1. Introduction

Our research is concerned with the establishment of links between deep mantle processes and surface deformation. Our main focus is on the instantaneous mantle dynamics of the European-Mediterranean region and its surface responses. Here we have constructed instantaneous 3-D dynamic models of the Western Mediterranean region with focus on subduction below the Betic-Rif-Alboran region. For the subducted slab in this region we have assumed an age of Jurassic/Early-Cretaceous of the oceanic lithosphere. We include the convergence of African and Eurasian plates.

Research questions: What is causing observed surface deformation (GPS motions, major fault activity) of the Betic-Alboran-Rif region? Can this be explained by crustal forcing only, or is coupling of the crust with the lithosphere slab important?

Here we present preliminary 3D instantaneous models of the region using an oversimplified geometry. Model complexities such as crust-lithosphere structure and rheology, more complex fault systems, will be added in due time.

1) This research is part of the EUROCORES TOP-EUROPE, particularly of project TOPO-4D.

2. Model description

We have modeled the instantaneous mantle flow, using the finite element code Sepran. The governing equations for a viscous flow of an incompressible fluid are as below:

\[ \nabla \cdot \mathbf{u} = 0 \]

\[ -\nabla P + \eta \nabla^2 \mathbf{u} = \rho \alpha T \mathbf{c}_T \]

Parameter values

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unit</th>
<th>Dimension</th>
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<tbody>
<tr>
<td>( \rho )</td>
<td>gPa</td>
<td>m^3 s^{-1}</td>
</tr>
<tr>
<td>( \eta )</td>
<td>Pa s</td>
<td></td>
</tr>
<tr>
<td>( \alpha )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \mathbf{c}_T )</td>
<td>m/s</td>
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The top and bottom surfaces of the models are free slip while all side surfaces are open (Chertova et al. 2012; see her poster). The resolution at the surface is 10 km.

4. Model setup

Temperature

Oceanic and continental lithosphere are distinguished through different temperature profiles

Plate Boundary and prescribed relative plate motion

Plate boundary is modeled as a region with lower viscosity which is displayed in this figure. Prescribed relative plate motion of Europe in an Africa fixed system is also presented.

In the figure below four cross sections of temperature structures are displayed. The cross sections are at latitude 33 (a), 34.5(b), 36 (c) and 36.5(d). In this research the slab is assumed to be of oceanic lithosphere.

A 3D view of the slab is presented in the figure below.

5. Results

We only have preliminary results from proof-of-concept tests of the general model geometry, boundary conditions, viscosity fields, etc. Here we show a few test examples for a slab geometry directly derived from tomography illustrating dependence of the flow field rheological choices. The flow field which is displayed below is for a model where viscosity of lithosphere and slab are 10^{20} Pa s and viscosity of the mantle is 10^{10} Pa s. The plate boundary is modeled as a region with 10^9 Pa s viscosity.

The computed flow field, varies dramatically with the chosen viscosity. In the pictures below the flow field for a model with less viscosity contrast between slab and the rest of the mantle is displayed. Where viscosity of lithosphere and slab is 10^{10} Pa s and viscosity of mantle is 10^{12} Pa s. Plate boundary is modeled as a region with 10^9 Pa s viscosity. Here subduction of the slab produces a dominant motion in the region.

3. The importance:

The importance for us to study this region is to find the link between the lithosphere slab at depth and the present-day surface deformation. Historical earthquakes and tsunamis like the great earthquake of Lisbon at 1755 have been associated to this dynamic setting (Gutscher 2004).

Plates convergence and motion of Betic-Rif

GPS survey observations reveals NW-SE convergence within the Mediterranean (which is 4.5 ± 1 mm yr^{-1} near Gibraltar (McClusky et al. 2003)) and a roughly southward motion (3 mm/yr) of the Rif Mountains relative to Africa. This motion is reported to be approximately normal to the direction of Africa-Eurasia relative motion which results in shortening of the Rif and crustal extension of the Alboran Sea region (Vernant et al. 2010).

Africa-Iberia Plate boundary

The Africa-Iberia plate boundary is diffuse and indistinct. This diffusive deformation is distributed over a broad area from the Betic in the north to the Atlas mountains in the south and extends to the west until Gloria fault (Calvert et al. 2000). Therefore several plate boundaries have been suggested. In this study we use the assumption suggested by Gutscher 2004 which is more compatible with the fault systems observed in the region.

Subduction and slab detachment

Seismic tomography has revealed an east-dipping positive wave-speed anomaly under the region interpreted as subducted lithosphere and created by westward rollback (Gutscher et al. 2002, Spakman and Wortel, 2004). The cartoon displays the overall geometry of the slab, which seems only attached to the surface beneath the Gibraltar arc and detached under the Betic region (Spakman and Wortel, 2004).

4.5 mm/yr Plate Boundary and prescribed relative plate motion of Europe in an Africa fixed system is also presented below.

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82 (2000)

8(2000)


4.5 mm/yr Plate Boundary and prescribed relative plate motion of Europe in an Africa fixed system is also presented below.

6. Conclusion

We aim at modeling the present-day dynamic state of the Betic-Alboran-Rif region. Our particular target is the coupling between the lithosphere slab underlying the region and crustal deformation.

We only have very preliminary results, which do not warrant drawing any conclusions, apart from the fact that our model set-up, boundary conditions, etc., is in place and working. We will pursue with a systematic search for model parameters/properties that determine the coupling of deep processes with the local crustal deformation.

References

[6] Plates convergence and motion of Betic-Rif

In the following text, please include the following references:


McClusky, S., Reilinger, R., Mahmoud, S., Ben Sari, D., Tealeb, A., 2000. GPS constraints on Africa (Nubia) and Arabia plates convergence and motion of Betic-Rif.


McCloskey, S., Reilinger, R., Mahomed, S., Ben Sari, D., Tealeb, A., 2002. GPS constraints on Africa (Nubia) and Arabia plates convergence and motion of Betic-Rif.