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# Instantaneous mantle dynamics of the Western Mediterranean region

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## 1.Introduction

Our research[1] 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 dynamics 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 TOPO-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:

$$\nabla \cdot \vec{u} = 0 \qquad -\nabla \Delta P + \eta \nabla^2 u = RaTe_z$$

**Parameter values**

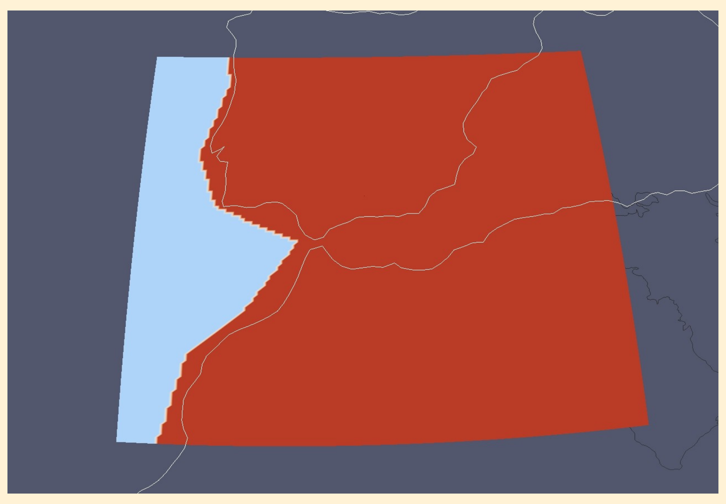
| Symbol | Parameter | Value | Dimension |
|---|---|---|---|
| $u$ | Convective flow velocity | - | $ms^{-1}$ |
| $\Delta P$ | Dynamic pressure | - | $Pa$ |
| $T$ | Temperature | - | $K$ |
| $\eta$ | Viscosity | - | $Pas$ |
| $Ra = \frac{\rho_0 \alpha g \Delta T h^3}{\kappa \eta_0}$ | Rayleigh number | - | - |
| $\eta_0$ | Viscosity scale | $10^{21}$ | $Pas$ |
| $h_0$ | Model depth | 660 | $km$ |
| $\kappa$ | Thermal diffusivity | $10^{-6}$ | $m^2s^{-1}$ |
| $g_0$ | Reference ground acceleration | 10 | $ms^{-2}$ |
| $\alpha$ | Thermal expansion coefficient | $3 \times 10^{-5}$ | $K^{-1}$ |
| $\Delta T$ | Vertical temperature contrast across model domain | 1300 | $K$ |
| $\rho_0$ | Mantle density | 4400 | $kgm^{-3}$ |

The top and bottom surfaces of the model are free slip while all side surfaces are open(Chertova et al. 2012; see her poster). The resolution at the surface is 10 km.

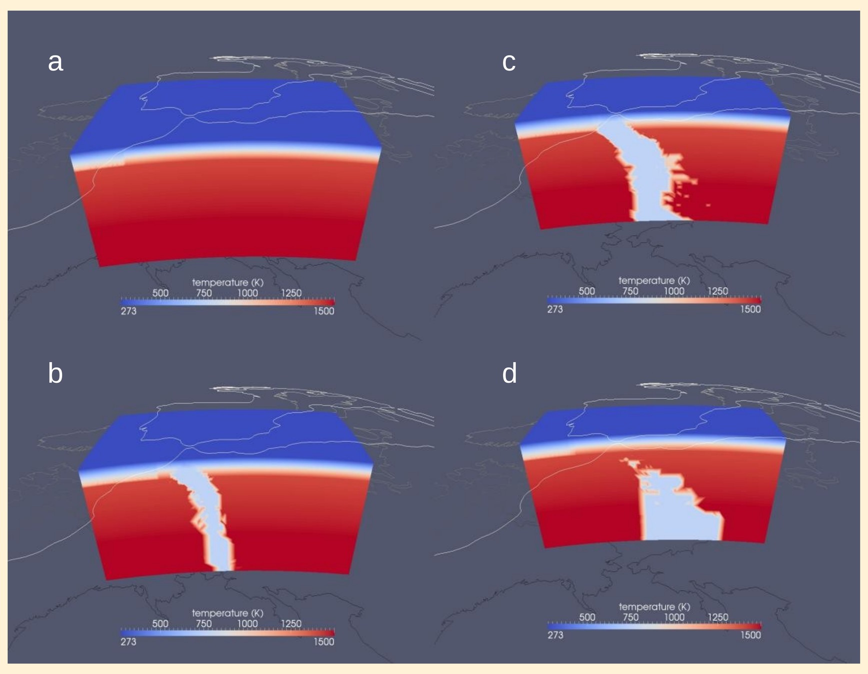
## 4. Model setup

### Temperature

Oceanic and continental lithosphere are distinguished through different temperature profiles

