Contribution of Space Geodesy to the Measurement of Recent Deformation in the Central Mediterranean Area

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1. Introduction

At the Matera Space Geodesy Centre "G.Colombo" GPS, SLR and VLBI geodetic solutions are regularly produced into the framework of different international commitments. This activity is now consolidated and these solutions are sufficiently strong and stable to allow the realisation of a reliable velocity field especially in the central Mediterranean area where a dense GPS network has been established just along the Italian peninsula. Moreover, in Italy the number of GPS permanent stations is continuously increasing and in few years it will permit a further better definition of the velocity field and the deformation rate in this area, which is a tectonically active region, where plate boundaries are still not well defined and the interaction among tectonic plates is still poorly constrained.

2. Features of the geodetic solutions

At Matera Space Geodesy Centre we produce GPS, SLR and VLBI geodetic solutions on a regular basis. Taking advantage from this opportunity, we thought to combine different and independent solutions to obtain more reliable results. As a first step, we combined two solutions: one GPS regional solution and one SLR global solution.

The GPS regional solution (fig.1) covers about seven years (1995-2002) of continuous observations, involving 35 European tracking stations. Stations velocity has been calculated as a linear fit over daily station positions, taking into account any jump due to antenna change, variations of the radome or anything else could have affected the position time series. Daily coordinate solutions have been obtained with a "quasi-free network" approach, estimating on each day the coordinates of all the stations in the network, besides nuisance parameters such as tropospheric zenith delays and ambiguities.

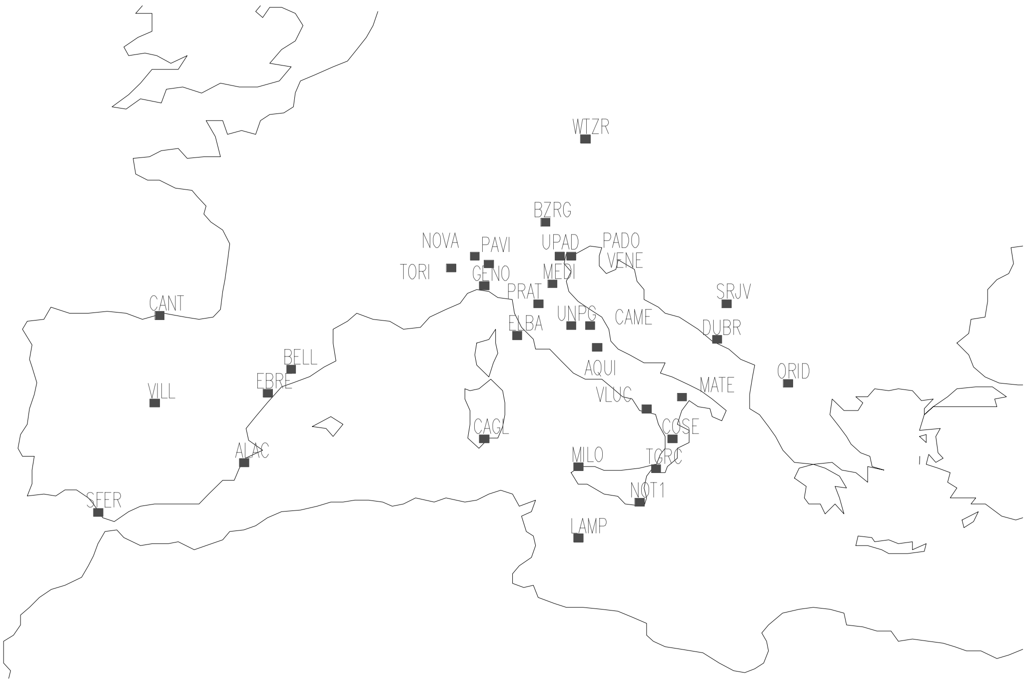

Fig.1: GPS network

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After this, each daily solution has been translated into the ITRF2000 reference frame, estimating the Helmert parameters using positions of five anchor stations: Matera, Cagliari, Noto, Villafranca and Wettzell. The SLR solution (fig.2) is based on LAGEOS-1 and LAGEOS-2 data covering the period from 1984 to 2001, involving 84 tracking stations all over the world. Velocity field and coordinates have been calculated directly into the reduction data run and the constraint to the ITRF2000 has been realised by fixing coordinates and velocity of Greenbelt and Herstmonceaux.

