Progetto S5 - RU 1.03

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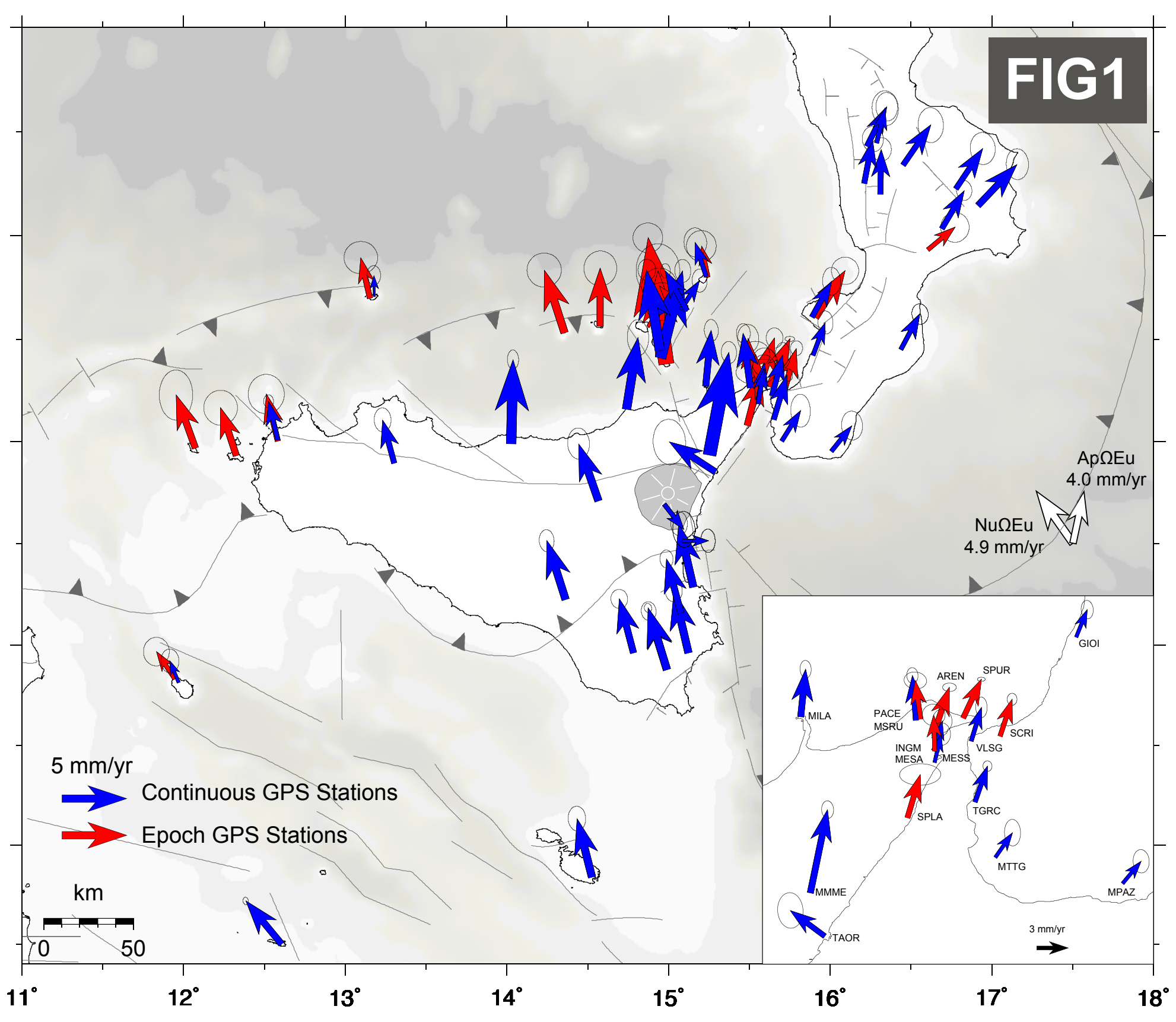
Strain Accumulation Across the Messina Straits and Kinematics of Sicily and Calabria From GPS Data and Dislocation Modeling

