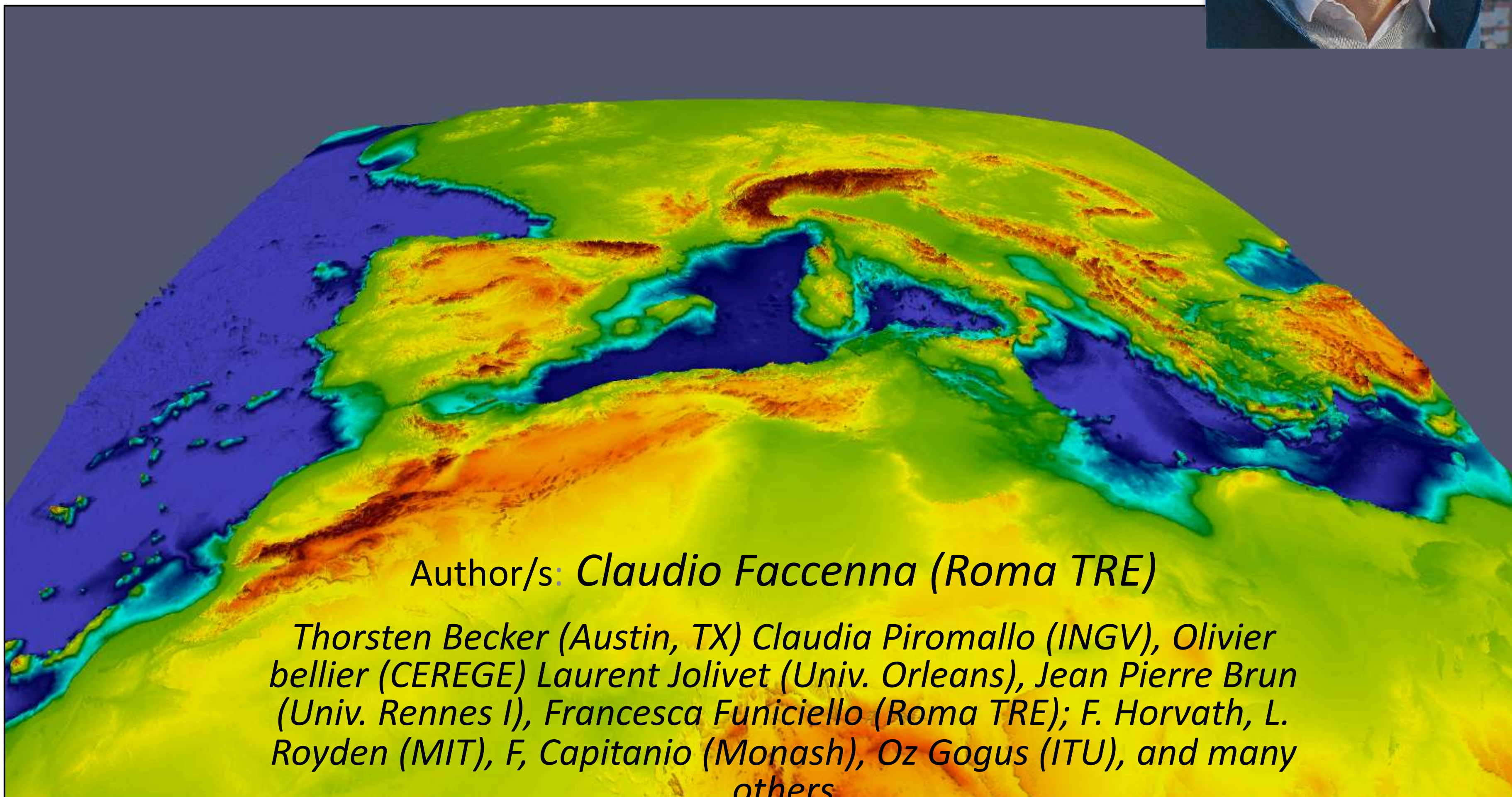
Berlin, january 2019

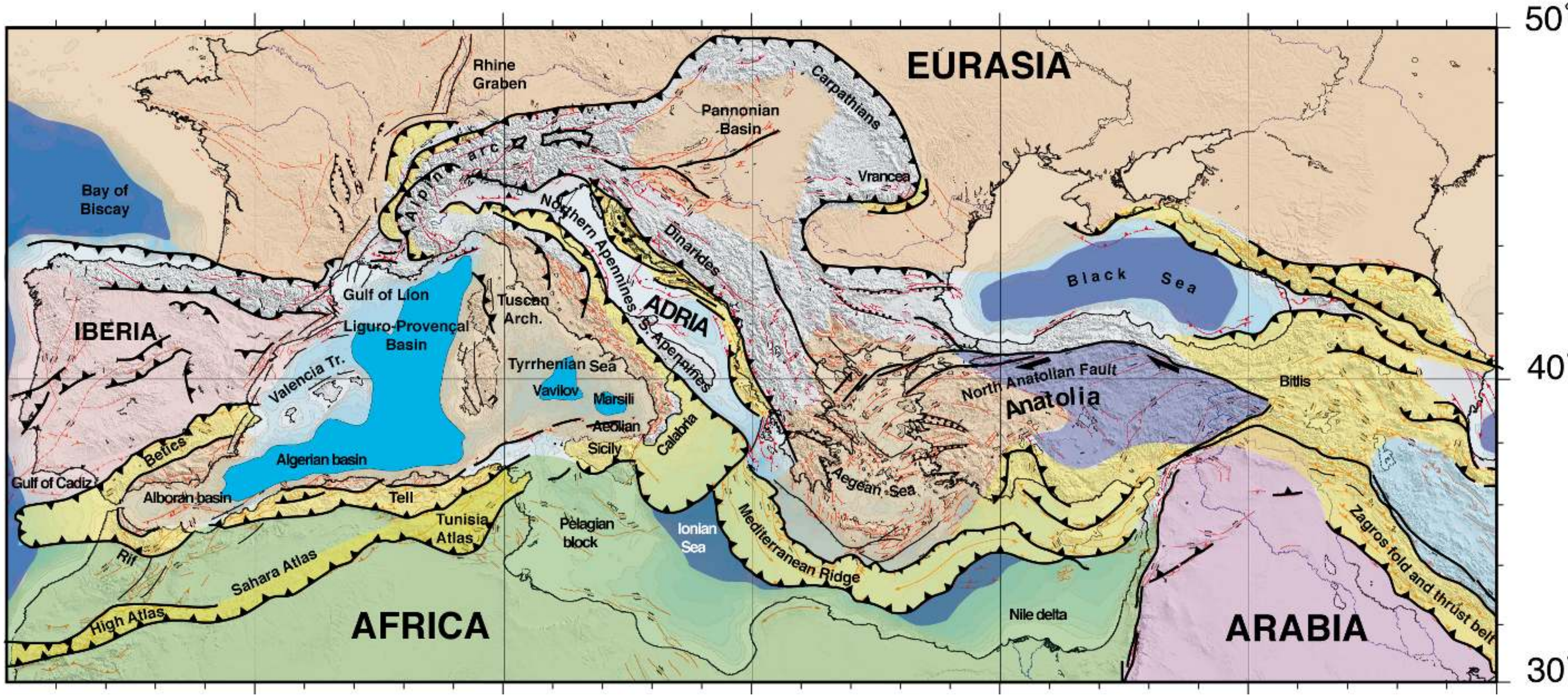
Mantle dynamics in the Mediterranean



Author/s: *Claudio Faccenna (Roma TRE)*

Thorsten Becker (Austin, TX) Claudia Piromallo (INGV), Olivier bellier (CEREGE) Laurent Jolivet (Univ. Orleans), Jean Pierre Brun (Univ. Rennes I), Francesca Funiciello (Roma TRE); F. Horvath, L. Royden (MIT), F, Capitanio (Monash), Oz Gogus (ITU), and many others

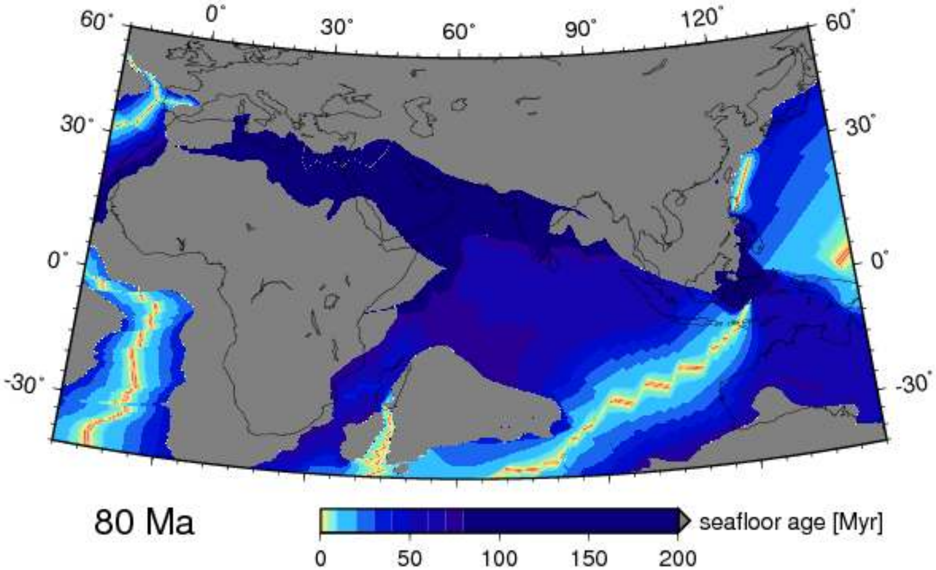
THE MEDITERRANEAN TECTONICS PUZZLE



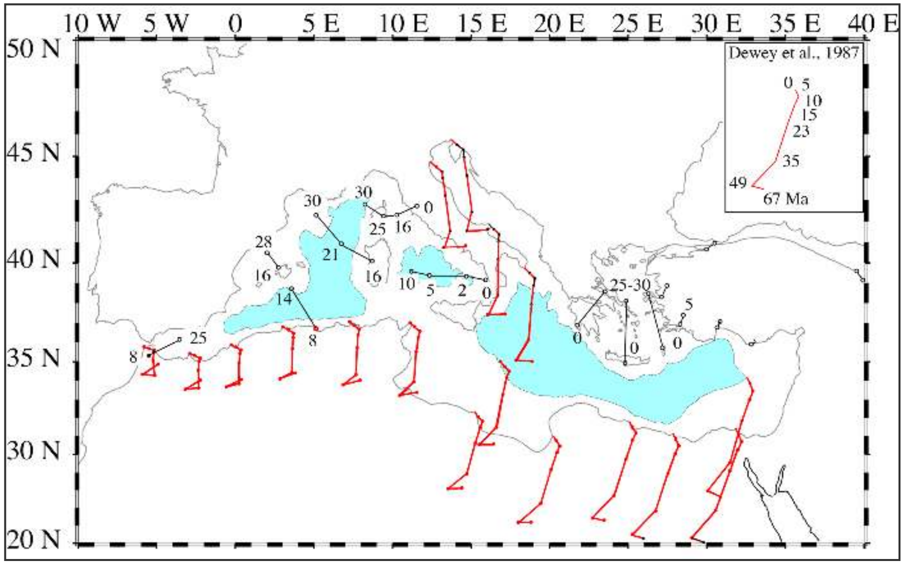
We will revise tectonic, geodetic, seismic data and model to show that the complexity of deformation may be explained by a relatively simple pattern of mantle convection

AFRICA, ARABIA AND INDIA KINEMATICS

- AF/EU convergence velocity



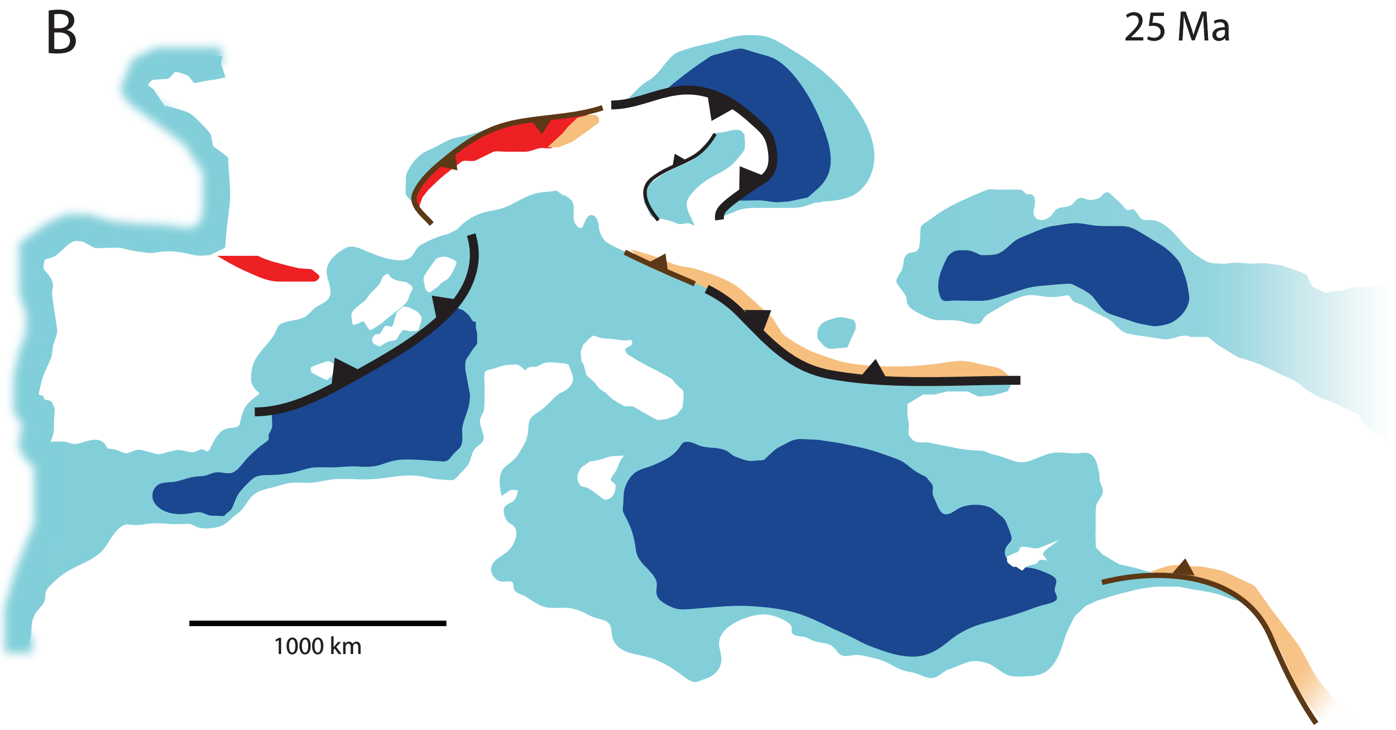
Müller et al., 2008; Torsvik et al., 2008



