Active Tectonics of the western Mediterranean: Geodetic evidence for roll back of a delaminated subcontinental lithospheric slab beneath the Rif Mountains, Morocco

GPS Observations and Data Processing

We analyze the GPS data using the GAMIT/GLOBK software (Herring, 1999; King and Bock, 1999) in a two-step approach. In the first step, we use GPS phase observations from each day to estimate station coordinates, the zenith delay of the atmosphere at each station, and orbital and Earth orientation parameters (EOP). In the second step we use the loosely constrained estimates of station coordinates, orbits, and EOP and their covariance matrices from each day, aggregated by survey, as quasi-observations in a Kalman filter to estimate a consistent set of coordinates and velocities. We provide orbital control and tie the regional measurements to an external global reference frame by including in the regional analysis data from 3–5 continuously operating stations from the International GPS Service (IGS) network for each day. The regional quasi-observations are then combined with quasi-observations from an analysis of phase data from over 100 stations performed by the Scripps Orbital and Permanent Array Center (SOPAC) at the University of California, San Diego (Bock et al., 1997). Before estimating velocities in the second step of our analysis, we examine the time series of position estimates to determine the appropriate weights to be applied to each group’s surveys. For the velocity solution, we re-weight the quasi-observations such that the normalized long-term scatter in horizontal position for each group is unity. Finally, to account for correlated errors, we add to the assumed error in horizontal position a random walk component of 0.5 mm/√yr.
The GPS solution is realized in a global reference frame by estimating a 13-parameter transformation between our loosely constrained GPS analysis and the known ITRF2000 positions and velocities of 46 core IGS tracking stations. From this solution the velocities of 23 stations on Eurasia and 13 stations on Africa (Table 1) are used to estimate the Eurasian and African Euler vectors relative to ITRF2000 (Table 2). These Euler vectors are then used to rotate the GPS velocity solution (in ITRF2000) into Eurasian and African fixed frames (Table 1).

Table 1. GPS velocities in an Africa-fixed and Eurasia-fixed reference frame (as determined in this study), 1-sigma uncertainties (σ), and correlation between the east and north components of velocity (RHO). Sites used to estimate Euler vectors are identified as + = Nubia, # = Eurasia.
Table 2. GPS-Euler vectors and 1-sigma uncertainties for Eurasia (EU) relative to Nubia (NU) from this study (*) and selected other geodetic studies. MC= (McClusky et al., 2003), SE= (Sella et al., 2002)

<table>
<thead>
<tr>
<th>Plates</th>
<th>Lat. (deg)</th>
<th>Long. (deg)</th>
<th>Rate (deg/Myr)</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>*EU-NU</td>
<td>-4.43 ± 1.0</td>
<td>-20.7 ± 0.8</td>
<td>0.06 ± 0.001</td>
<td>This study</td>
</tr>
<tr>
<td>EU-NU</td>
<td>-0.95 ± 4.8</td>
<td>-21.8 ± 4.3</td>
<td>0.06 ± 0.005</td>
<td>MC</td>
</tr>
<tr>
<td>EU-NU</td>
<td>-18.23± 9.5</td>
<td>-20.01± 3.7</td>
<td>0.062±0.005</td>
<td>SE</td>
</tr>
</tbody>
</table>

References

Bock, Y., Behr, J., Fang, P., Dean, J., and R., L., 1997, Scripps Orbit and Permanent Array Center (SOPAC) and Southern California Permanent GPS Array (PGGA),