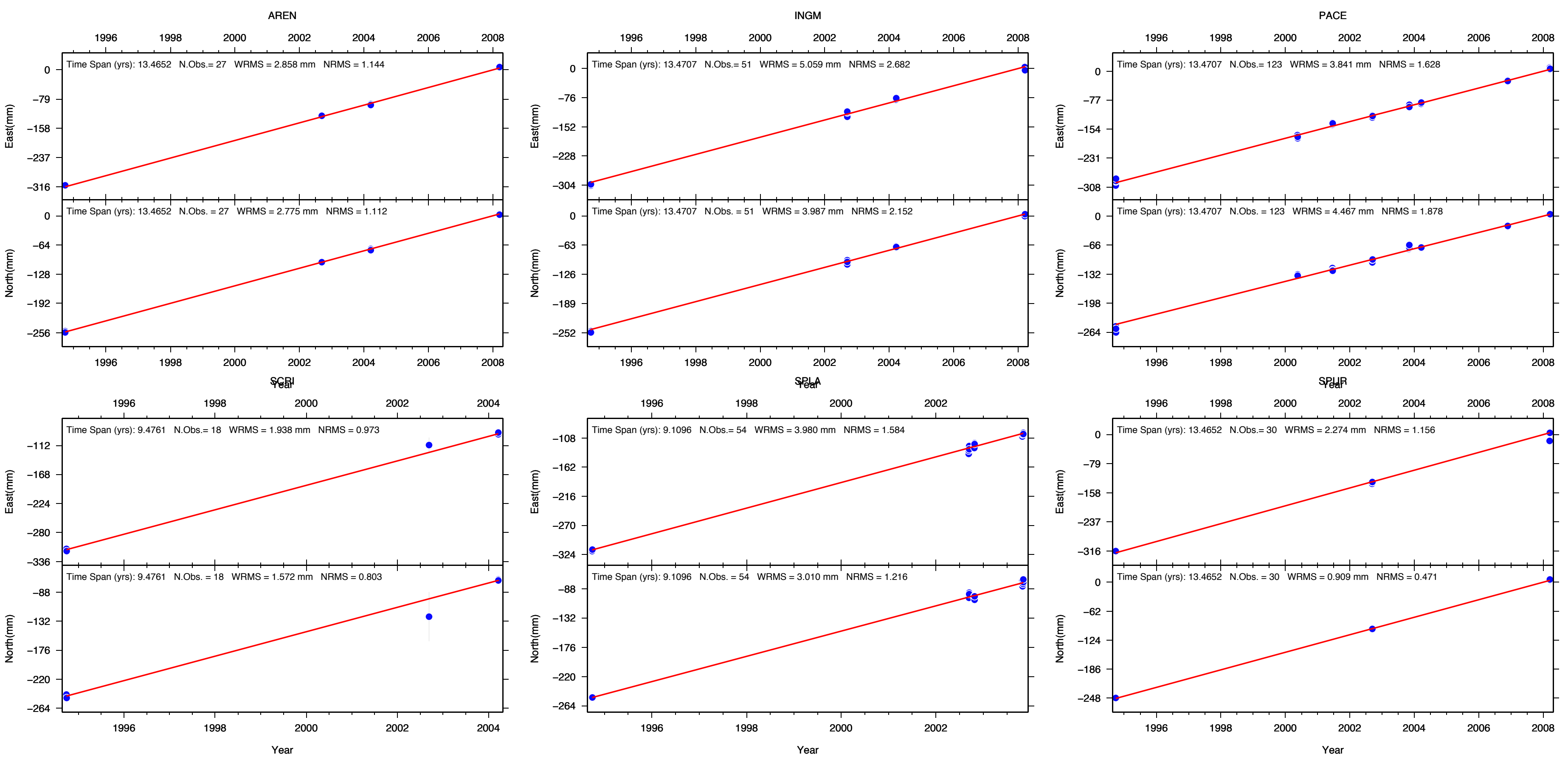
S5 INGV-DPC 2007-2009 http://dpc-s5.rm.ingv.it/
High-resolution multi-disciplinary monitoring of active fault test-site areas in Italy

GPS Velocity Field

We used the GAMIT/GLOBK software to analyze data collected during repeated GPS surveys over the Messina Straits network (Fig.1) from 1994 to 2008, together with data from >800 continuous GPS stations operating in the Euro-Mediterranean region in the 1996-2010 time span. We used the ST_FILTER program to combine our loosely-constrained solutions with SOPAC's global ones, and consistently defined a global reference frame, aligned to the IGS realization of the ITRF05 reference frame. Velocities have been determined from time-series analysis. Velocity uncertainties have been estimated adopting a white+random walk noise model for survey-mode GPS sites, and a white+flicker noise model for the CGPS sites. Figure 1 shows horizontal velocities, and 95% error ellipses, given with respect to a fixed Eurasian frame (located at Longitude -98.85±0.24°E, Latitude 54.74±0.30°N and with rotation rate of 0.257±0.001°/My.Absolute time-series for some survey-mode GPS sites are also presented.