……a slow convergence

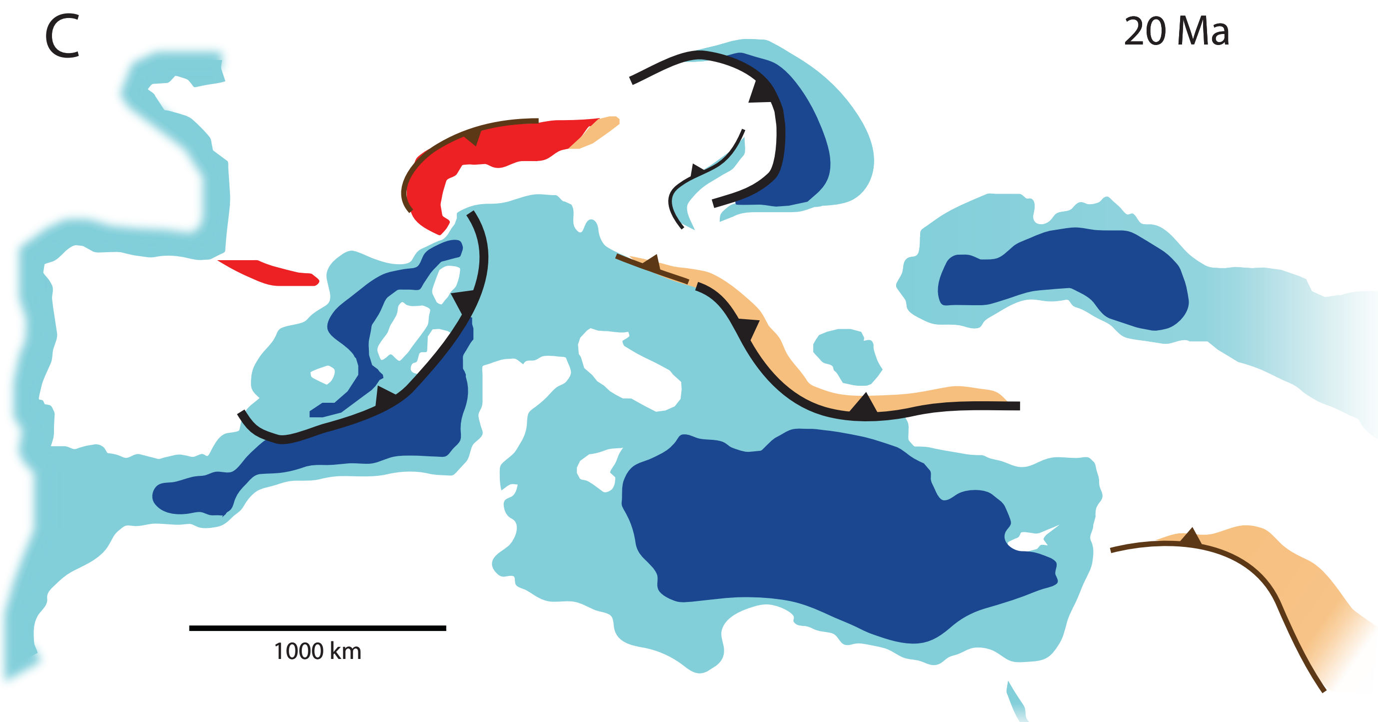
EVOLUTION OF THE MEDITERRANEAN

Leigh Royden



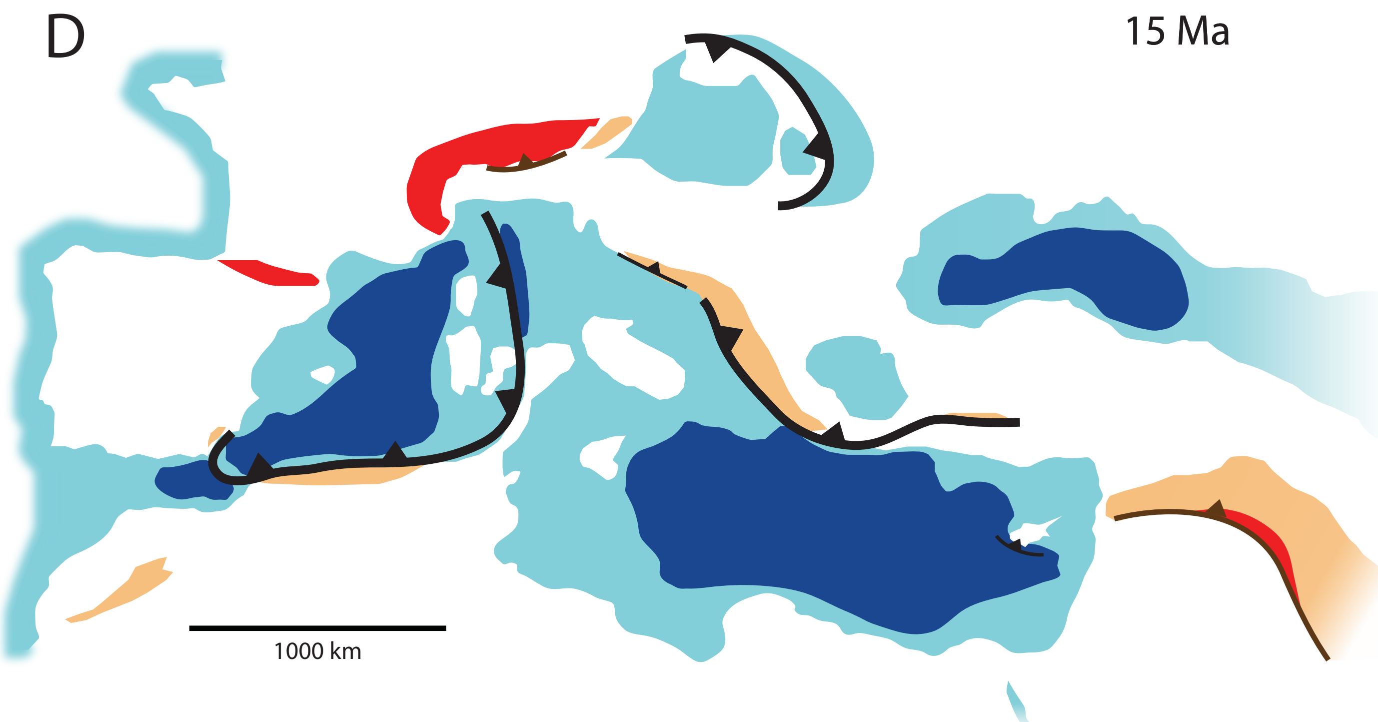
Royden and Faccenna, 2018

EVOLUTION OF THE MEDITERRANEAN



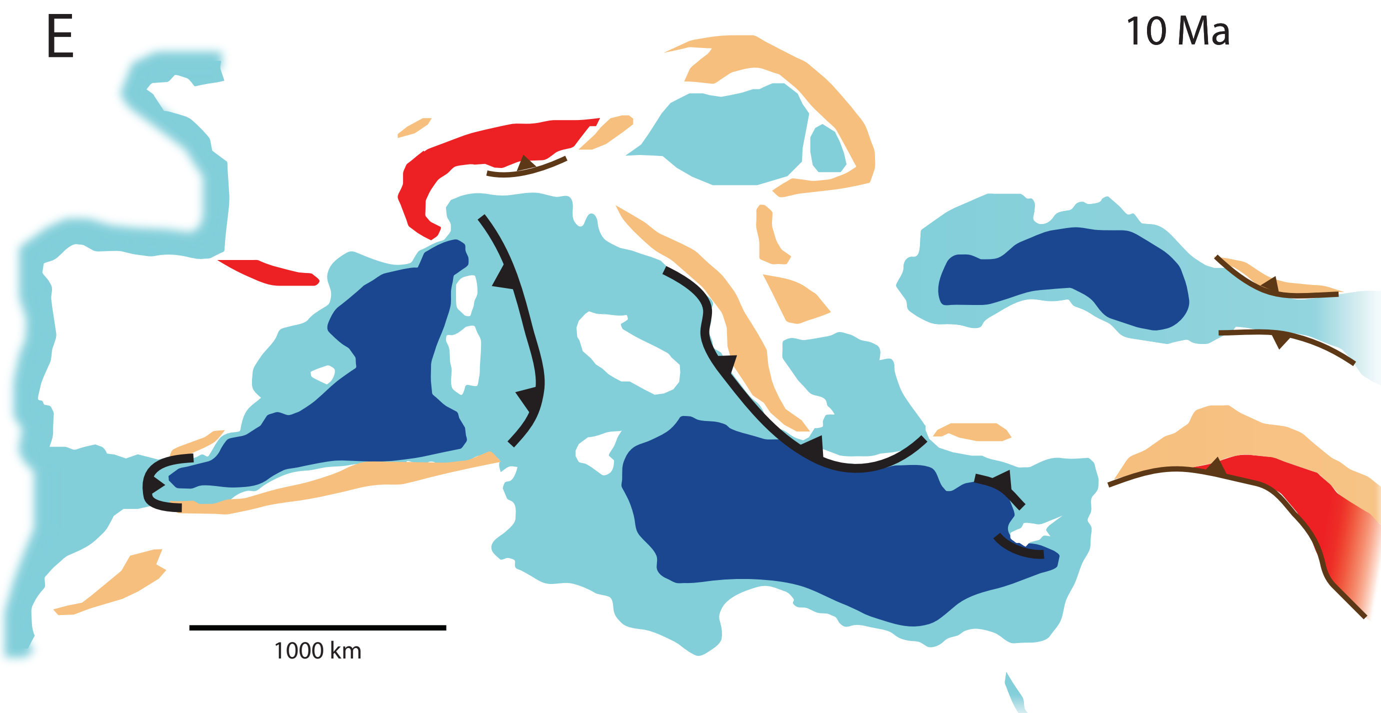
Royden and Faccenna, 2018

EVOLUTION OF THE MEDITERRANEAN



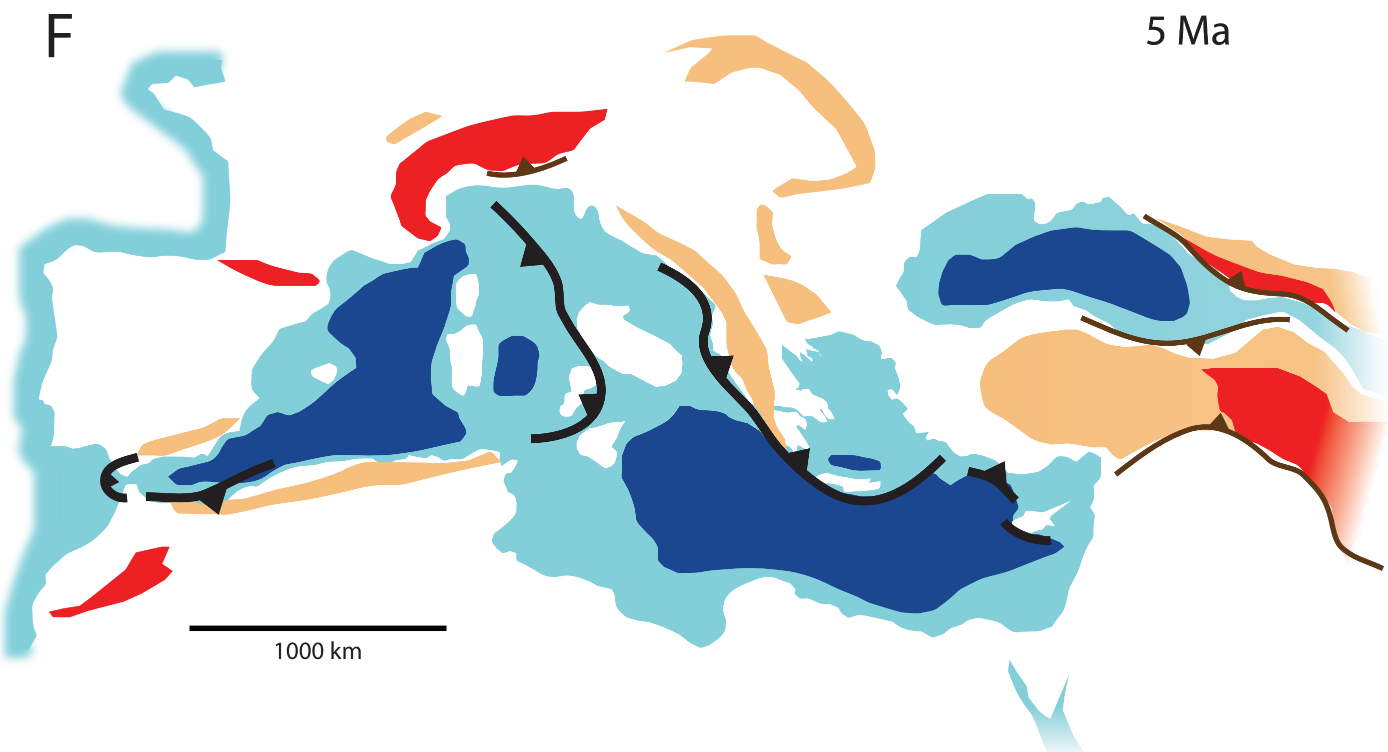
Royden and Faccenna, 2018

EVOLUTION OF THE MEDITERRANEAN



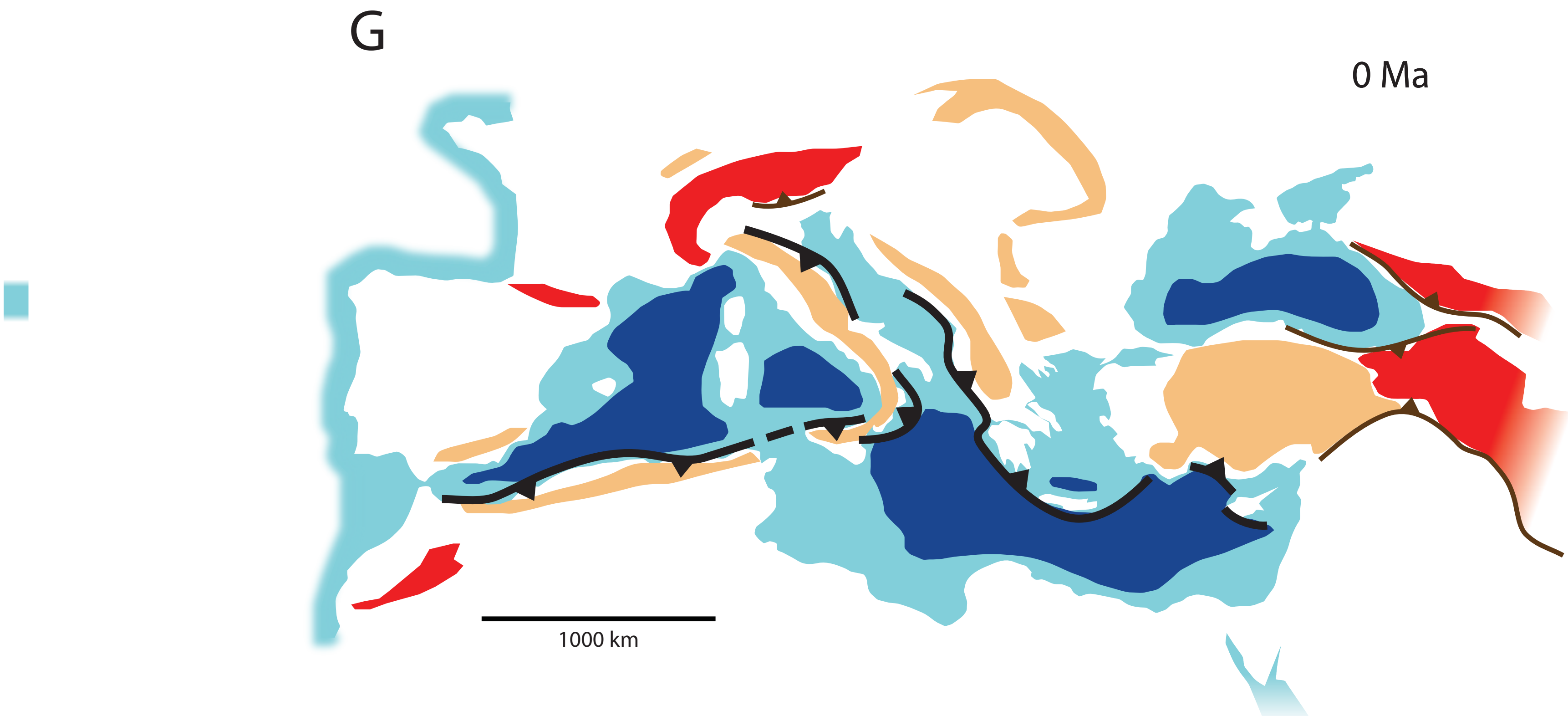
Royden and Faccenna, 2018

EVOLUTION OF THE MEDITERRANEAN



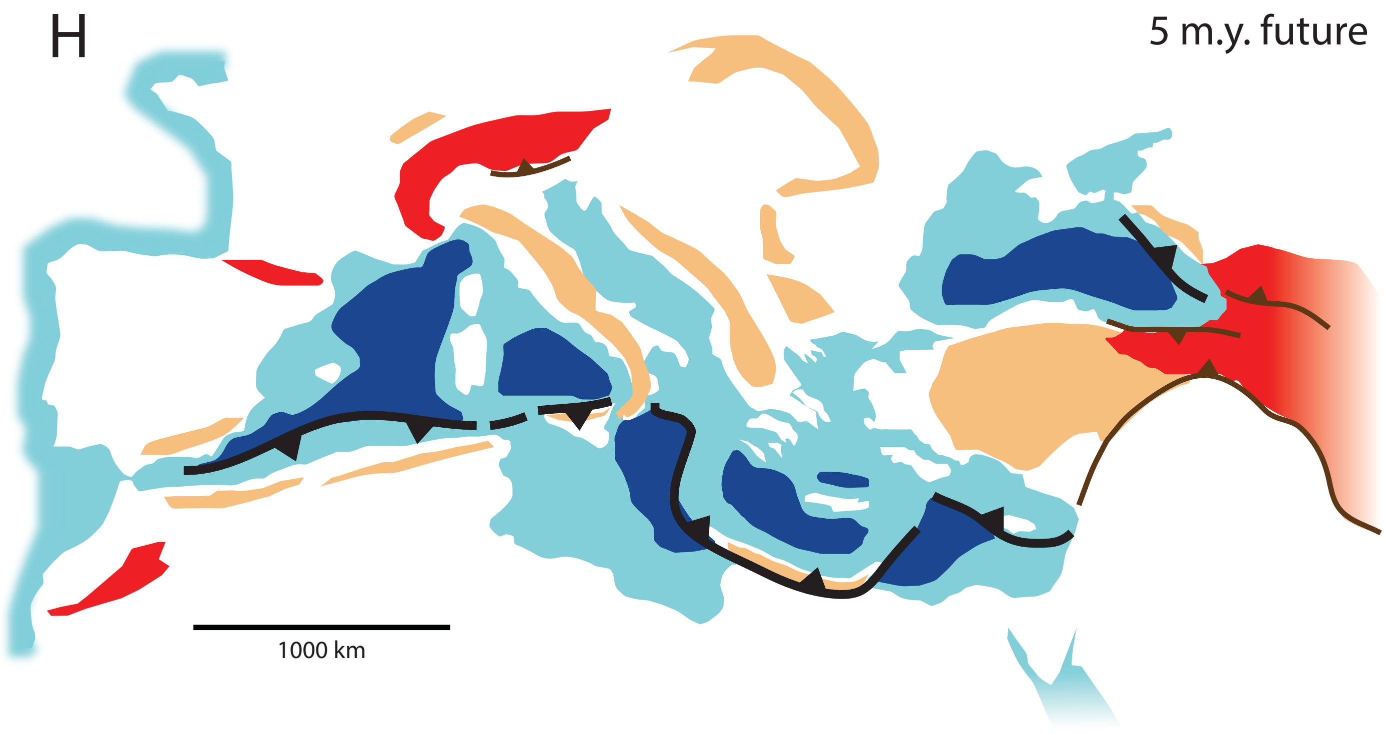