Fig.2: SLR network

3. Combination of the geodetic solutions

The two geodetic solutions have been constrained into the same terrestrial reference frame: the ITRF2000. However, each single-technique solution can still be affected by unknown rigid roto-translations drifting in time, depending on how the reference frame has been realised in the region of interest. For this reason, the GPS velocity solution and the regional segment of the SLR global velocity solution together with their associated covariance matrix have to be re-transformed into the common reference frame by estimating translation drifts, scale and rotations (DEVOTI at al., 2002a). Once each velocity field was expressed in the common reference system, the combined 3-D velocity field has been estimated in a least squares sense, minimizing the velocity residuals. The corresponding weight matrix has been built up using the solution covariance matrices. Therefore the combined solution is by definition estimated in the ITRF2000 reference frame.

4. The Eurasian eulerian pole

The velocity field obtained after the combination has been evaluated in terms of residual motion with respect to the Eurasian plate. The residual velocities with respect to the Eurasian block can be computed by subtracting the rigid motion of Eurasia expressed in the ITRF2000 reference frame. To estimate the corresponding eulerian vector we minimized the velocity residuals with respect to a rigid plate motion of selected 22 ITRF2000 sites (fig.3) located in central Europe. This pole was then used to predict and remove the Eurasian velocity at each considered site.

The estimated eulerian pole (-93.8±0.6/W, 59.6±1.2/N) differs significantly from the NUVEL-1A pole (-112/W, 50/N) and the estimated rotation rate is also significantly higher (0.27±0.01//My estimated; 0.23//My Nuvel1A). However these differences could be explained by systematic differences between the ITRF and the NUVEL reference systems; what is important for us is to subtract a rigid motion for the Eurasian plate expressed in the same terrestrial reference frame as our velocity solution and this is assured by the very small residuals (very close to its own error) found at the European sites after subtracting the eulerian pole (fig.3).

5. Velocity field and strain rate in the Mediterranean area

The velocity field in the Mediterranean area around the Italian peninsula has been evaluated as residuals with respect to the Eurasian plate (fig.4) considered as a rigid plate or with negligible intra-plate motions. But residual horizontal velocities at some sites in the interesting area have been also used for evaluating ongoing deformations. Considering sites as vertices of convex polygon we can evaluate the strain rate tensor at the barycenter of the polygon by symmetrization of the velocity differenced pair-wise. It is assumed, as approximation, a linear variation of the horizontal velocity pair differences with respect to the sites distance. Choosing triangles as polygons the problem is simplified; we can evaluate the velocity gradient tensor at the barycenter by solving exactly the system of equations relating the unknown tensor components with the known residual velocity differences. This quantity, related to the strain rates, tells us about the ongoing deformation in that area.

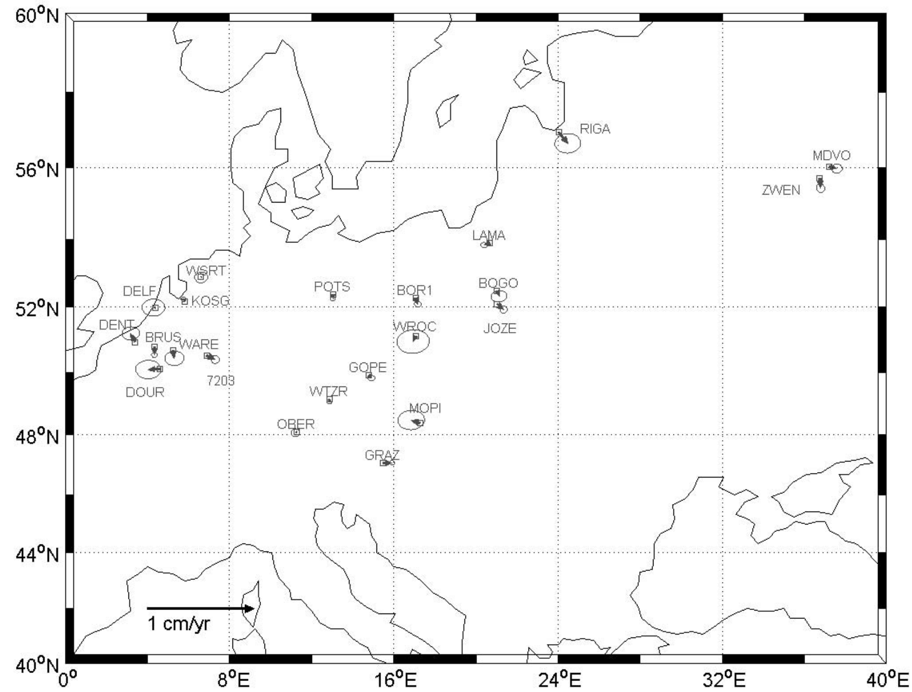

Fig.3 ITRF2000 sites used for calculating the Eurasian eulerian pole: velocity vectors and sigma shown at sites are the residuals after subtracting the Eurasian eulerian pole estimated.