FIG1

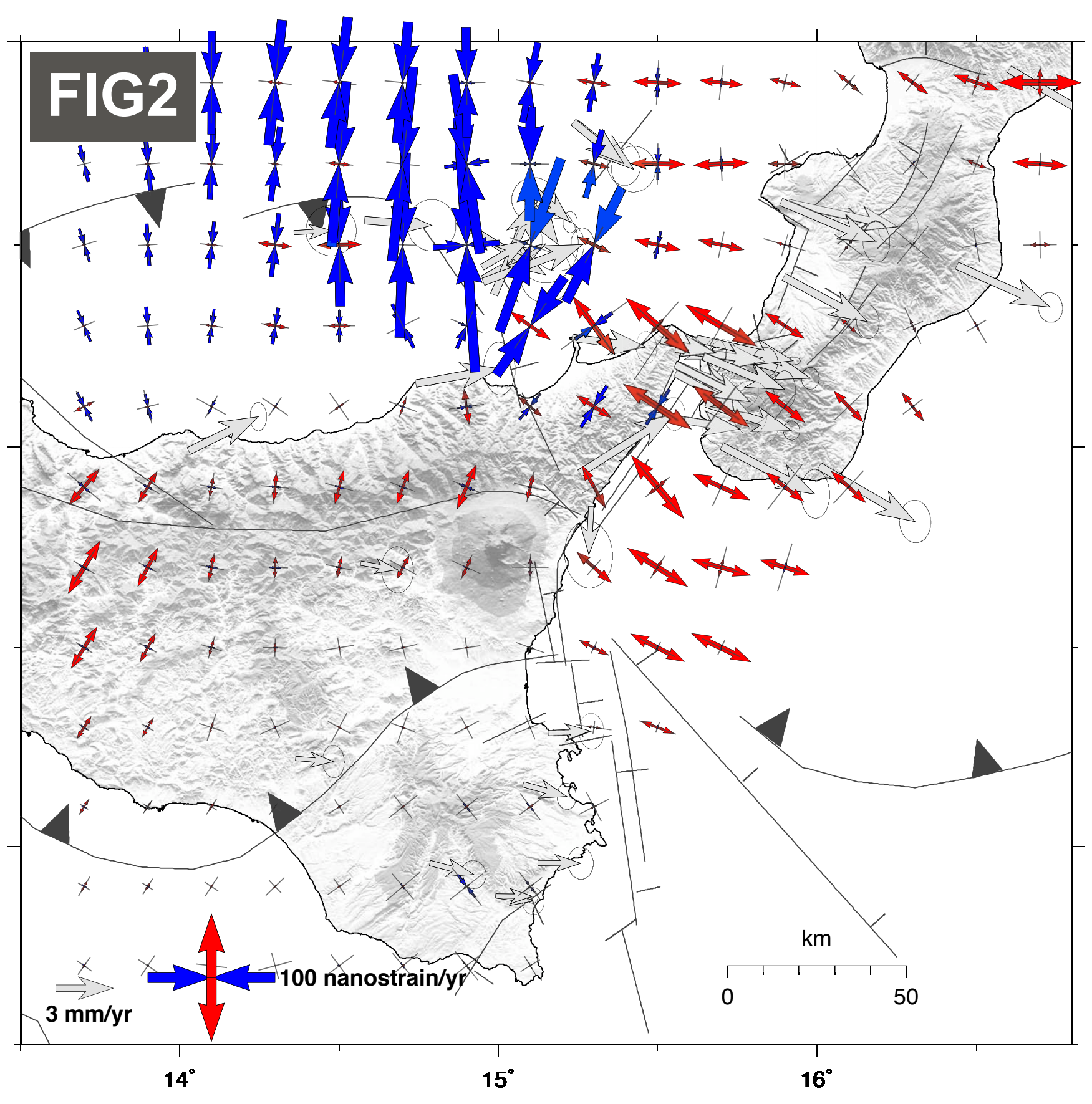


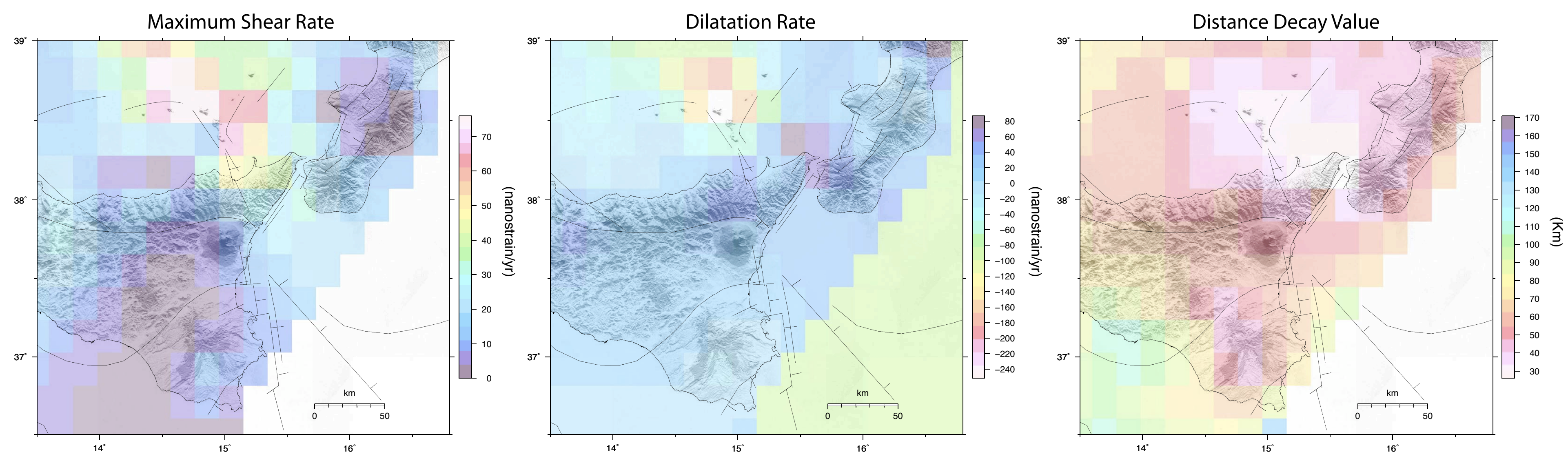


Strain-rate Field

Horizontal velocities (Fig. 1) are used to invert the strain rate field over a regular grid (Fig. 3), through least squares, each time estimating strain and rotation rates at one spot using velocity data in the neighborhood (Shen et al., JGR, 1996). Data are reweighted by a Gaussian function exp(–Δ2 / D2), where Δ is the distance between a GPS station and the spot being evaluated, and D is a smoothing distance that is obtained through balancing a trade-off between the formal uncertainty estimate of the strain rate and the total weight assigned to the data.

FIG2





Maximum shear rate, dilatation rate and distance decay value. The parameter D (in km) is used to rescale the velocity data, and may be considered as an indicator of how local or regional the strain-rate tensor inverted at each grid point is. We obtain values ranging between 20 and 100 km, with a typical value of ~60 km. Figures are obtained by gridding of the strain-rate tensors of Figure 2.