Royden and Faccenna, 2018

EVOLUTION OF THE MEDITERRANEAN



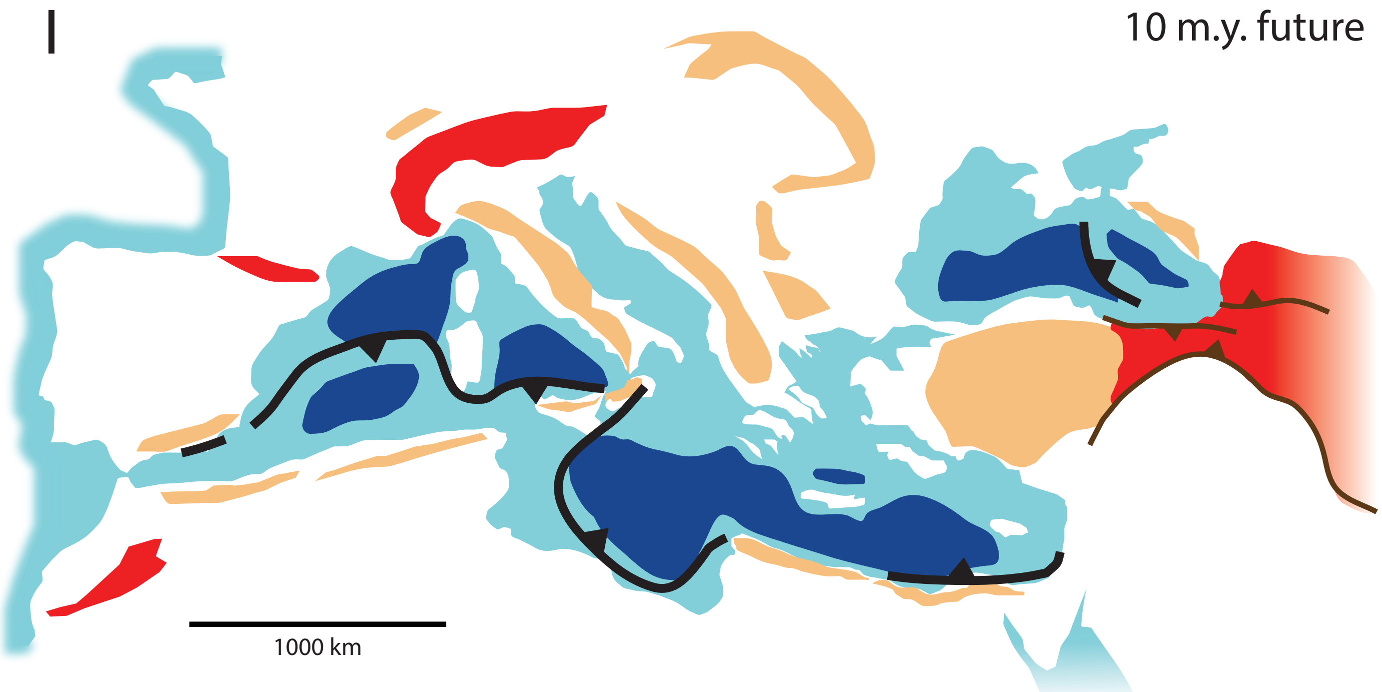
Royden and Faccenna, 2018

EVOLUTION OF THE MEDITERRANEAN



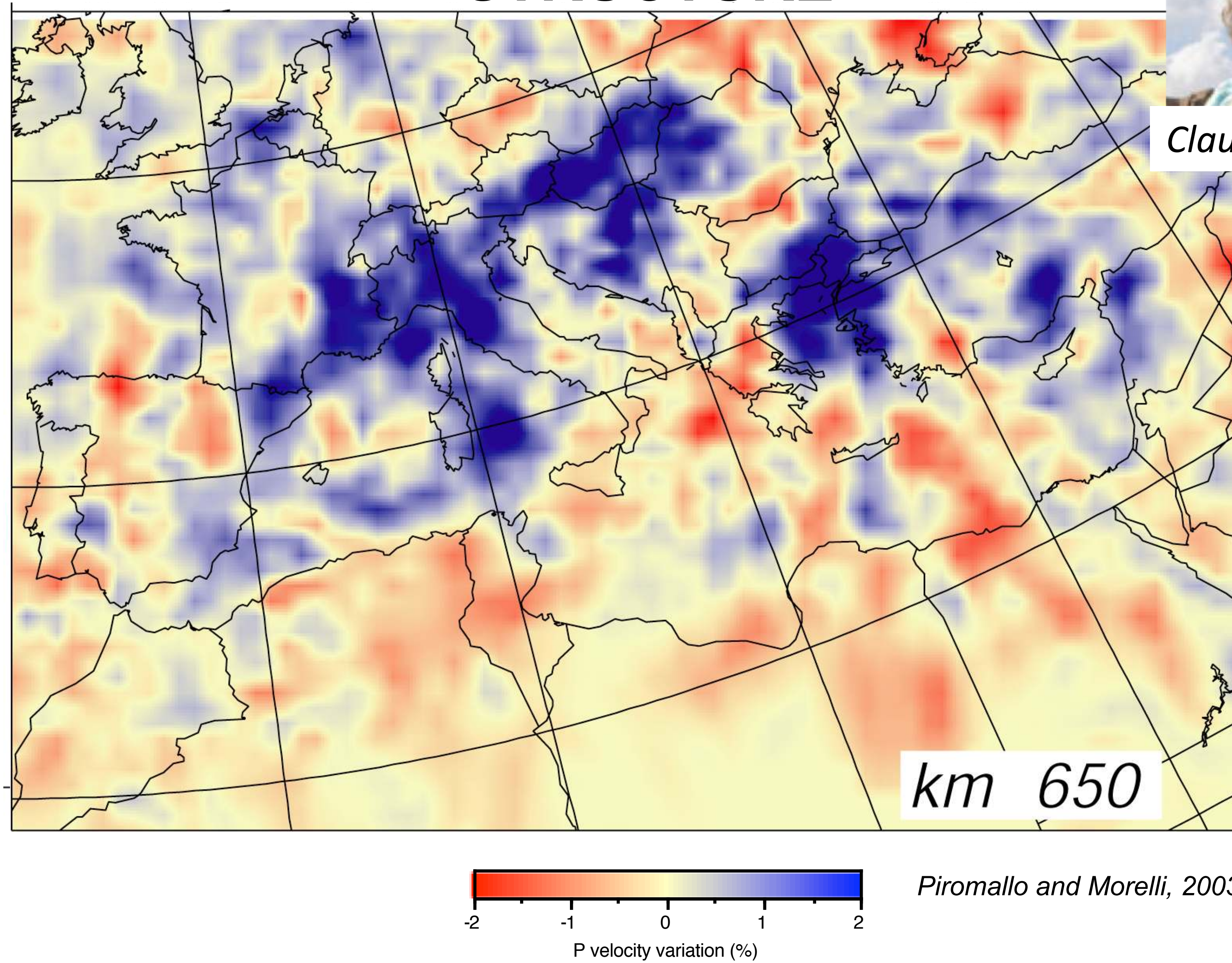
Royden and Faccenna, 2018

EVOLUTION OF THE MEDITERRANEAN



Royden and Faccenna, 2018

THE MEDITERRANEAN MANTLE STRUCTURE

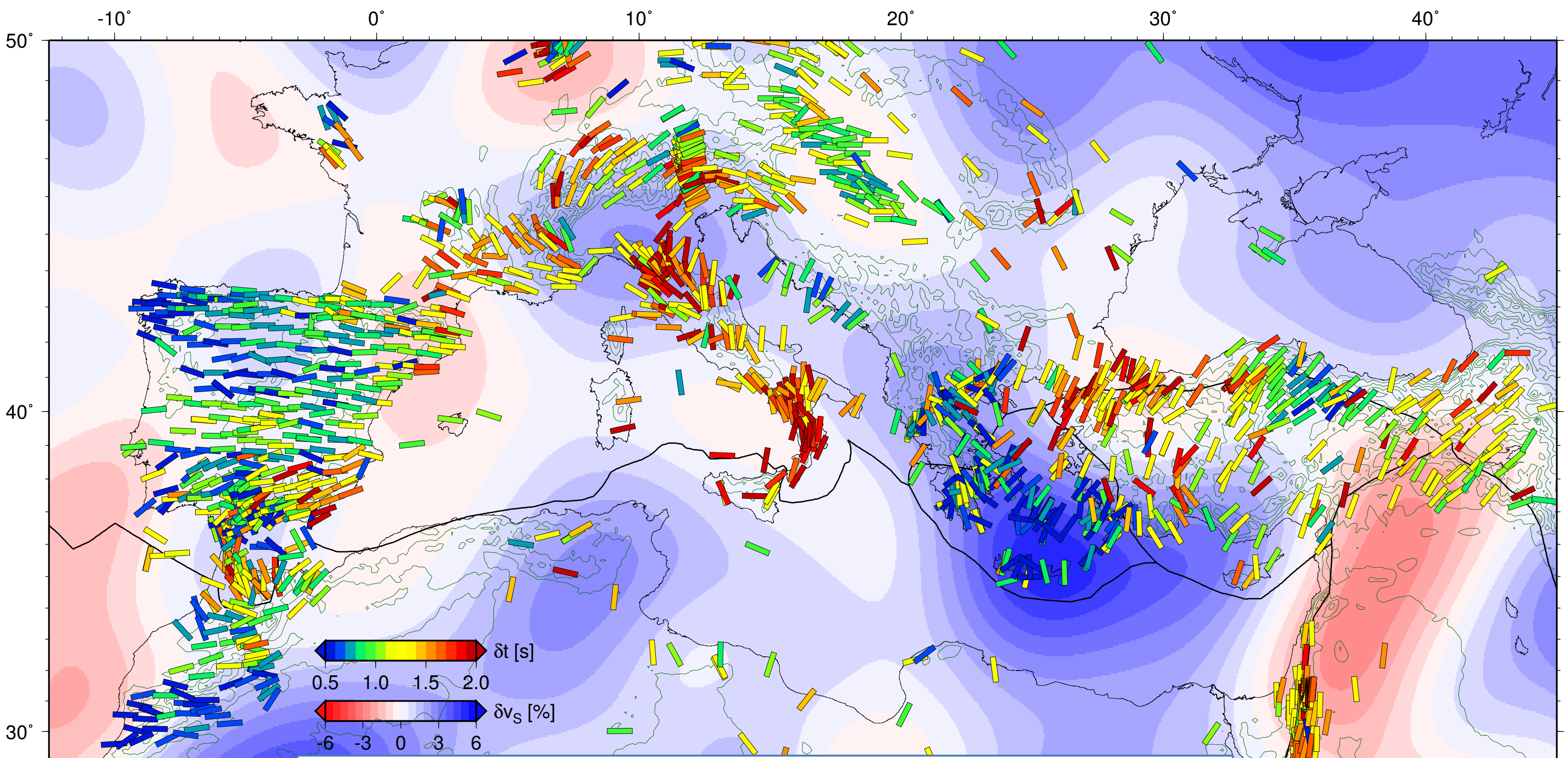


Piromallo and Morelli, 2003

Claudia Piromallo

an almost restricted upper mantle …

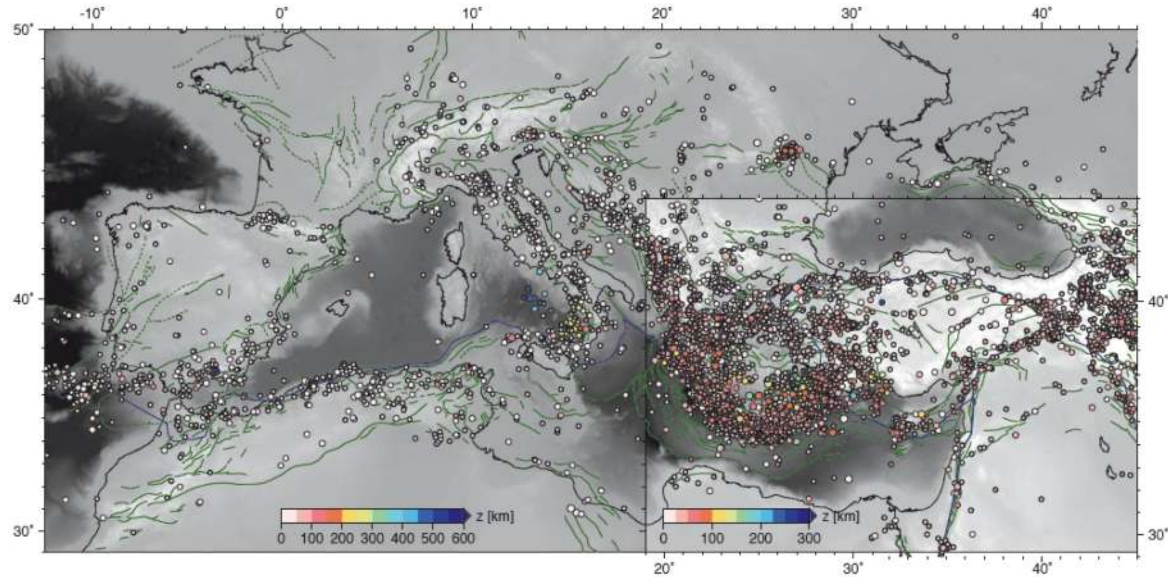
SEISMIC ANISOTROPY



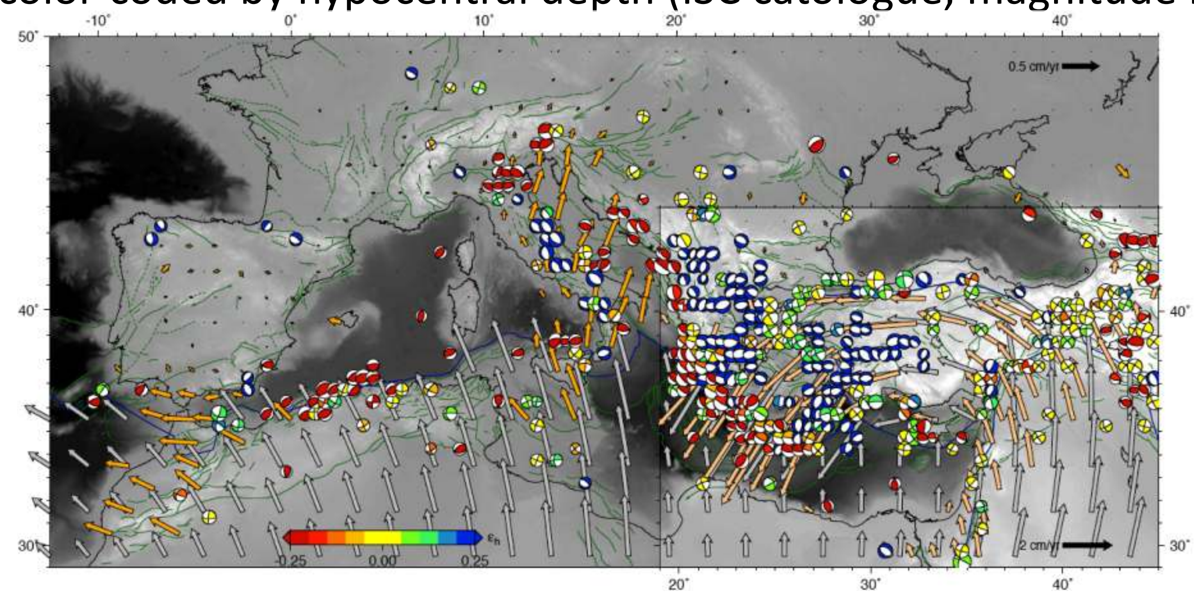