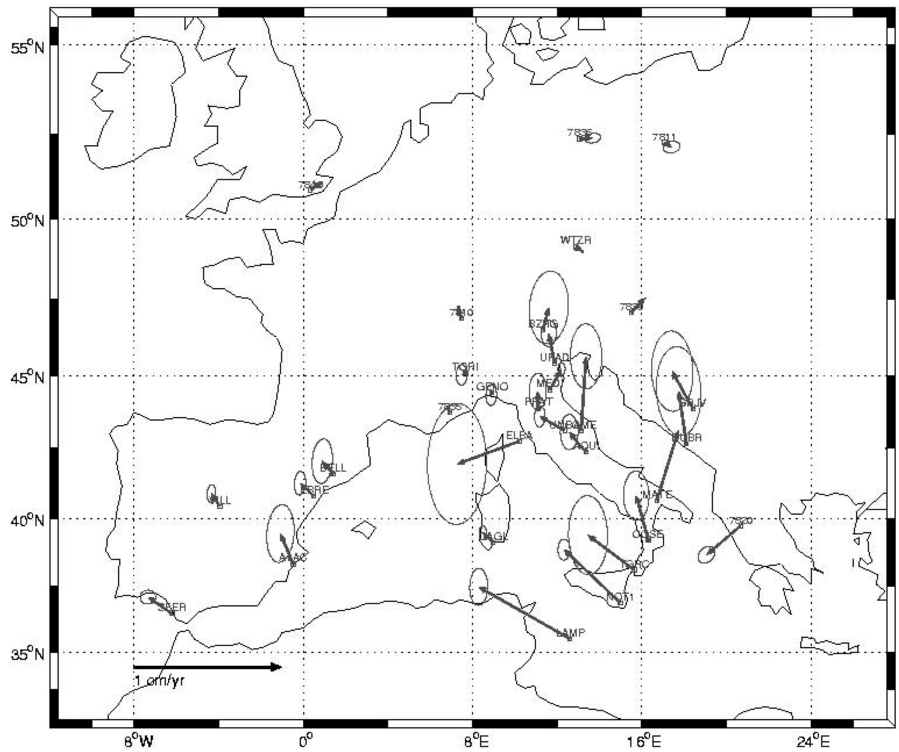

Fig.4 Velocity residuals w.r.t. Eurasian eulerian pole ITRF2000.

6. Results

Large residual motions w.r.t. Eurasian rigid plate are present in the Italian region, according to an active tectonic and an ongoing deformation (DEVOTI et al., 2002b); the large compression (fig.5) near the northern African margin is compatible with the convergence between African and Eurasian plate; very preliminary results can be shown also in the central Appenines chain, where the station close to the foredeep (Camerino) seems to move away from the hinterland (Elba), confirming an ongoing compression towards Adriatic foreland in this zone of the chain.

In the Adriatic region a compression regime seems to be confirmed by the strain rate calculated in the triangle Aquila-Matera-Sarajevo; a main extensional regime is present between Cagliari and Matera and between Matera and Noto, according to geological evidences of active extensional tectonics in the Calabrian arc (fig.5). The Alpine region still suffers of an active compressional regime as shown in fig.6. The Iberian peninsula seems to be stable, showing strain rate values generally within or very close to its error.

7. Conclusions

The space geodesy confirms more and more to be a very important tool for studying the ongoing geodynamics, mainly for complex areas, such as the Mediterranean one, which is an active plate boundary zone.

Just for this purpose geodetic network of permanent stations, mainly GPS, in this area is continously densifying and an increasing number of sites is getting stable results in terms of absolute velocity.

In order to make a stronger solution, a combination of SLR and GPS geodetic solutions has been performed. Results show movements in fine agreement with geological models (DEVOTI et al., 2002b).