Dislocation Modeling

FIG3

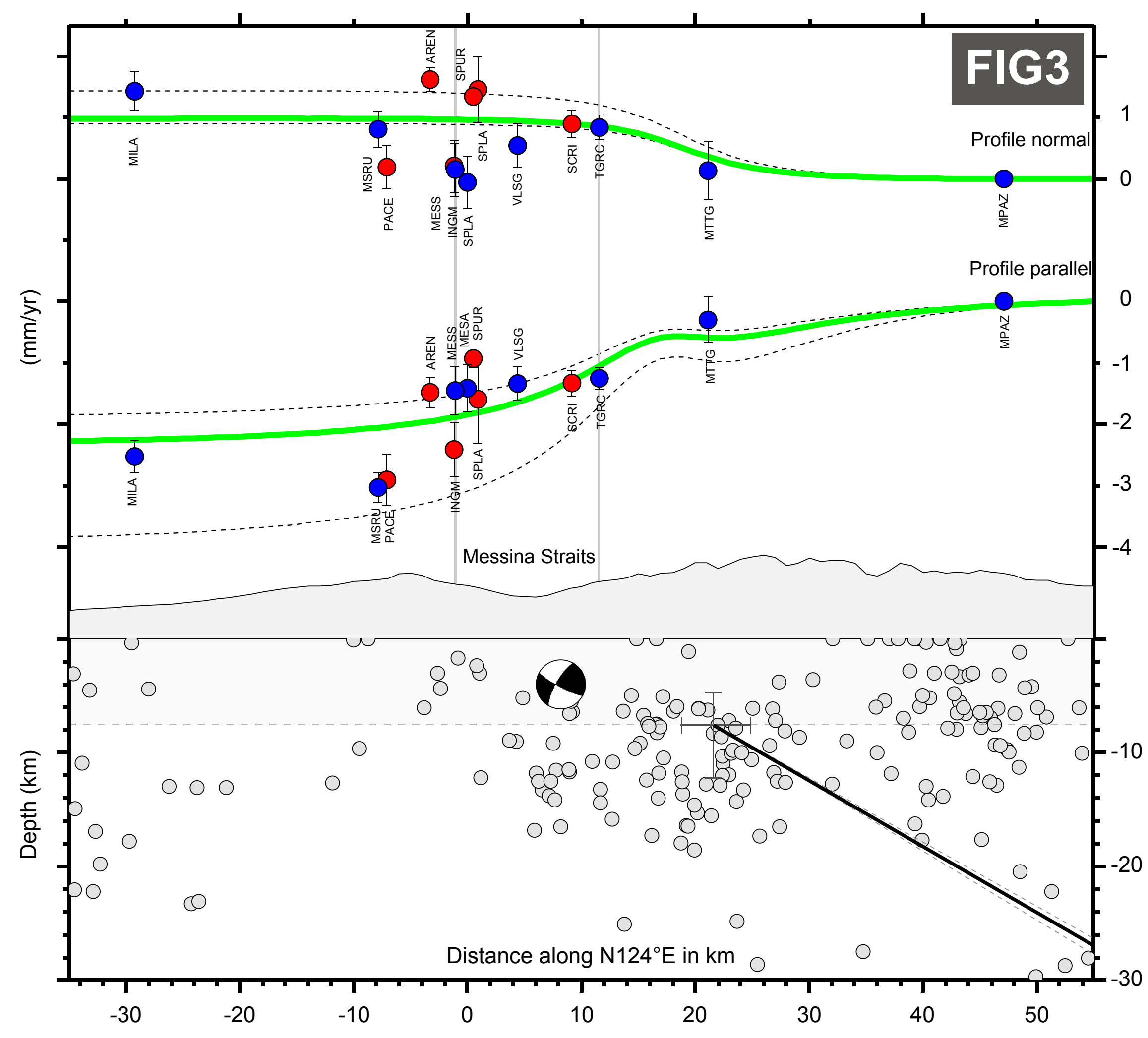


Fig.3 - N124°E cross section showing the horizontal velocity gradients (with respect to station MPAZ) from optimally inverted fault parameters and slip-rates (green line), where the light grey dotted lines display fault slip-rate 68% confidence error bounds from the bootstrap analysis. Blue and red circles, with 1σ uncertainties error bars, show survey-mode and CGPS stations, respectively.

We develop first-order models of the deformation using elastic dislocation theory (Okada, 1985) assuming that the observed velocity gradient is the effect of slip on a planar dislocation locked above a given depth and that all strain that accumulates interseismically is elastic. In the inversion we employ rectangular, uniform-slip dislocations embedded in an elastic, homogeneous and isotropic half-space, and a constrained, non-linear optimization algorithm, which solves for the best fit dislocation geometry and fault slip rate. We use GPS stations across the Straits (Fig.3) and assume a quasi-2D model geometry, constraining fault strike to be perpendicular to the maximum extensional strain. The optimal model fault plane (WRSS/N = 3.8) and slip-rates, with 95% confidence intervals estimated using the bootstrap percentile method (Arnadottir and Segall, JGR, 1994) are:

	Locking Depth (km)	Dip SE-ward (decimal degree)	Strike Slip (mm/yr)	Ext. Dip Slip (mm/yr)
Optimal model	7.6	30.1	1.6	3.5
Bootstrap	$8.8^{-5.1}_{+7.5}$	$30.8^{-1.5}_{+3.3}$	$1.9^{-0.4}_{+0.5}$	$4.1^{-1.8}_{+4.4}$