Compilation of anisotropy from different sources
Plotted on average P wave velocity depth 100-400 km PMO1 model

EW (west) to NE-SW (east) trending pattern in backarc region (i.e., not correlated with plate convergence) normal to the subduction zones

SEISMICITY



Seismicity color-coded by hypocentral depth (ISC catologue, magnitude range >4).

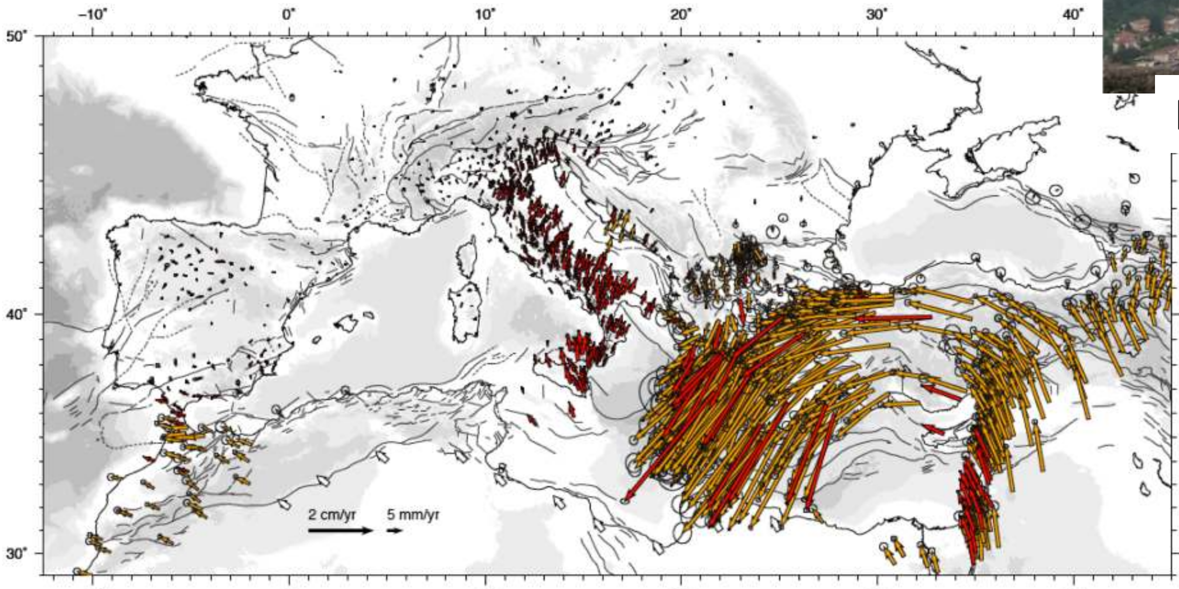


orange vectors: Interpolated GPS velocities, gray vectors: MORVEL (de Mets et al., 2010) plate velocities, Kostrov summed Harvard/gCMT moment tensor solutions (depth < 75 km)