References

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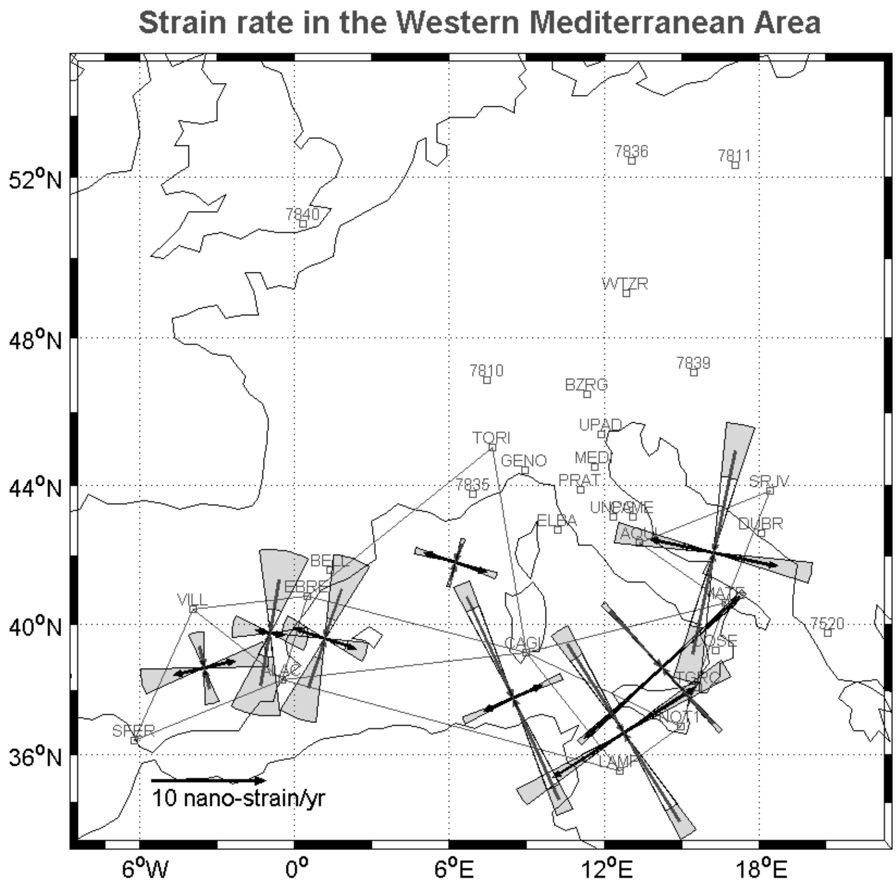

Fig. 5 Strain rate in the W-Mediterranean area

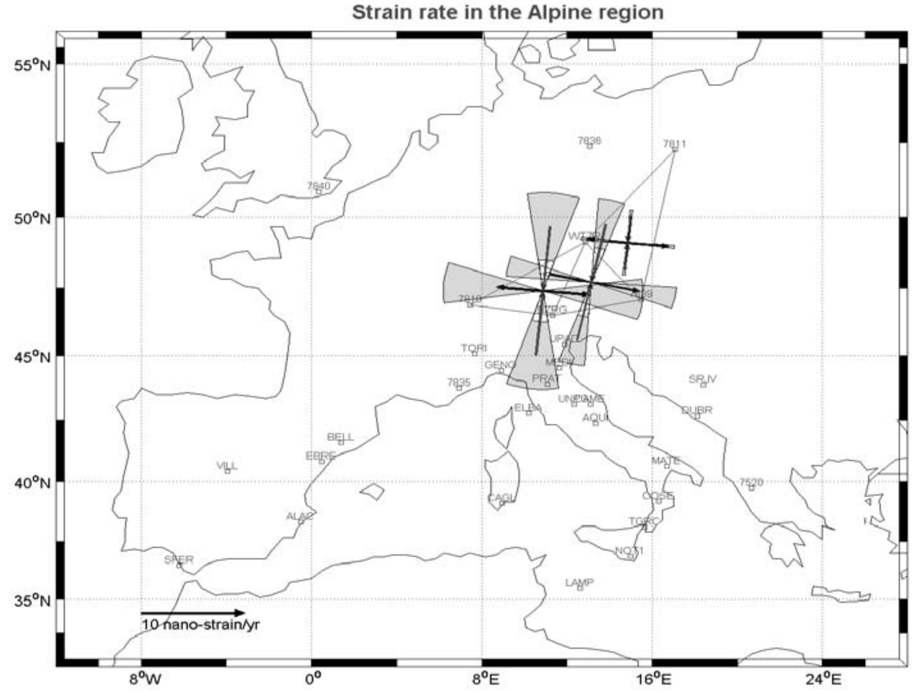

Fig. 6 Strain rate in the Alps region