Microplate Kinematics

FIG4

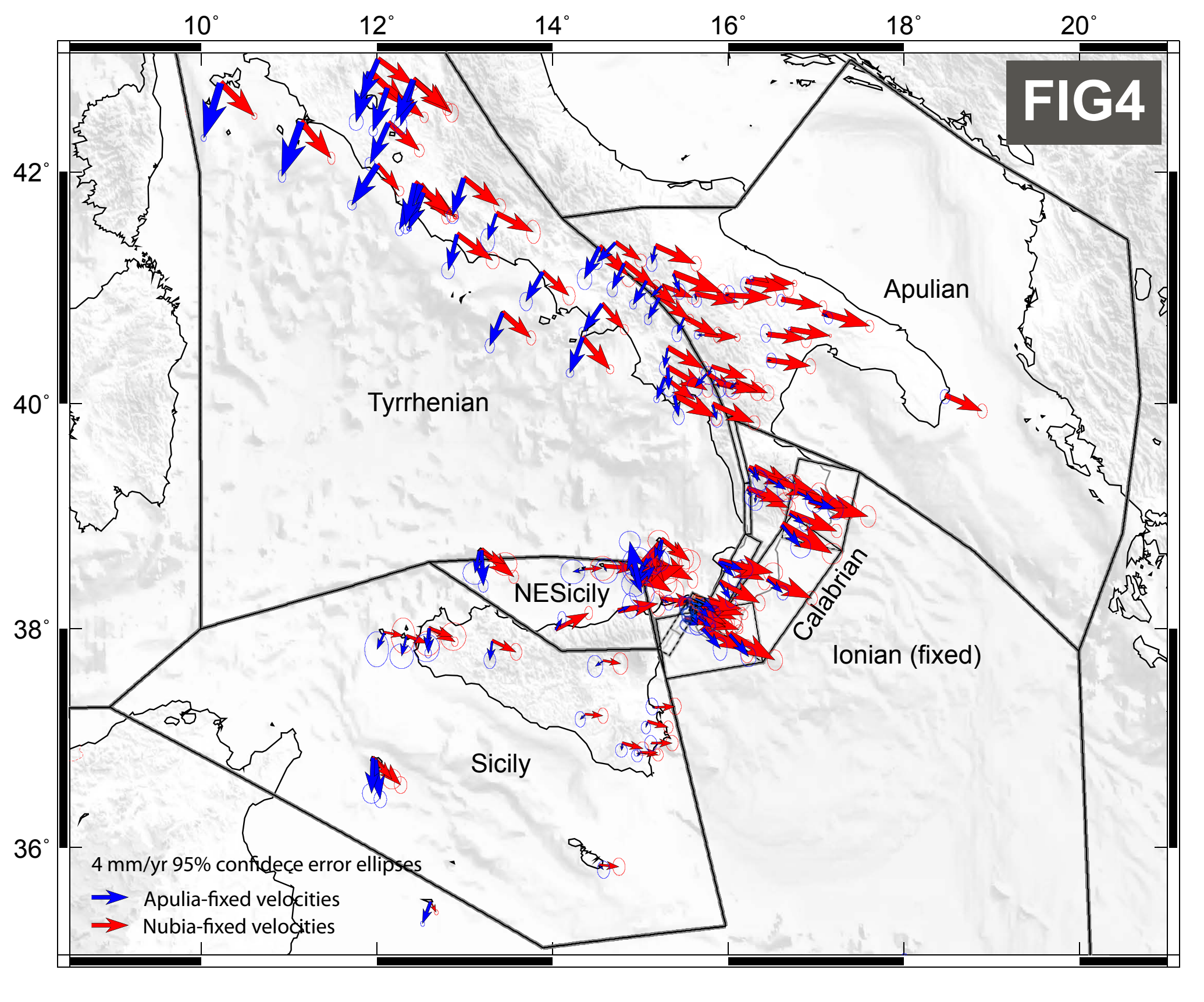


Fig.4 - Block model geometry and horizontal GPS velocities rotated into the Apulia-fixed (blue arrows) and Nubia-fixed (red arrows) reference frames.