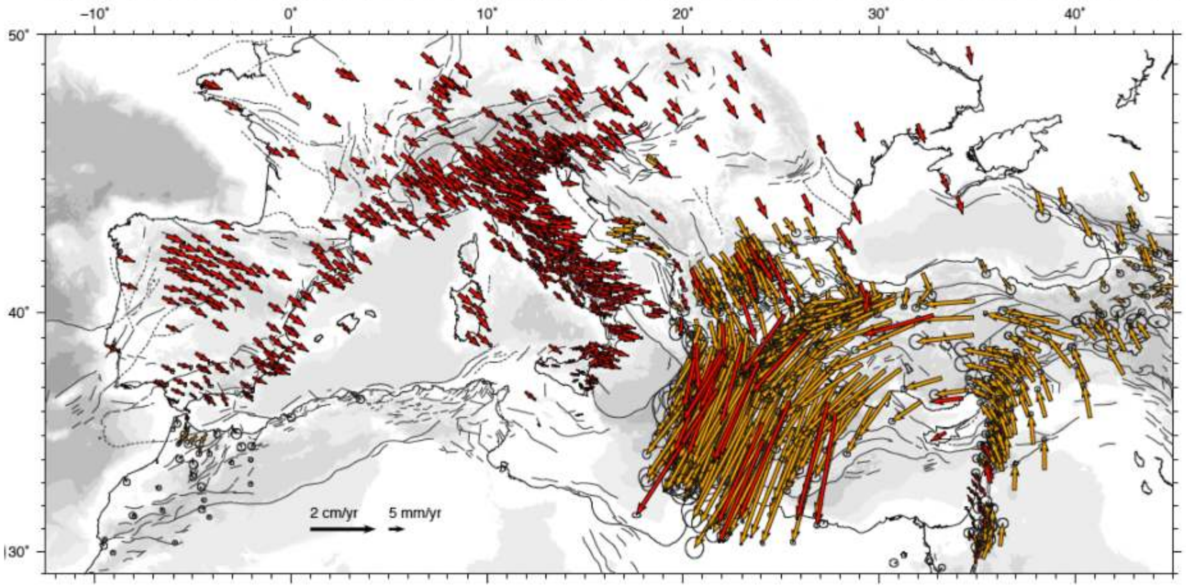
GPS velocity field

Enrico Serpelloni

- Eurasia

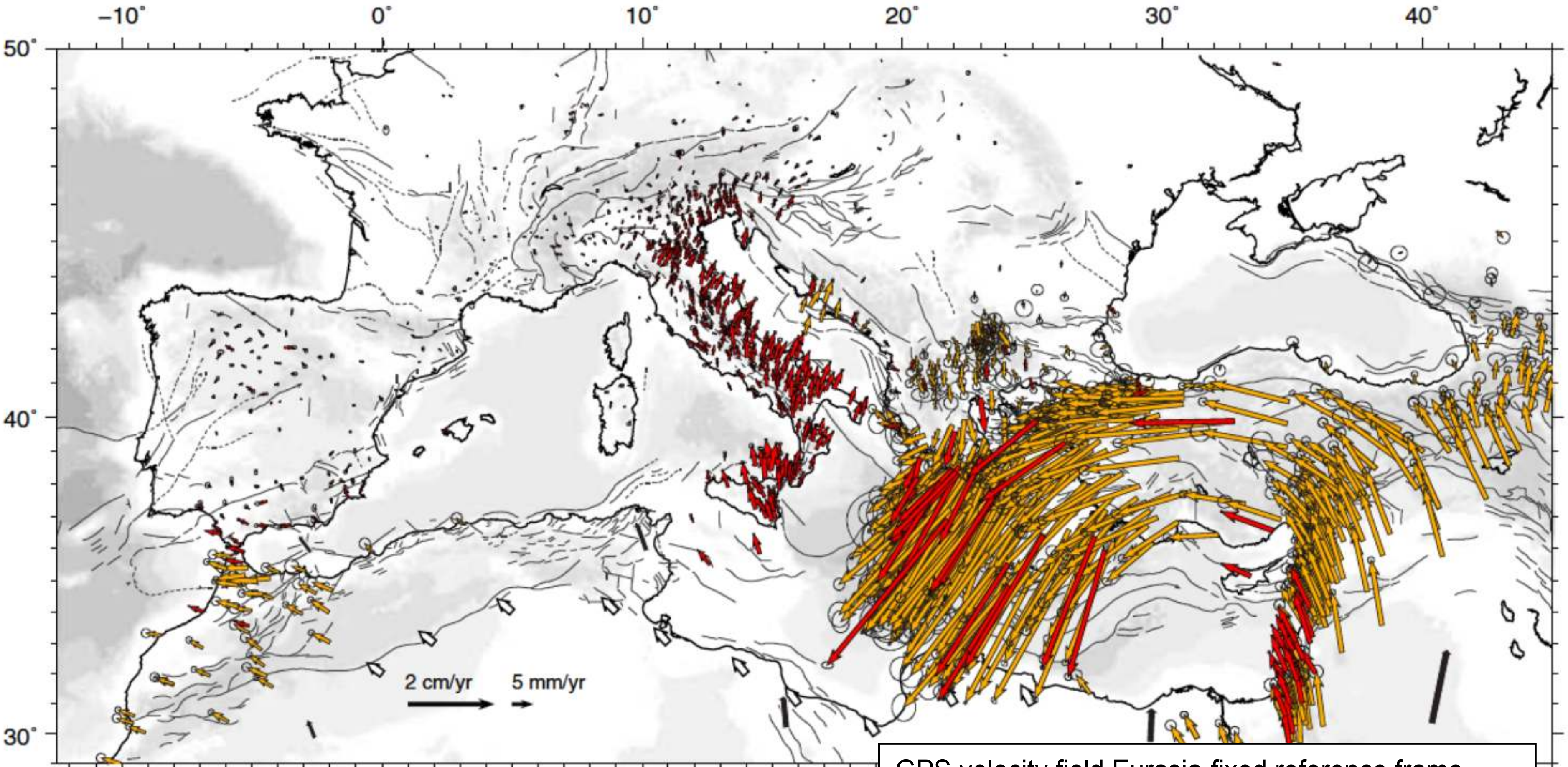


- Nubia



Compilation
by E. Serpelloni

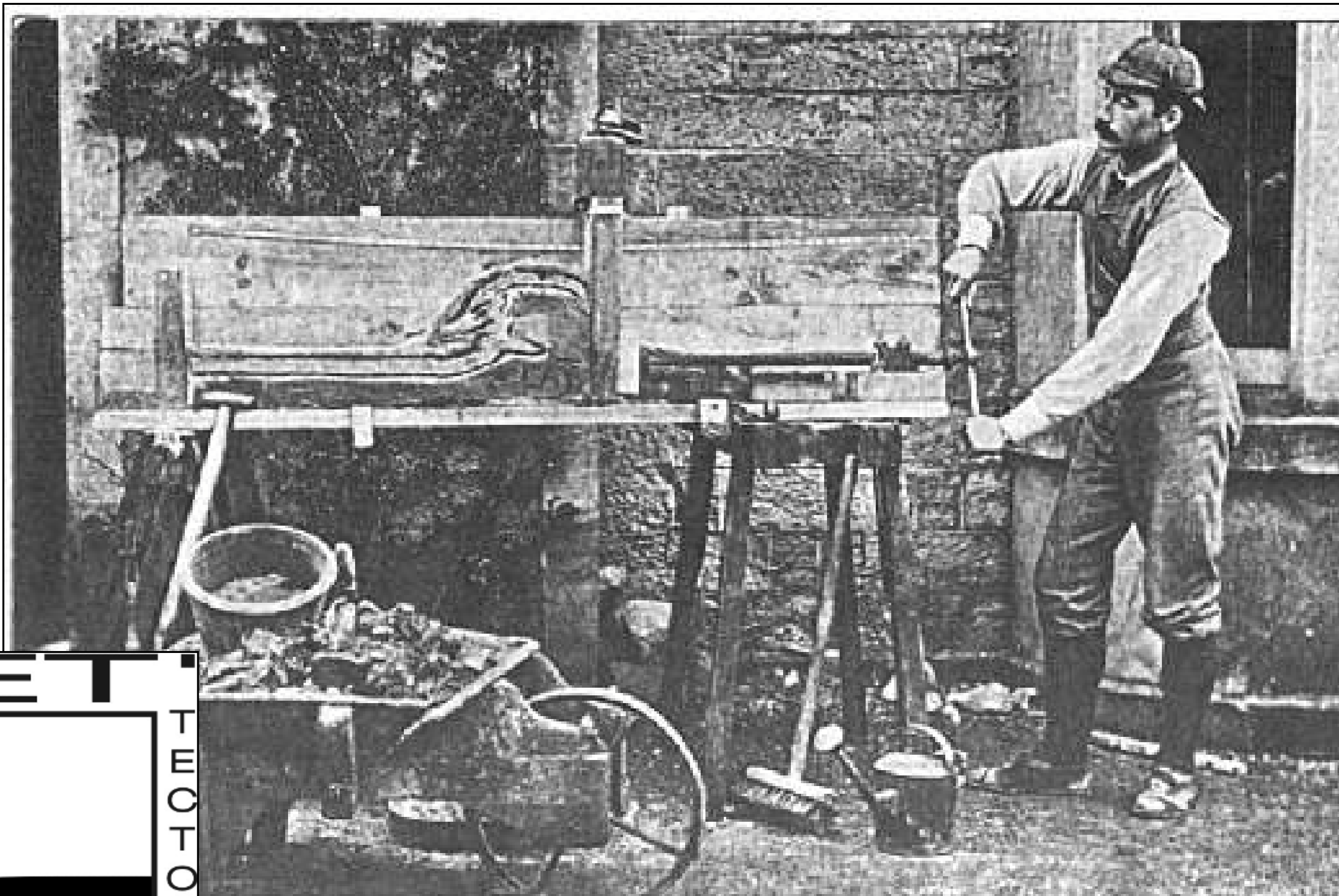
THE MEDITERRANEAN PUZZLE



GPS velocity field Eurasia-fixed reference frame compilation by Serpelloni in *Faccenna et al., 2014*

What does drive microplates (i.e., Anatolia) ?
Which are the forces at work in the Mediterranean ?
Which is the dominant style of mantle convection ?

