The western section of the Africa-Eurasia plate boundary zone: GPS-derived deformation field

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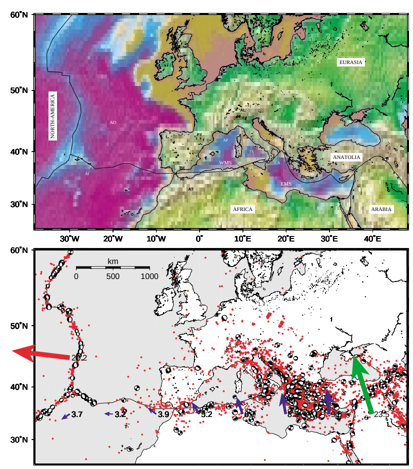
Tectonic Setting

The **Africa-Eurasia plate boundary** zone forms the western section of Alpine-Himalayan collisional belt. The present-day tectonics is dominated by ongoing north-northwestward direct push of the Africa plate against Eurasia. This complex region constitutes a distinct example of distributed deformation at a plate boundary and contains a variety of tectonic processes at various degrees of evolution. The western section of the Africa-Eurasia plate boundary marks the zone that runs from the Azores Islands on the mid-Atlantic ridge, through the Straits of Gibraltar, and into the western and central Mediterranean in southern Italy.

Significant **tectonic processes** in this section include continental collision (Atlas, Betic-Rif Cordilleras, Pyrenees, Alps), ocean subduction (Calabrian arc), basin formation (Alboran, Algero-Provencal, and Tyrrhenian basins), rifting (Azores, Straits of Sicily). Volcanism (e.g., Azores, Madeira, Eolian Islands or Vesuvius) and continuous low-to-moderate (M<5) seismicity, accompanied by a few high destructive earthquakes (e.g., Cape S. Vincente, Portugal, 1969, M=8; El-Asnam, Algeria, 1980, M=7.3), are also commonplace.

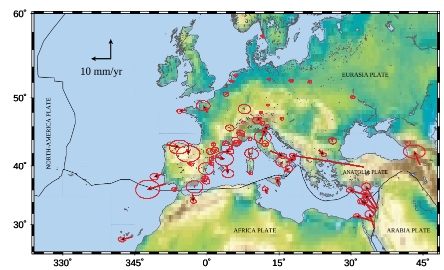
The Atlantic and Mediterranean Interdisciplinary GPS Observations (**AMIGO**; http://mat.fc.ul.pt/amigo/amigo.html) collaboration was formed to ascertain better the nature of this boundary using GPS measurements.



The Africa-Eurasia plate boundary zone. (top) Topography and bathymetry. The boundaries between major plates (whose names are indicated by lettering on white background) are marked by the thin back line. AO-Atlantic Ocean, AI-Azores Islands, AP-Algero Provencal Basin, AS-Alboran Sea, WMS-Western Mediterranean Sea, EMS-Eastern Mediterranean Sea, TS-Tyrrhenian Sea, GS-Gibraltar Strait, SR-Sicily Rift, AT-Atlas, PY-Pyrenees, AL-Alps, BE-Betic, RI-Rif Cordillera, AD-Adriatic Sea, AE-Aegean Sea, CA-Calabrian Arc. (bottom) Epicenters (red dots) from the USGS earthquake data base and focal mechanisms from the Harvard CMT catalog. Arrows indicate NUVEL-1A motions of Africa (blue), Arabia (green) and North-America (red) plates relative to Eurasia. Rates shown at the arrow base are in mm/yr.

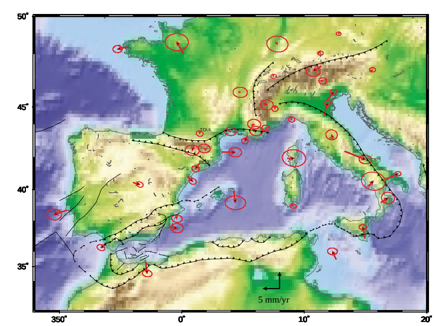
GPS Kinematic Field

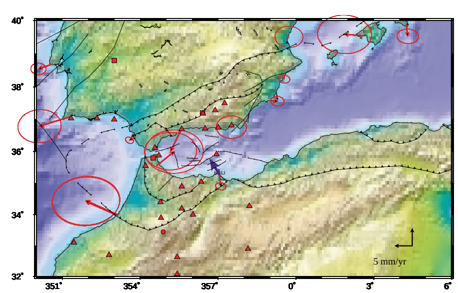
GPS determination of present-day crustal deformation from between1-3 years of permanent GPS data at several sites in Africa, Europe and the Middle East superimposed on a map colored by elevation. Estimates of horizontal velocities (arrows) and corresponding 95% confidence levels (error ellipses at the arrow tips) for these sites are shown relative to Eurasia.



Eurasia Reference Frame: 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 13 sites (blue) assumed to define a stable Eurasia plate. The deviations from zero velocity of the north and east components of velocity of these reference sites are all less than 2 and 1 mm/yr, respectively, and the rate weighted root-mean-square is 1.1 mm/yr. The estimated velocities in the eastern Mediterranean are in agreement with other recent geodetic measurements in that region.

Regional Deformation: Sites in the western section of the Africa-Eurasia plate boundary zone with 95% confidence rates (ellipses) of 3 mm/yr or less. At the level of resolution of our data (~2 mm/yr), there is little motion of the stations in Iberia relative to stable Eurasia. For example, the relative motion between stations immediately north and south of the Pyrenees mountains (TOUL and BELL) is 1.3±1.1 mm/yr (N131°E). On the other hand, the weighted mean of the north and east components of velocity of stations in the Iberia peninsula is -0.8 and 0.7 mm/yr, respectively. Their standard deviations are 0.6 and 1.9 mm/yr. Therefore, these sites seem to define a rather coherent block at the ~2 mm/yr.





Local Deformation: Sites in the Betic-Rif Cordilleras and Alboran Sea with 95% confidence rates (ellipses) of 8 mm/yr or less. Red symbols mark the location of permanent (squares and circles) and campaign (triangles) GPS stations in this region that have not been operating long enough to produce accurate velocity estimates and have not included in this solution yet. The blue arrow indicate NUVEL-1A motion relative to Eurasia at site MELI, on the southern shore of the Alboran Sea, which differs significantly from our GPS estimate of velocity at that site. Future data will help us resolve the distribution of deformation in this region and compare present-day geodetic estimates of relative motion and modeled values based on geological data.

Some Purely Kinematic Questions

- How rigid is Eurasia?
- Are present-day relative motions between Eurasia and Africa consistent with modeled motion for millions of years from geological data?
- Is deformation in this region confined to a narrow belt at the plate boundary or is it distributed over a broad zone spanning several faults and tectonic domains?
- If distributed, where does deformation accommodate and how is it partitioned?
- Do extension and compression processes still coexist in the Betic-Rif region and Alboran Sea?

... And Some Answers

- We detect no deformation within (our definition of) stable Eurasia at the 2 mm/yr (weighted root-mean-square) level with 99% confidence. This deformation (or lack thereof) reveals statistically insignificant strain accumulation rate at the 1 nanostrain/yr level.
- 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 Pyrenees mountains appear to not accomodate any significant deformation at the 2 mm/yr level.
- Sites within the Iberia peninsula seem to define a rather coherent block at the 2 mm/yr level.
- The GPS-derived velocity at site MELI, in the Alboran region, and the velocity implied by NUVEL-1A circuit closure differ significantly.

Acknowledgements

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