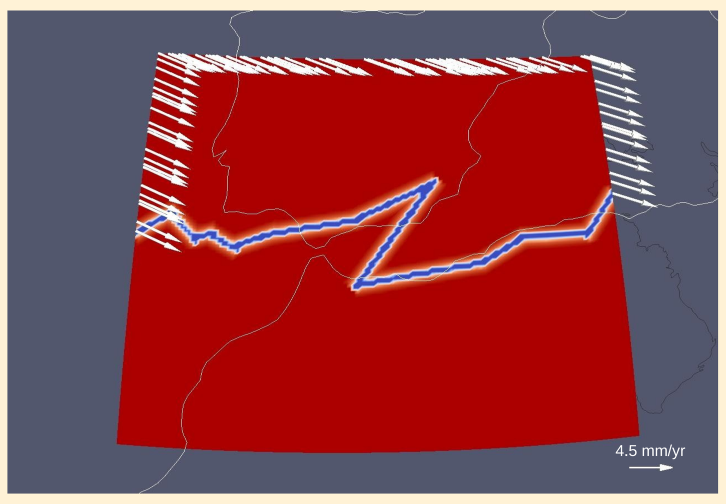


In the figure below four cross sections of temperature structures are displayed. The cross sections are at latitude 33 (a), 34.5(b), 36 (c) and 36.5(d). In this research the slab is assumed to be of oceanic lithosphere.

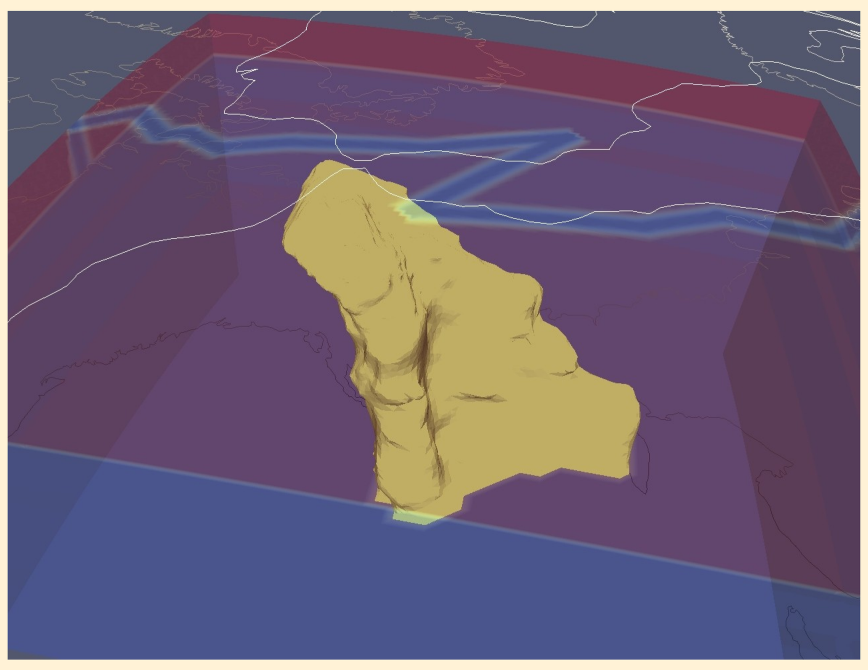



### Plate Boundary and prescribed relative plate motion

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 below.




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



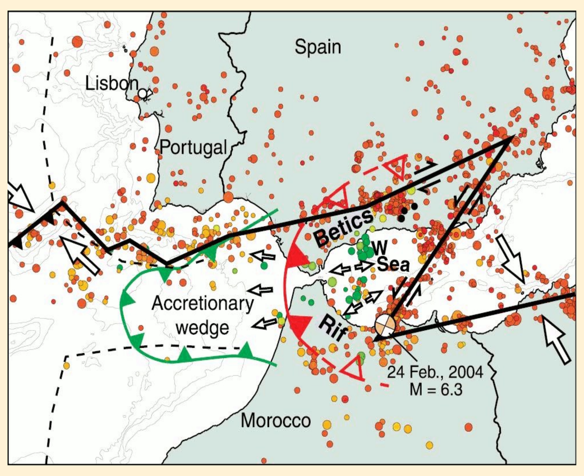
## 3. The importance:

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 (Gutcher 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(Mc Cluscky *et al*. 2003)) and a roughly southward motion (3mm/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)

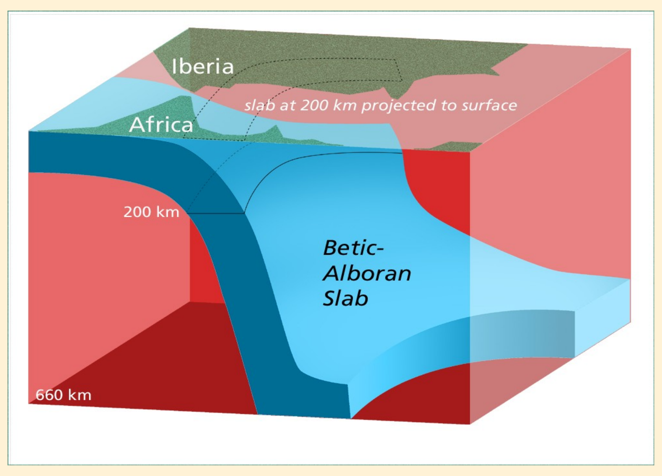
### Africa-Ibera Plate boundary




The Africa-Iberia plate boundary is diffuse and indistinct. This diffusive deformation is distributed over a broad area from the Betics 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.

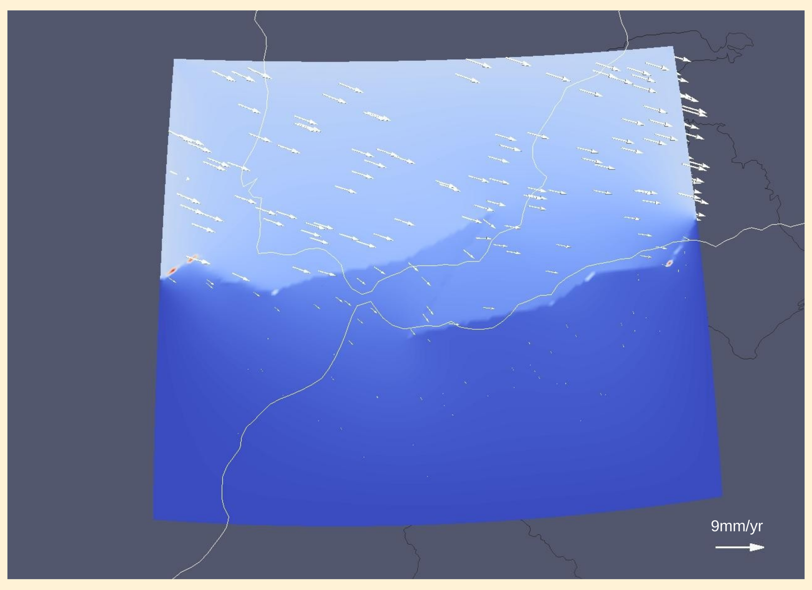
### Subduction and slab detachment

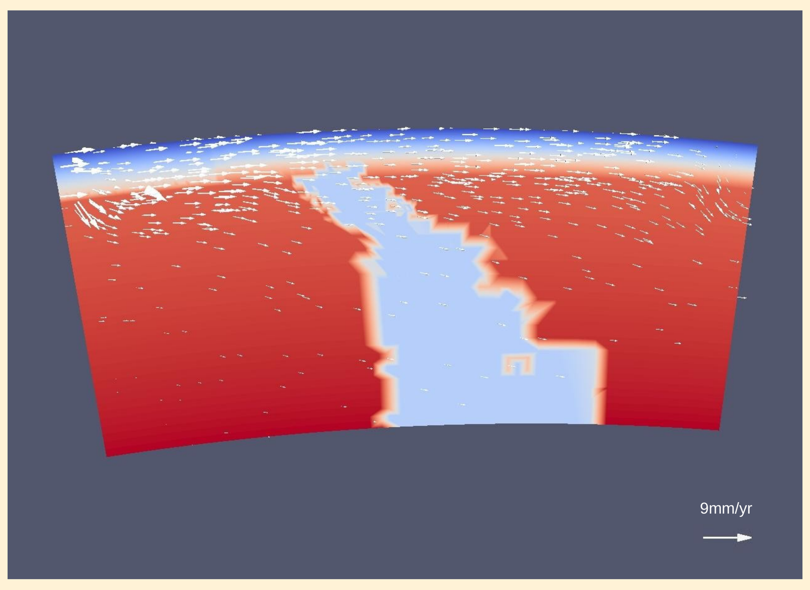
Seismic tomography has revealed an east-dipping positive wave-speed anomaly under the region interpreted as subducted lithosphere and created by westward rollback (Gutscher *et al*. 2002, Spakman and Wortel, 2004). The cartoon displays the overall geometry of the slab, which seems only attached to the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