MODELLING THE MEDITERRANEAN MANTLE DYNAMICS



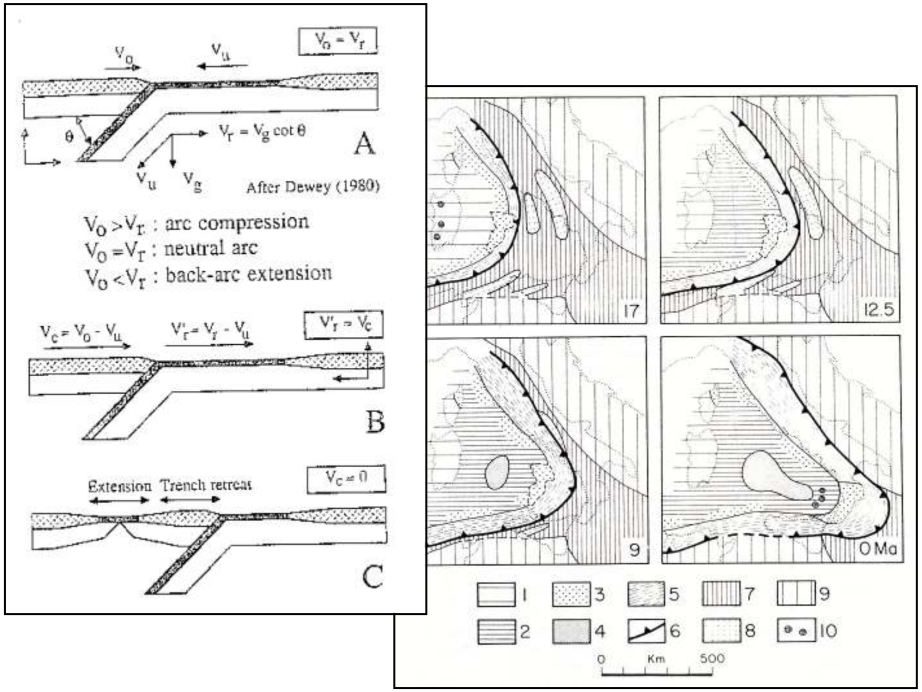
Experiments in Mountain Building

ROMA TRE

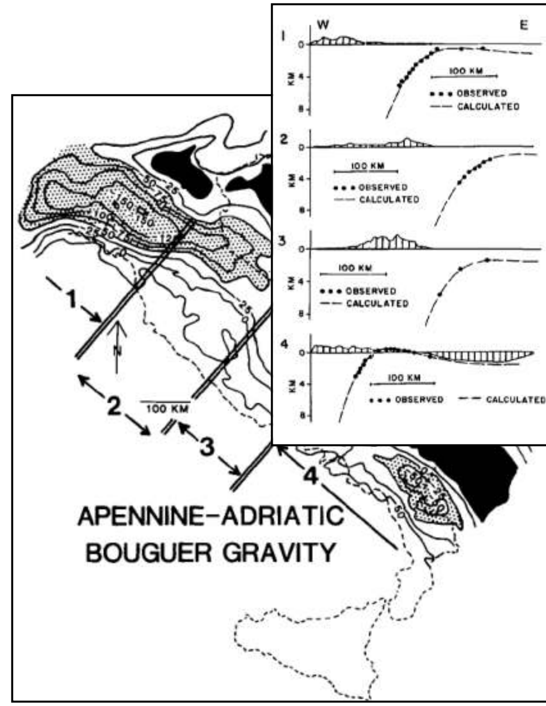
LET

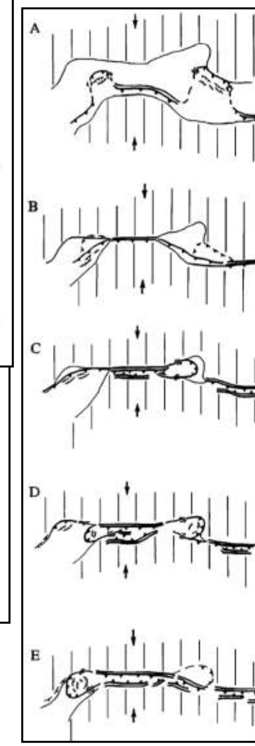
LABORATORY EXPERIMENTAL TECTONICS

THE SLAB ROLLBACK and FLEXURAL MODEL

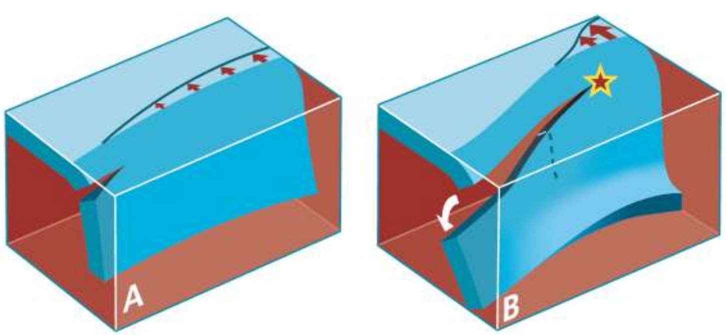


Malinverno and Ryan (1986)



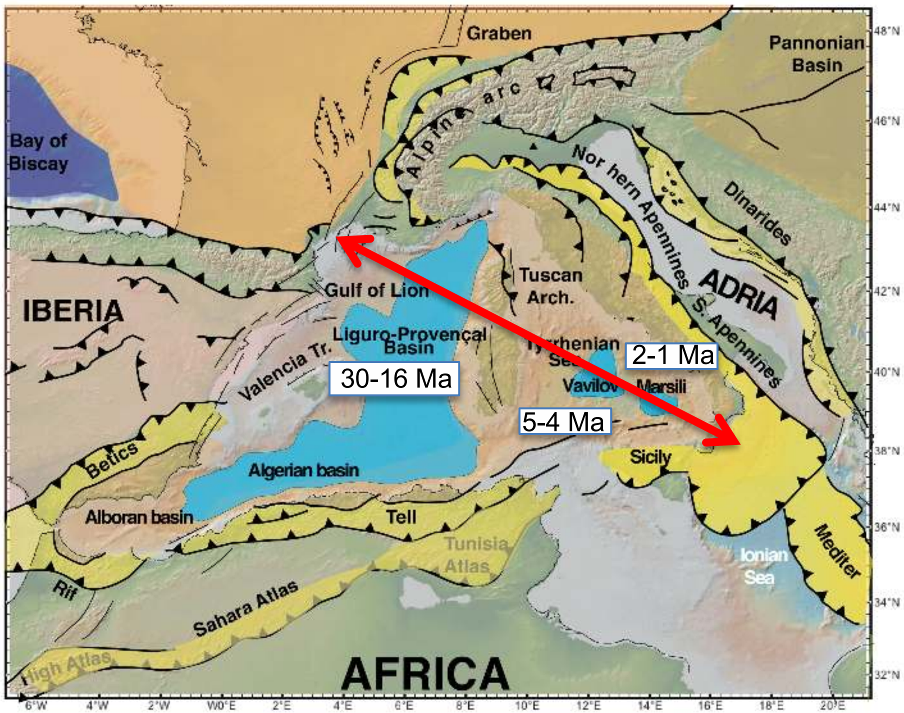


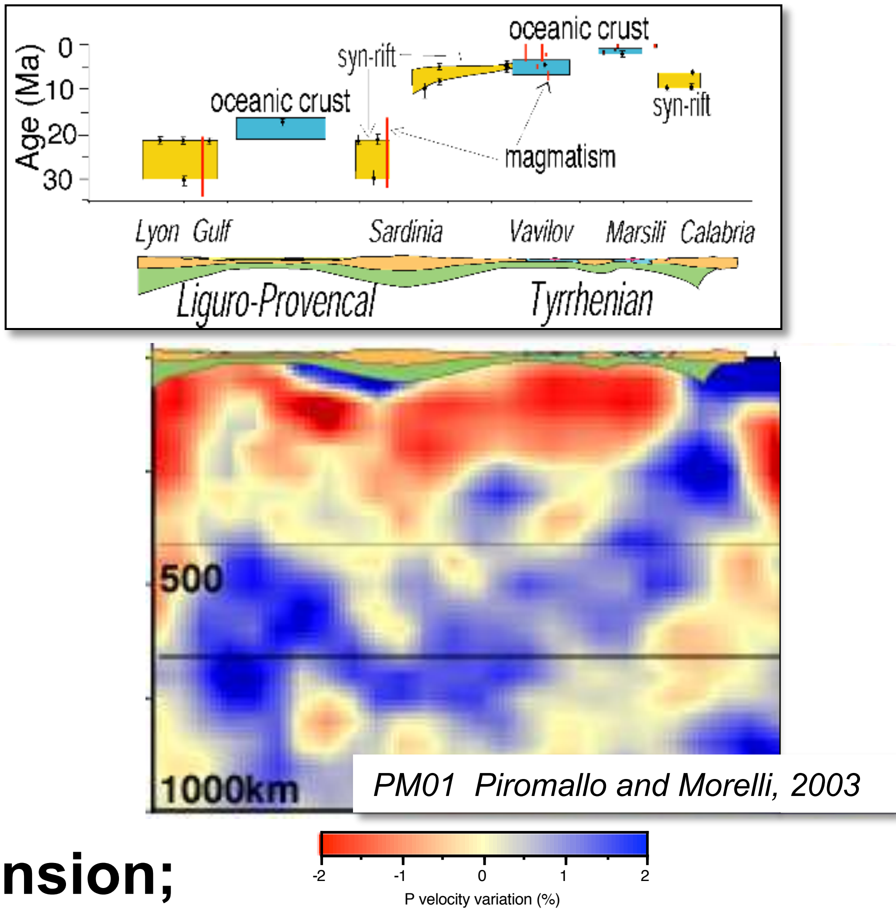
Royden (1993)



Wortel and Spakman (2000)

BACK-ARC EXTENSION

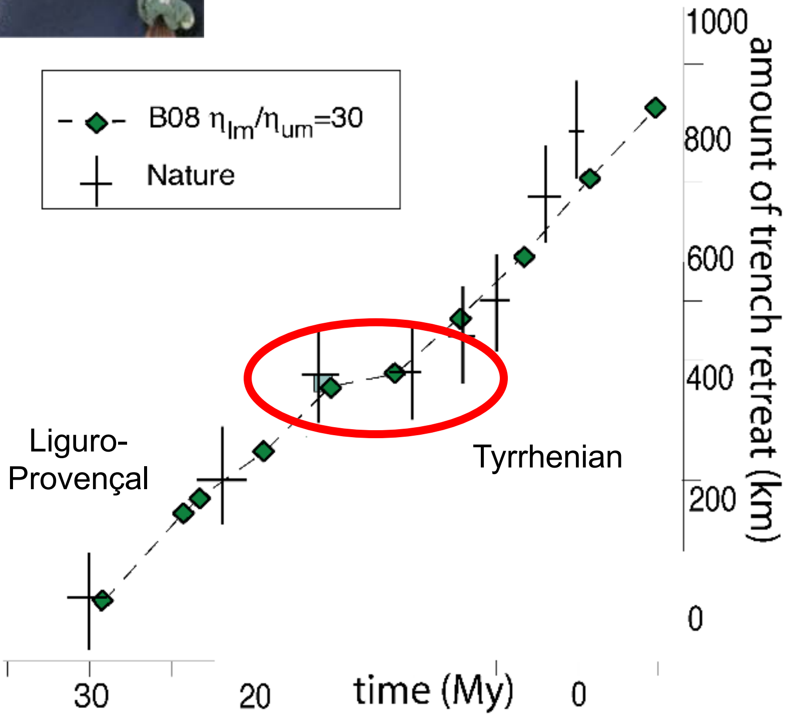




- more than 800 km of back-arc extension;
- three pulses of spreading.