FIG5

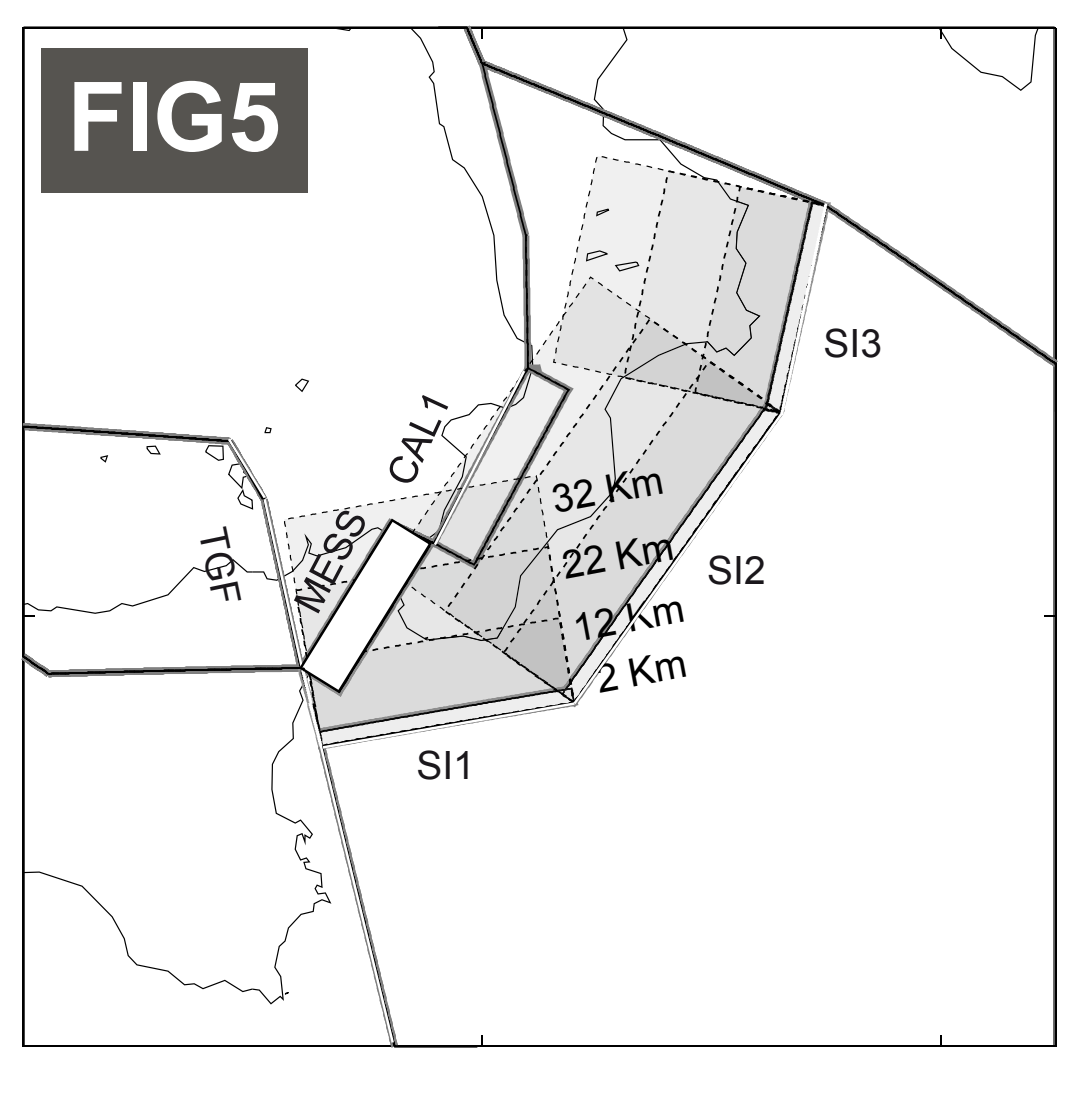


Fig.5 - Fault systems investigated in this work, keeping fixed the geometry of the Messina fault (MESS) at the values obtained from the local dislocation model. For the western Calabrian normal fault system (CAL1) and the Tindari-Giardini fault system (TGF) the locking depth varies from 0 to 20 Km, whereas for the Calabrian subduction interface (SI1, SI2, SI3) the locking depth varies from 0 to 40 Km.

The Messina Straits is surrounded by other active fault systems that are likely to be locked during the interseismic phase and are likely accumulating elastic strains. We developed a kinematic elastic block-model with the goal of understanding if and how much the observed velocity gradient, and consequently the modeled slip-rate across the Messina Straits, could be influenced by some (unknown or poorly known) parameters of the active faults that surround the Straits. In particular, the impact of the possible interseismic elastic signal due to a locked, or partially locked, subduction interface offshore Calabria on the observed velocity gradients in the Messina Straits turns out to be very important. A Ionian-fixed velocity field (Fig.4) allows us to implement a relatively simple block geometry, accounting for the two end-members kinematics plate-boundary conditions along the Sicily-Calabria plate boundary.

