AMIGO GPS measurements to investigate geodynamic processes along the western section of the Africa-Eurasia plate boundary zone

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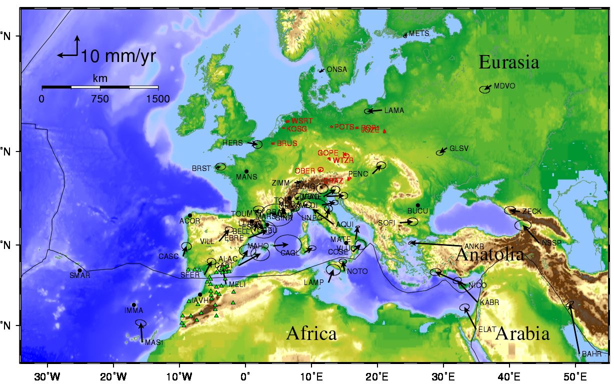
Introduction

The western section of the Africa-Eurasia plate boundary zone contains a unique transition from a well-defined oceanic-oceanic lithospheric boundary in the West (from the Azores triple junction on the Mid-Atlantic Ridge to approximately Gibraltar) to a rather diffuse continental-continental lithospheric boundary in the East (from Gibraltar to southern Italy). As a consequence of the convergence between the African and Eurasian plates in this region, mountains were built (e.g., the Betic-Rif Cordilleras, the Pyrenees, the Alps) and basins formed (e.g., the Alboran Sea, The Algero-Provencal and Tyrrhenian basins) by continental collision and associated compressional and extensional processes.

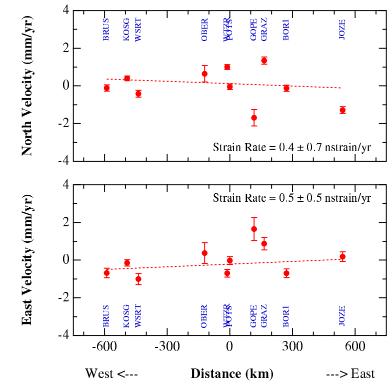
The AMIGO (Atlantic and Mediterranean Interdisciplinary Geophysical Observations) Project is a scientific collaboration among researchers involved in GPS (Global Positioning System) activities along the western section of the Africa-Eurasia plate boundary zone. An important objective of AMIGO is to use ongoing GPS measurements to constrain models for the geodynamic processes responsible for deformation in this region.

Geodetic Measurements of Africa-Eurasia Present-Day Deformations: Stability of Eurasia

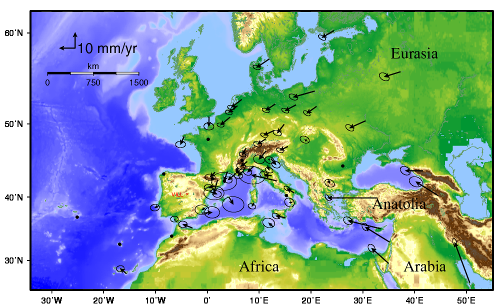


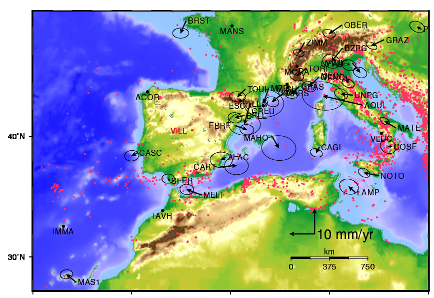
GPS determination of present-day crustal deformation (left) from between 1-3 years of permanent GPS data at several sites in Africa, Europe and the Middle East superimposed on a map colored by elevation. Estimates of horizontal velocities (arrows) and corresponding 95% confidence levels (error ellipses at the arrow tips) for these sites are shown relative to Eurasia. Symbols mark the location of permanent (black dots) and campaign (green triangles) GPS sites in this region that have not been operating long enough to produce accurate velocity estimates or have not been included in this combined solution yet. Plain lines are Nuvel-1 (*DeMets et al.*, 1990) plate boundaries.

We have realized the Eurasia fixed reference frame by estimating and subtracting from the velocity field that rigid rotation which minimized the residual velocities of the 10 sites (red) assumed to define a stable Eurasia plate. The right figure shows the north (top) and east (bottom) velocity estimates of these sites proyected onto an east-west profile centered at the position of POTS (Potsdam, Germany). (Uncertainties are 1-σ.) The components of horizontal velocity are all less than 2 mm/yr. We detect no deformation at the 2 mm/yr (weighted root-mean-square) level among these sites with 99% confidence. From the slope of the best fitting line through these estimates (red, dashed line) we can conclude that neither component reveals statistically significant strain accumulation rate at the 1 nstrain/yr level. The strain rate uncertainties were derived by scaling the formal errors by the square-root of the chi-square per degree of freedom of the linear fit.



