Kinematics of the Suez-Sinai area from an updated combined GPS velocity field

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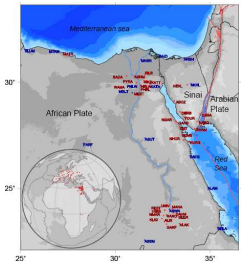
A combined GPS velocity solution covering a wide area from Egypt to Middle East allowed us to infer the current kinematics of the Suez-Sinai area, where the interaction of the African and Arabian plates is active.
We have estimated 126 velocities from time series of 90 permanent and 36 non permanent GPS sites located in Africa (Egypt), Eurasia and Arabia plates in the time span 1996–2015, the largest available for the Egyptian sites. We have combined our velocity solution in a least-squares sense with two other recent velocity solutions of networks located around the eastern Mediterranean, obtaining a final IGb08 velocity field of about 450 sites.
We have estimated the IGb08 Euler poles of Africa, Sinai and Arabia, and focused on the kinematics of the Sinai area, estimating the 2D strain rate field and examining particular velocity profiles.
We show that it is possible to reliably model the rigid motion of Sinai block only including some GPS sites located south of the Carmel Fault. The estimated relative motion with respect to Africa is of the order of 2–3 mm/yr, however there is a clear mismatch between the modeled and the observed velocities in the southern Sinai sites.
We have also assessed the NNE left shear motion along the Dead Sea Transform Fault, estimating a relative motion between Arabia and Africa of about 6 mm/yr in the direction of the Red Sea opening.

Data processing

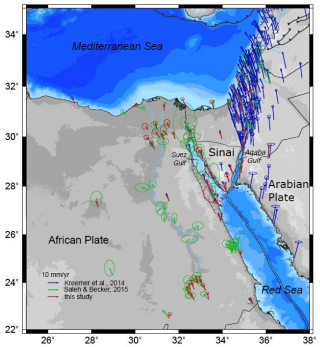
The National Research Institute for Astronomy and Geophysics (NRIAG) established different GPS networks around active areas in Egypt, starting in 1996 and in 2006 started the construction of a permanent GPS network in Egypt (EPGN – Egyptian Permanent GPS Network), consisting at present of 16 stations.

We have homogeneously reprocessed by the Bernese software GPS data of 16 permanent and 36 non permanent sites in Egypt in the time span 1996-2015 (campaigns cover the interval 1996-2005, while continuous sites span from 2006 to 2015); we have included in the processing IGS sites in the surrounding regions and some other permanent stations archived by SOPAC and UNAVCO, for a total amount of 126 sites.



Permanent (blue) and non permanent (red) GPS sites processed by Bernese software

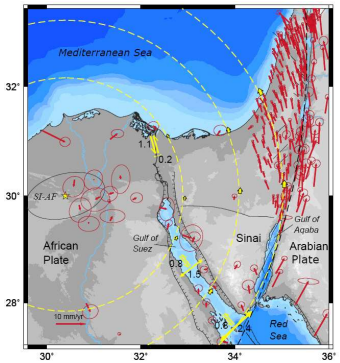
We have combined our IGb08 (IGS realization of the ITRF2008) velocity solution with the solution of Saleh and Becker (2015) and with a velocity subset of the global solution published by Kreemer et al. (2014), obtaining a final IGb08 velocity field of 457 sites in our study area.



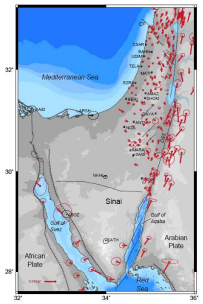
Different velocity solutions with respect to Eurasia fixed frame (Altamimi et al., 2012)

The velocity combination procedure consists of a linear least-squares approach. We consider each velocity field as a sample of the true velocity field and the combined velocity as the best estimate of the true velocity field.
The combined product allows a validation of the velocity field in which the velocity repeatability can be assessed and also represents the solution that reduces to a minimum the chance of including biased velocities.
The normal matrix is formed from the 3 independent velocity solutions, and then it is inverted to estimate the unified velocity field of the entire network. As the covariance matrix is usually known apart from a constant multiplier, and in order to balance the relative weights of the input solutions, the combination is iterated 2 times in order to estimate a solution weighting factor based on each solution χ^2.