By having different relative velocities (see Fig.4) across the subduction thrust, the only parameters that change in the two experiments are the rotational parameters and the slip-rates of the blocks that share a boundary with the Ionian block. As demonstrated in Fig.6, this does impact the Messina fault slip rate inverted from the GPS data under the two respective kinematic frameworks, and demonstrates that the the other two fault systems investigated do not impact the model velocity gradients across the Straits.

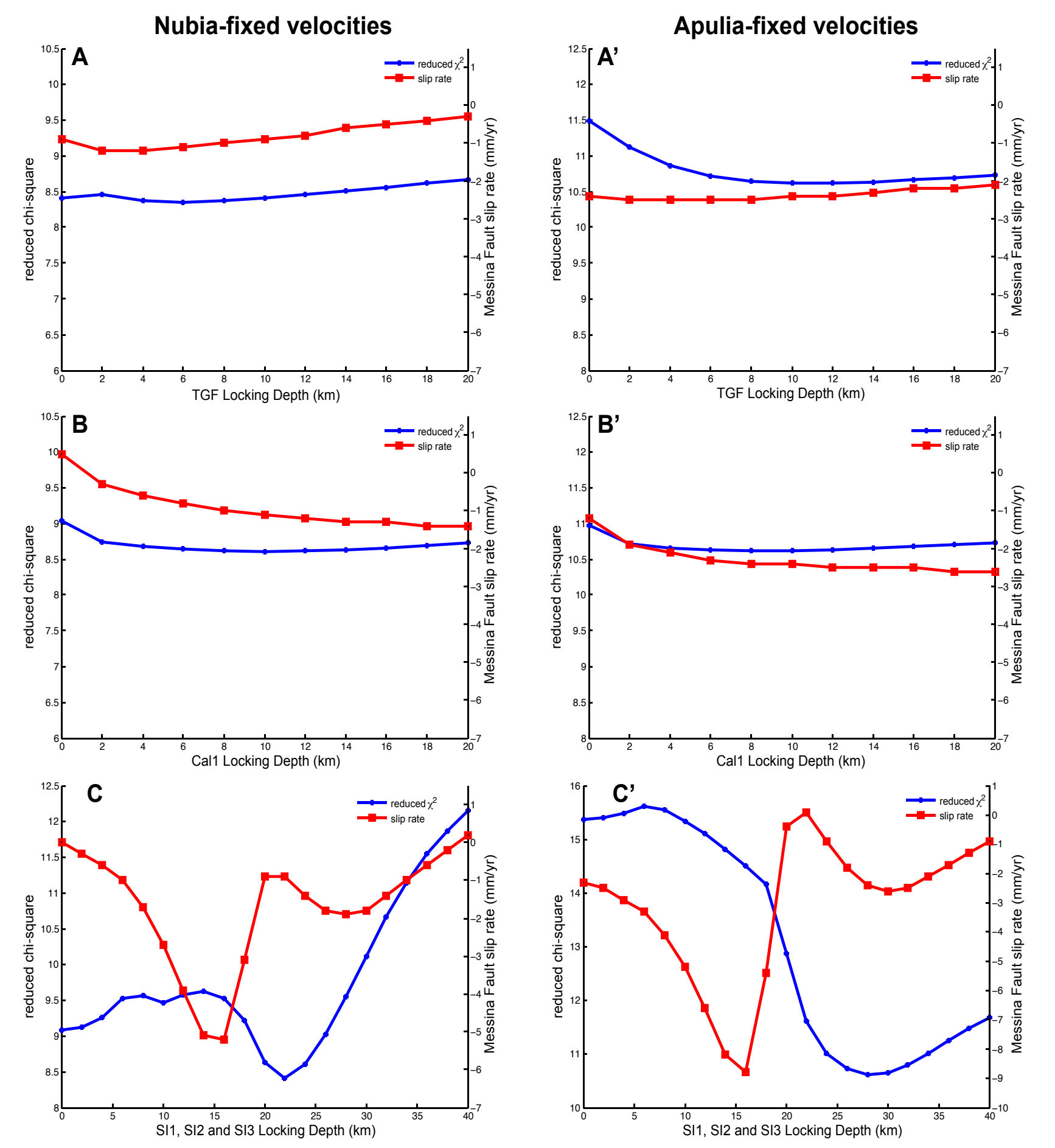


FIG6