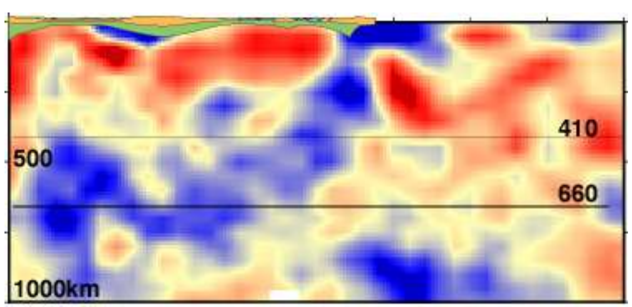
ANALOGUE MODELLING

Francesca Funiciello

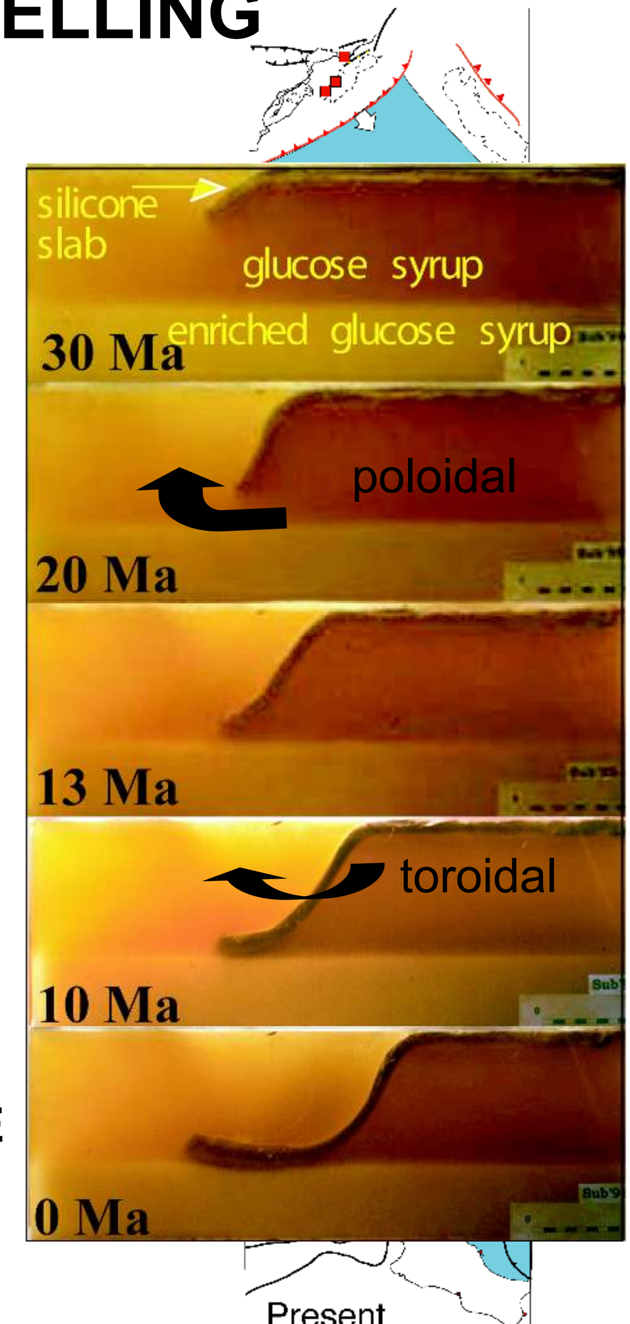


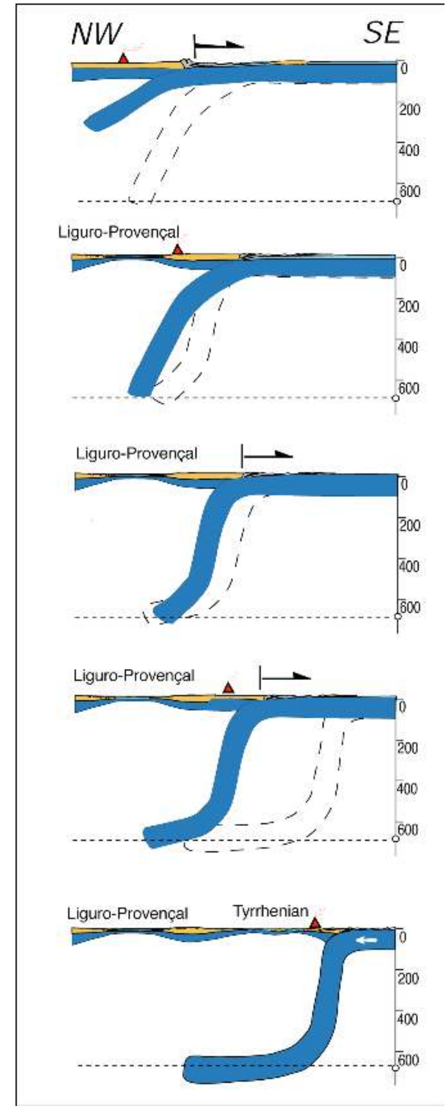
Liguro-Provençal *Tyrrhenian*

NW



SE

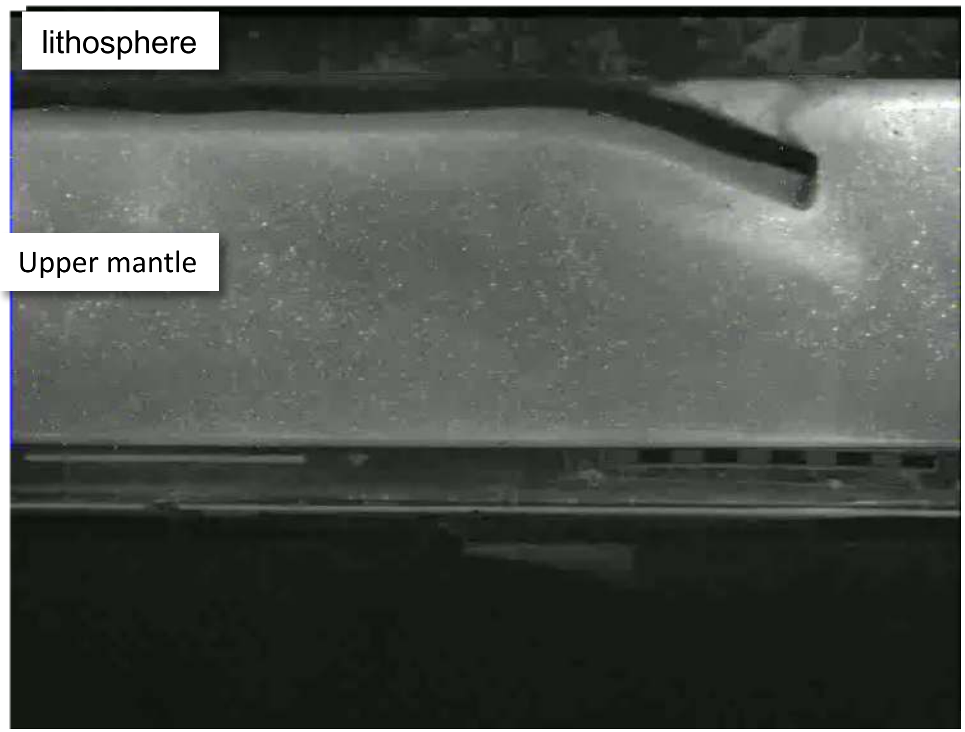




Faccenna et al., 2001

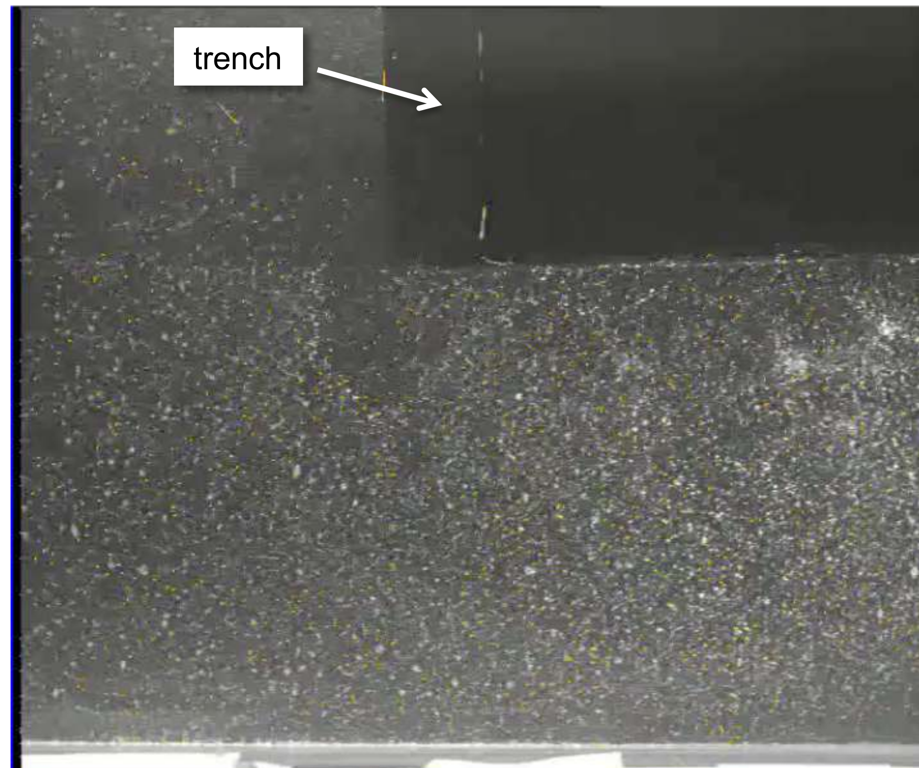
MANTLE CIRCULATION DURING RETREAT OF A NARROW SLAB
(LABORATORY MODELS)

Poloidal Flow



lateral view

Toroidal Flow

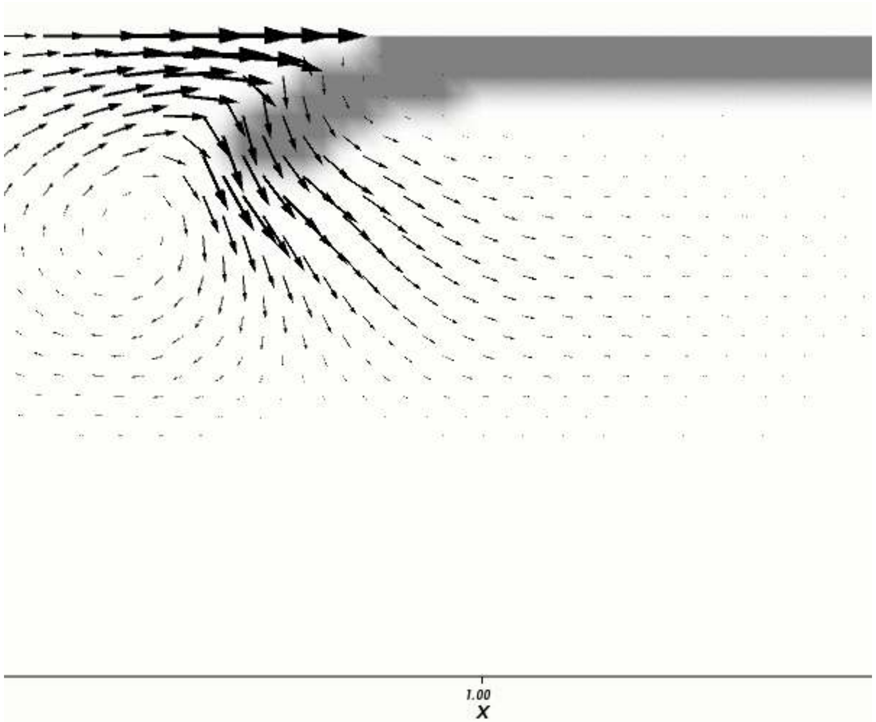


Funiciello et al., 2000, 2003, 2004, 2006

MANTLE CIRCULATION DURING RETREAT OF A NARROW SLAB (NUMERICAL MODELS)

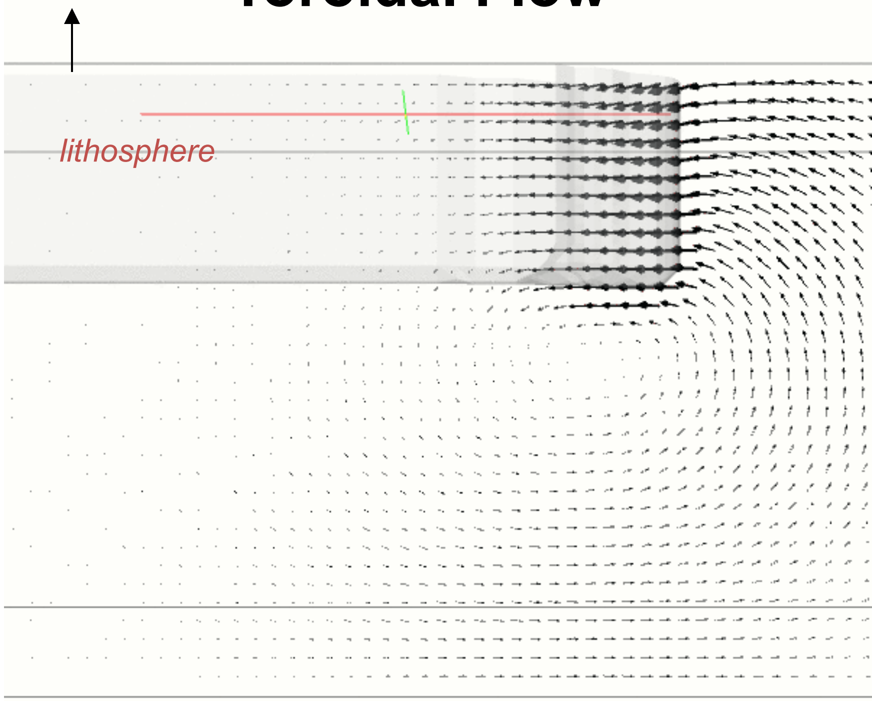
Claudia Piromallo

Poloidal Flow



lateral view

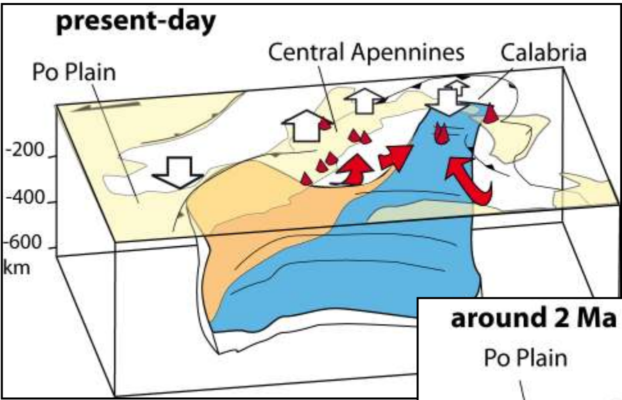
Toroidal Flow

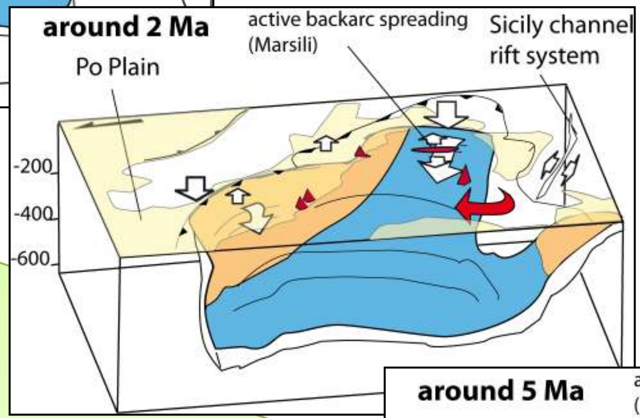


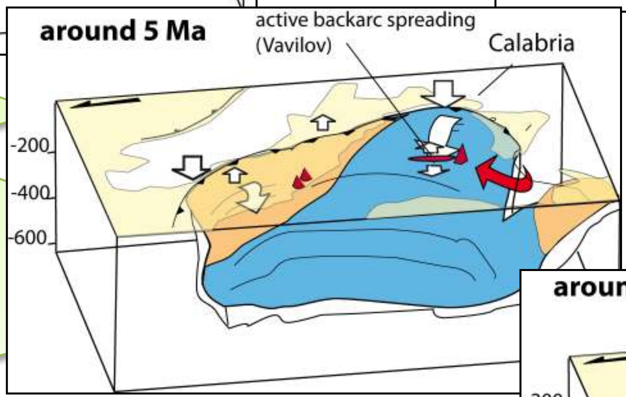
top view

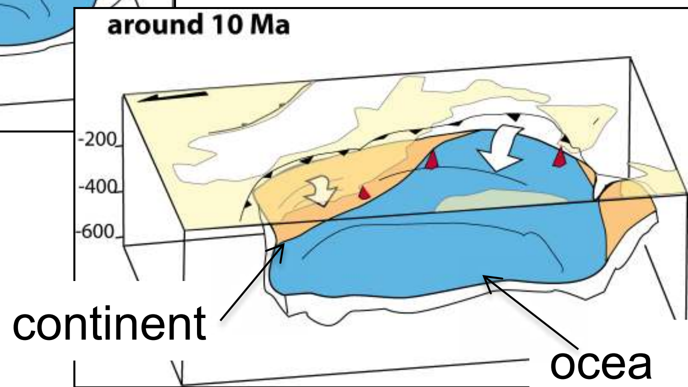
Piromallo et. al, 2006

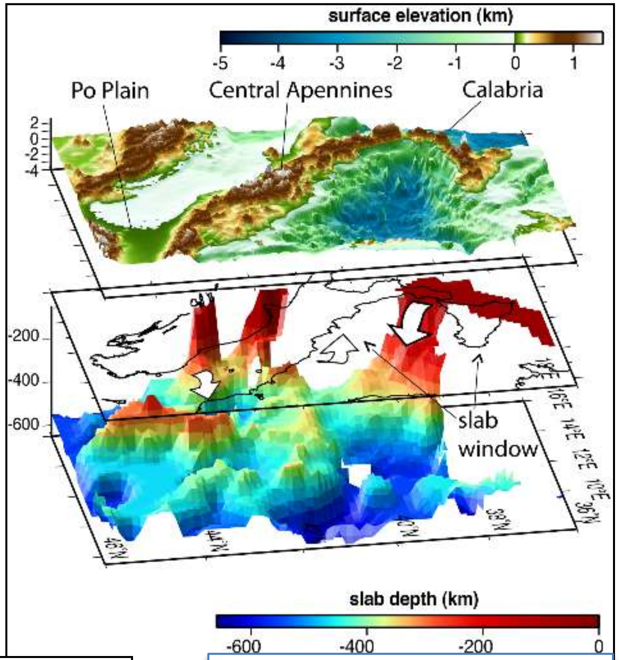
DISRUPTION OF THE TYRRHENIAN SLAB











Isosurface of the >0,8 % P wave anomalies from Piromallo and Morelli (2003) model