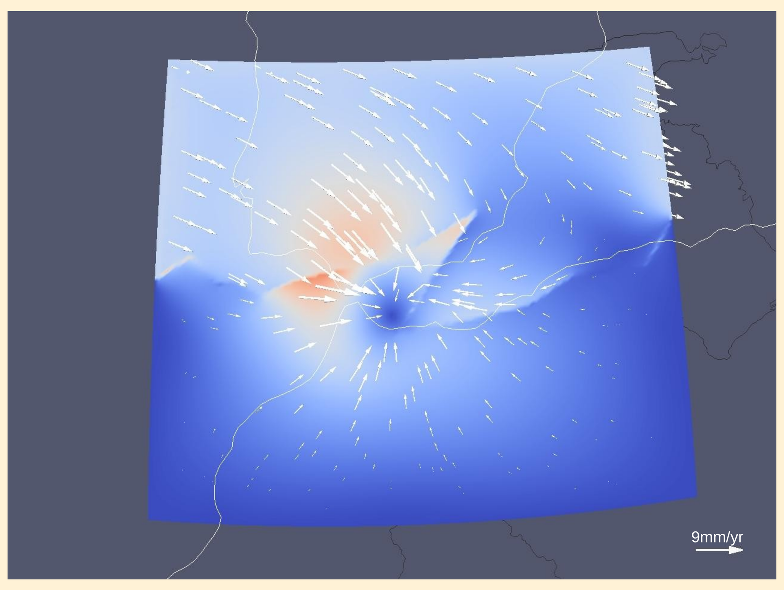

## 5. Results

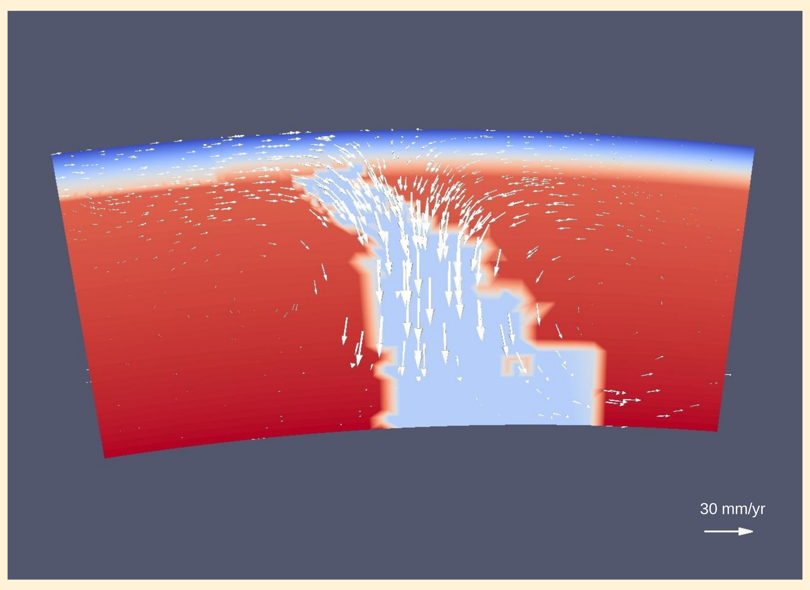
We only have preliminary results from proof-of-concept tests of the general model geometry, boundary conditions, viscosity fields, etc. Here we show a few test examples for a slab geometry directly derived from tomography illustrating dependence of the flow field rheological choices. The flow field which is displayed below is for a model where viscosity of lithosphere and slab are $10^{23}$ *Pa s* and viscosity of the mantle is $10^{21}$ *Pa s*. The plate boundary is modeled as a region with $10^{19}$ *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 $10^{21}$ *Pa s* and viscosity of mantle is $10^{20}$ *Pa s*. Plate boundary is modeled as a region with $10^{18}$ *Pa s* viscosity. Here subduction of the slab produces a dominant motion in the region.




## 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

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