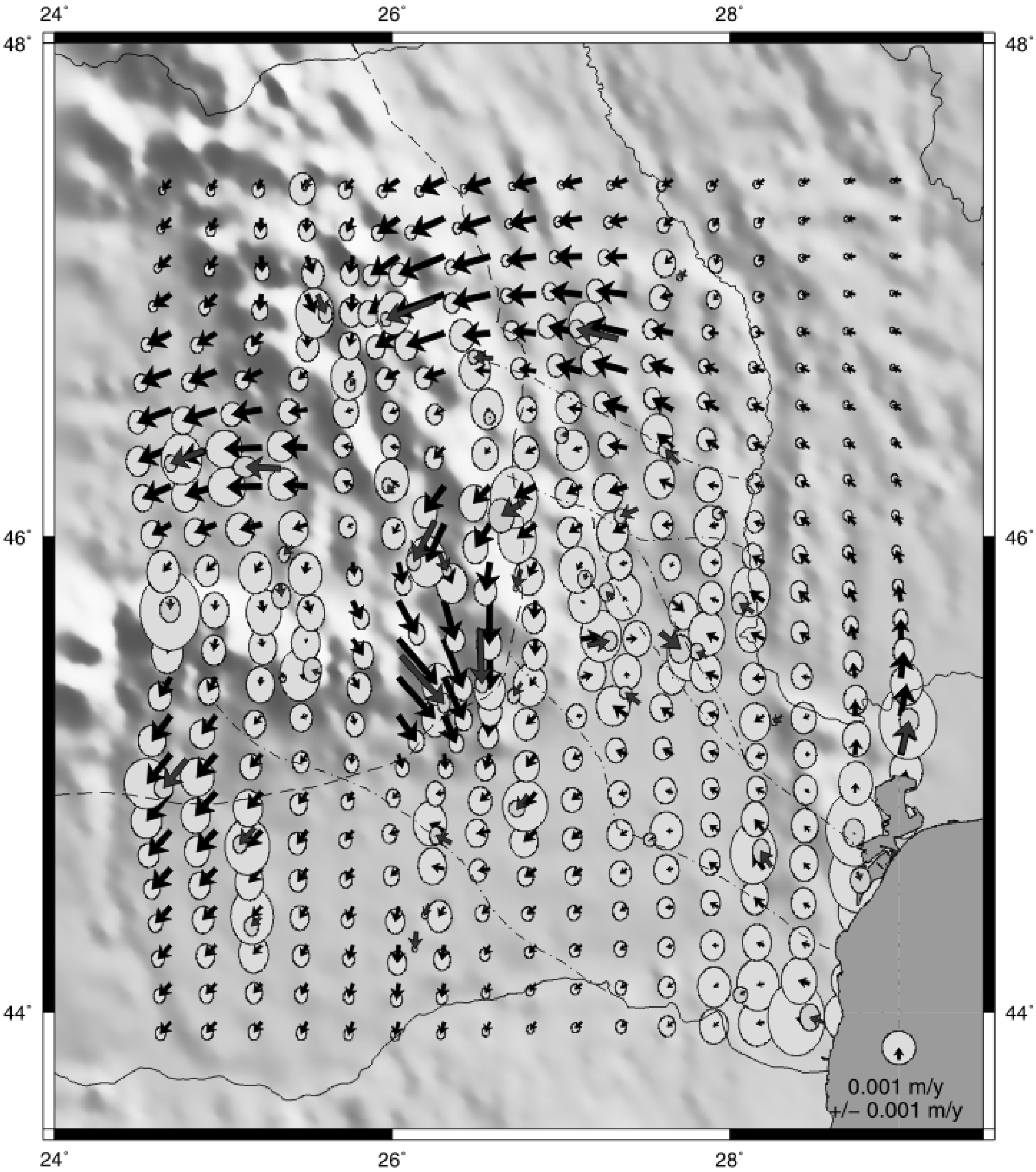

Fig. 5. Horizontal velocity field with standard deviations.

In fig. 6 the vertical movements are represented, in this case not as a continous field but for the single GPS points, again with standard deviations. Areas of significant uplift and subsidence can be identified. Transylvanian Basin, Brasov Basin, Focsani Basin and the areas close to the Black Sea are evidently subsiding regions. In opposition to this areas the Carpathian arc, Moesian platform and European platform are uplift areas.