Results



1 - Combined velocity field with respect to Africa
Yellow star and arrows tangent to yellow dashed circles indicate the rotation pole and the rigid motion of Sinai block with respect to Africa; yellow symbols along Gulf of Suez indicate predicted extension and shear (values in mm/yr). Black dashed circular line represents the rigid motion of Arabia with respect to Africa



2 - Residual velocities with respect to Sinai Euler pole; *in black, sites selected for pole estimation*

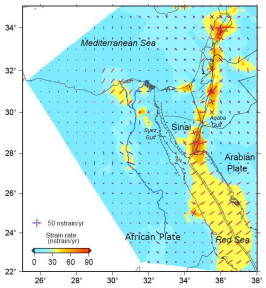
The rigid plate model for Sinai
- predicts that Gulf of Suez is undergoing to a decreasing extension from S (2.4 ± 0.3) mm/yr to N (0.2 ± 0.3) mm/yr
- predicts a nearly constant, left-lateral strike-slip movement of about 1 mm/yr along the Gulf of Suez block margin
- does not fit velocities of Sinai sites (all non permanent) located along Suez and Aqaba Gulfs (residuals of 2-3 mm/yr), evidencing the weakness of the model near the triple junction

The *Carmel Fault System* (CF) represents the boundary of Sinai block along its NE corner.

The *Dead Sea Transform* (DST) lies just along the great circle representing the rigid motion of Arabia with respect to Africa, from the triple junction south of the Sinai tip to the north of Dead Sea.

	ω_X (°/Myr)	ω_Y (°/Myr)	ω_Z (°/Myr)	Lat (°)	Lon (°)	ω (°/Myr)
Africa	0.0389	-0.1654	0.2098	51.0	-76.8	0.270 ± 0.004
Sinai	0.2726	-0.0285	0.3661	53.2	-6.0	0.457 ± 0.023
Arabia	0.3186	-0.0532	0.3972	50.9	-9.5	0.512 ± 0.008

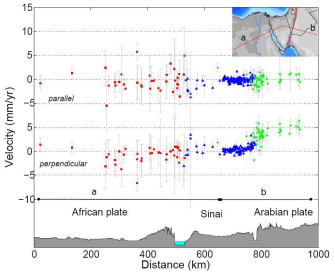
Euler pole parameters (IGb08)
Sinai pole estimation includes some Israeli sites since Sinai site velocities are poorly constrained and/or influenced by boundary deformations



3 - Strain rate interpolated on a regular grid *(Shen et al., 1996); principal axes and total strain rate*

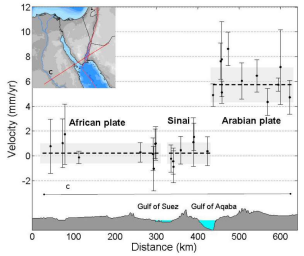
Extension rate of 40-50·10^{-9}yr^{-1} is reached in the Red Sea, orthogonal to the direction of Red Sea opening, and in the region of the Nile delta.

Along the DST shear rate prevails, maximum values of total strain rate are reached in this area, up to 90·10^{-9}yr^{-1}.



4 - Velocity profiles (a, b) crossing and being orthogonal to the Gulf of Suez and to the DST respectively

Comparison between the parallel and perpendicular components (profiles ***a***, ***b***) evidences the extension vs shear motion components
- parallel component shows negligible extension rate across Gulf of Suez, confirming the misfit between the observed and the predicted velocities in the southern part of Sinai
- perpendicular component shows evidence of the shear rate along the DST, its trend is in agreement with a model of elastic loading on a locked dislocation that accommodates pure left-lateral shear at depth (e.g. Savage and Burford, 1973)



5 - Velocity profile (c) crossing Sinai from Africa to Arabia, parallel to the Red Sea opening direction

Velocities projection along profile ***c*** evidences that in this area the motion between Sinai and Africa appears insignificant, as we are considering the tip of Sinai where sites are not representative of the rigid block motion.
Highly active is the separation between Arabia and Sinai-Africa with a relative motion of about 6 mm/yr.

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