Geodetic Measurements of Africa-Eurasia Present-Day Deformations: Regional Deformation





We measure significant deformation all along the Africa-Eurasia plate boundary zone. Relative to Eurasia, sites in the western and central Mediterranean roughly move north-northeast, and sites in the eastern Mediterranean move west-northwest. For example, relative to site POTS (Potsdam, Germany) in stable Eurasia, site SFER (San Fernando, Spain) in the western Mediterranean moves at ~8±3 mm/yr (~N28°E), site LAMP (Lampedusa, Italy) in central Mediterranean moves at ~7±4 mm/yr (~N21°E), and sites ANKR (Ankara, Turkey) and ELAT (Tel Aviv, Israel) in the eastern Mediterranean move at ~26±3 (N87°W) and 12±3 (N72°W), respectively. These velocities are generally consistent with the tectonic framework of the Mediterranean (see discussion of results), which is dominated by the collision of the Africa and Arabia plates with Eurasia (eg. *McKenzie*, 1970) and the westward displacement and counterclockwise rotation of the Anatolia plate (e.g. *Reilinger et al.*, 1997).

To visualize regional deformation, the top two figures show the GPS-derived velocity field relative to VILL (Villafranca, Spain; red) in the western Mediterranean. Sites located north and east of the Pyrenees and Alps (top left) show quite similar velocities relative to VILL, whereas stations in Iberia show no significant motion relative to VILL. The estimated velocity of stable Eurasia relative to VILL is ~6-8±3 mm/yr (~N135°-155°W). The components of horizontal velocity of stations within Iberia (top right) relative to VILL are less than 6 mm/yr. These sites exhibit no motion with respect to each other within the present resolution of our observations (4 mm/yr, weighted root-mean-square).

Discussion of Results

The estimated velocities in the central and eastern Mediterranean are in agreement with recent geodetic measurements obtained with GPS (e.g. *Reilinger et al.,* 1997) and VLBI (available via WWW at, e.g., URL: http://lupus.gsfc.nasa.gov/global/velocity.html). The velocities derived for the western Mediterranean, and in particular for Villafranca and San Fernando, the two sites in the Iberia peninsula with currently our most accurate velocity estimates, are also in agreement with GPS estimates by other authors (see, e.g., URL http://bowie.mit.edu/~fresh/) but are somewhat larger than those from VLBI. For example, VLBI reports no motion between stations Robledo (near Villafranca) and Wettzell, Germany, at the 0.6 mm/yr level (1-σ).

Little is presently known about the accomodation of present-day crustal deformation within this section of the Africa-Eurasia plate boundary and in particular of the Iberia peninsula. The seismicity extends over a wide area of more than a thousand kilometers that covers most of Iberia and the northern coast of Africa (near left). On the basis of simple examination of the velocity field, a substantial part of the motion of Iberia relative to Eurasia appears to happen as deformation in the Pyrenees mountains.

The global plate tectonic model NUVEL-1A (*DeMets et al.*, 1994) indicates that Africa is moving northwest (~N48°W) relative to Eurasia at a rate of ~4 mm/yr at 35°N, 3°W, the location of the GPS site MELI (Melilla, Spain) within the Rif mountain belt in northwest Africa. Our estimated velocity for this site, ~8±4 mm/yr (~N12°-26°W) is roughly consistent with NUVEL-1A. The current data are not yet sufficient to accurately determine the partioning of deformation along this diffuse boundary zone.

Conclusions

- We detect no deformation within (our definition of) stable Eurasia at the 2 mm/yr level with 99% confidence.
- We measure significant deformation along the Africa-Eurasia plate boundary zone. The pattern of deformation changes upon crossing different tectonics provinces. We find our velocity field to be generally consistent with other studies.
- In the western Mediterranean, the Iberia peninsula moves north-northeast (~N25°-45°E) relative to stable Eurasia at a rate of ~6-8±3 mm/yr.
- Sites within the Iberia peninsula seem to define a coherent block at the 4 mm/yr level.
- Future data will help us resolve the distribution of does deformation in this region providing new contraints on geodynamic processes.

Acknowledgments

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