Both horizontal and vertical movements match more or less with the geological and geophysical knowledge. Especially the moderate uplift of the Vrancea area coincides with the model of prograssive delamination of the soft coupled slab as shown in fig. 2. The results of the strain analyses based on the continous velocity field are not significant and therefore not presented (Nuckelt, 2007; Schmitt et al., 2007).

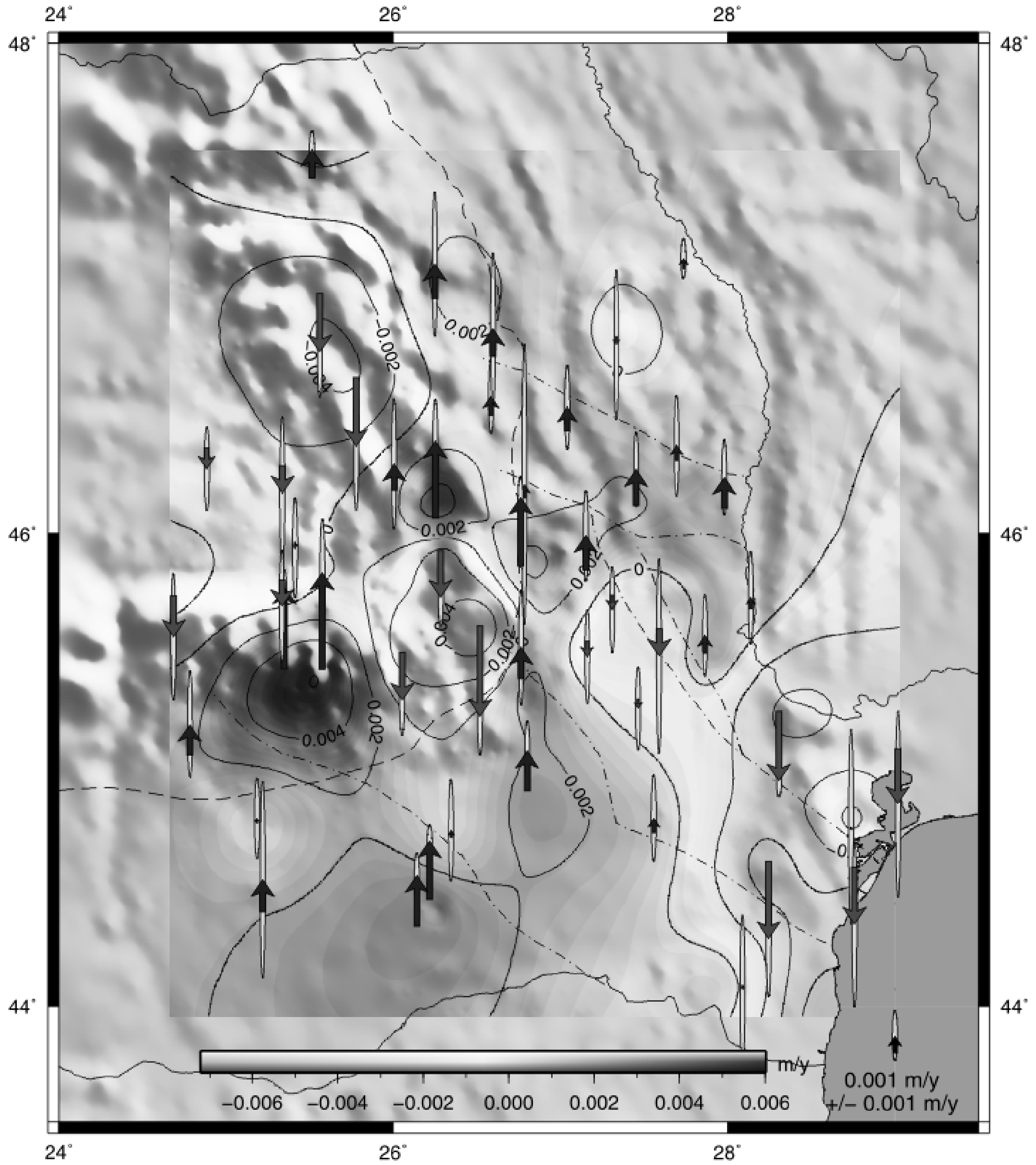

Fig. 6. Vertical velocities with standard deviations.

3. ACKNOWLEDGEMENTS

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