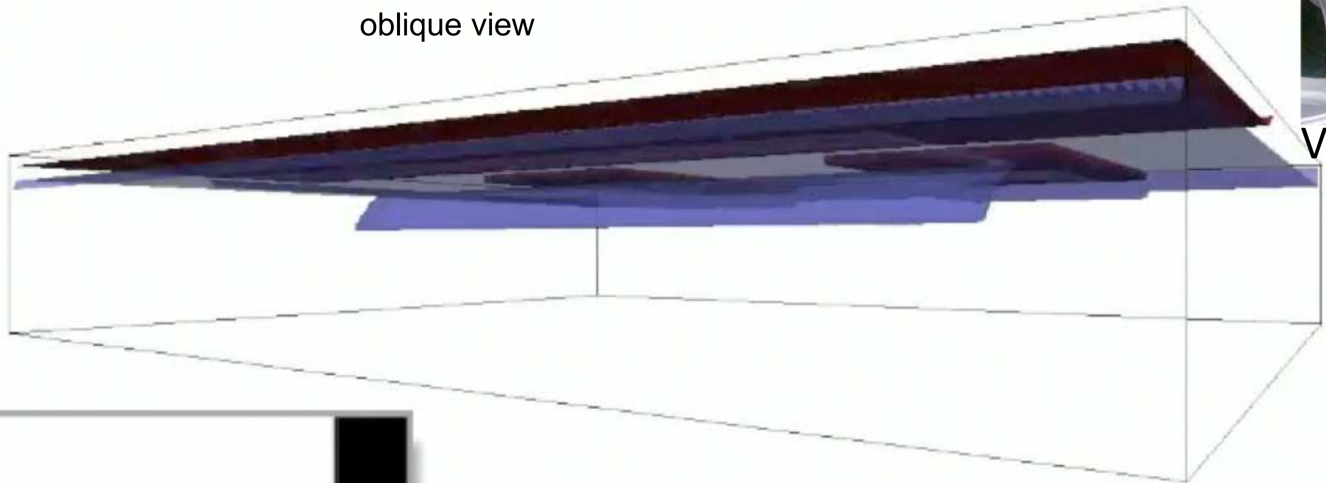
short-lived catastrophic events of slab disruption

Faccenna et al., 2005; 2007

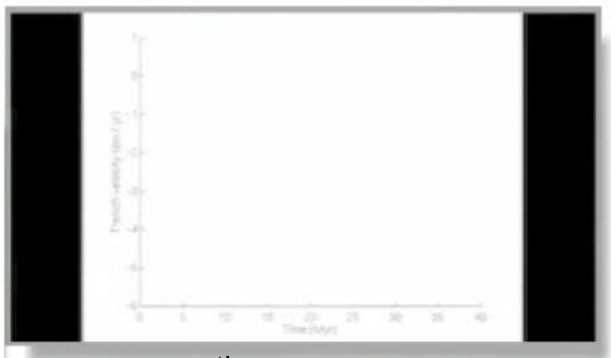
BACKARC EXTENSIONAL MODELS

Valentina Magni

oblique view

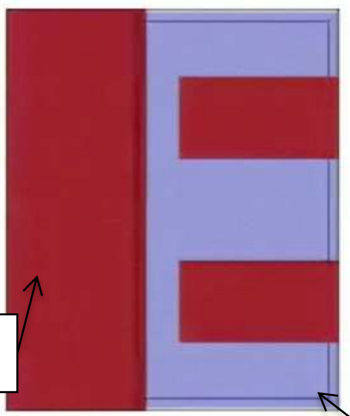


roll-back velocity



time

lateral view



continent

ocean

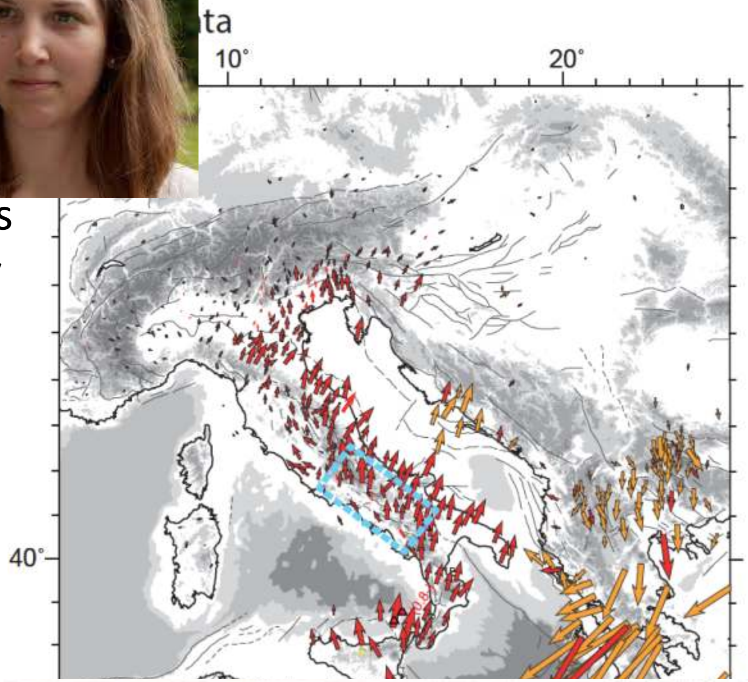
top view

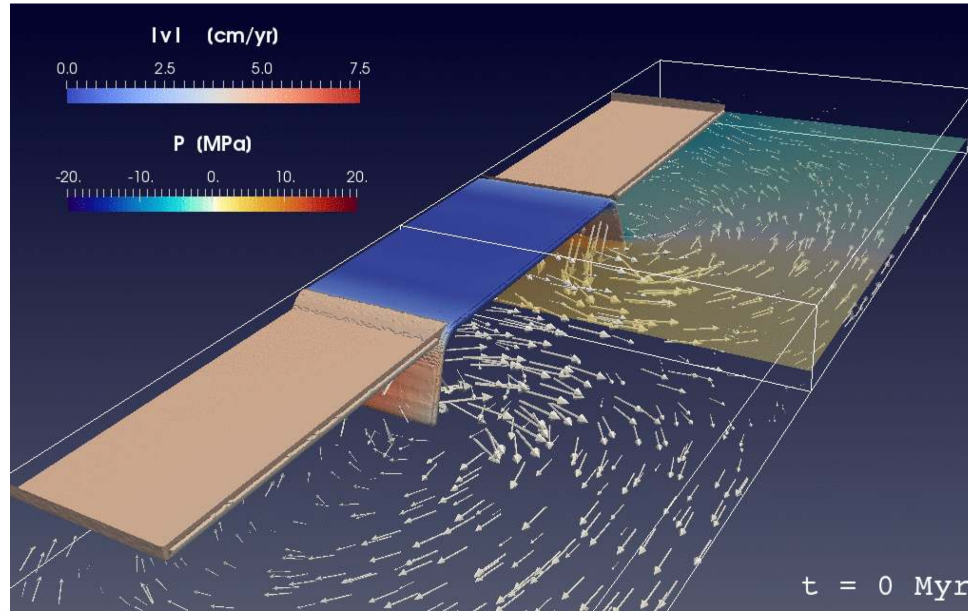
collision, backarc extension and slab disruption

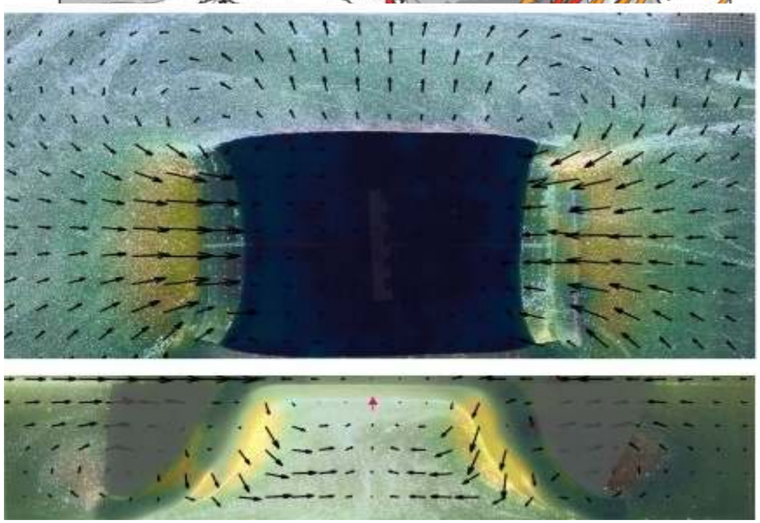
Magni et al., 2014

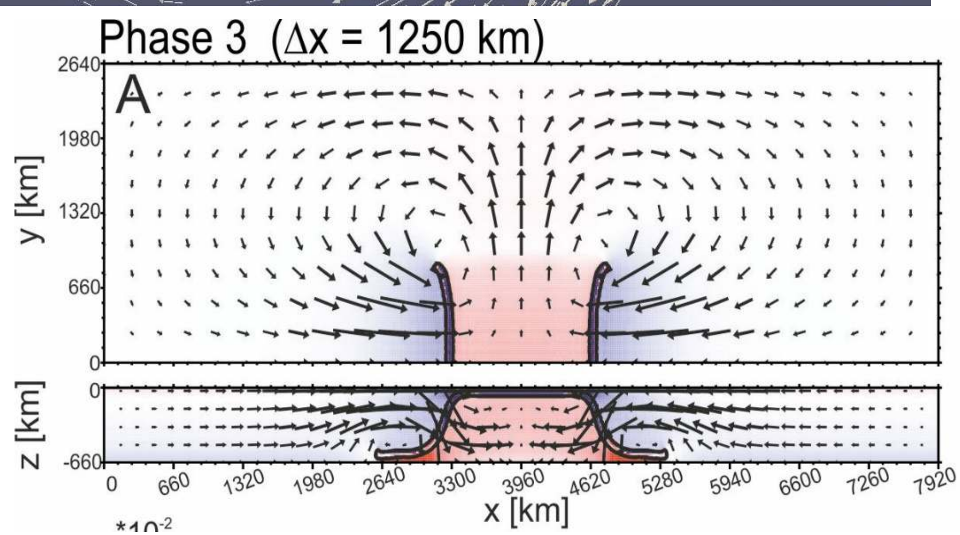
DOUBLE SUBDUCTION BENEATH ADRIA

Agnes Kiraly





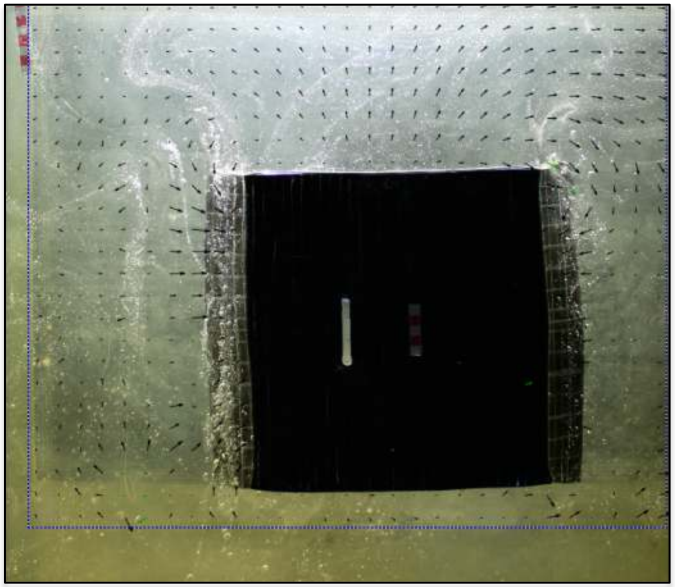


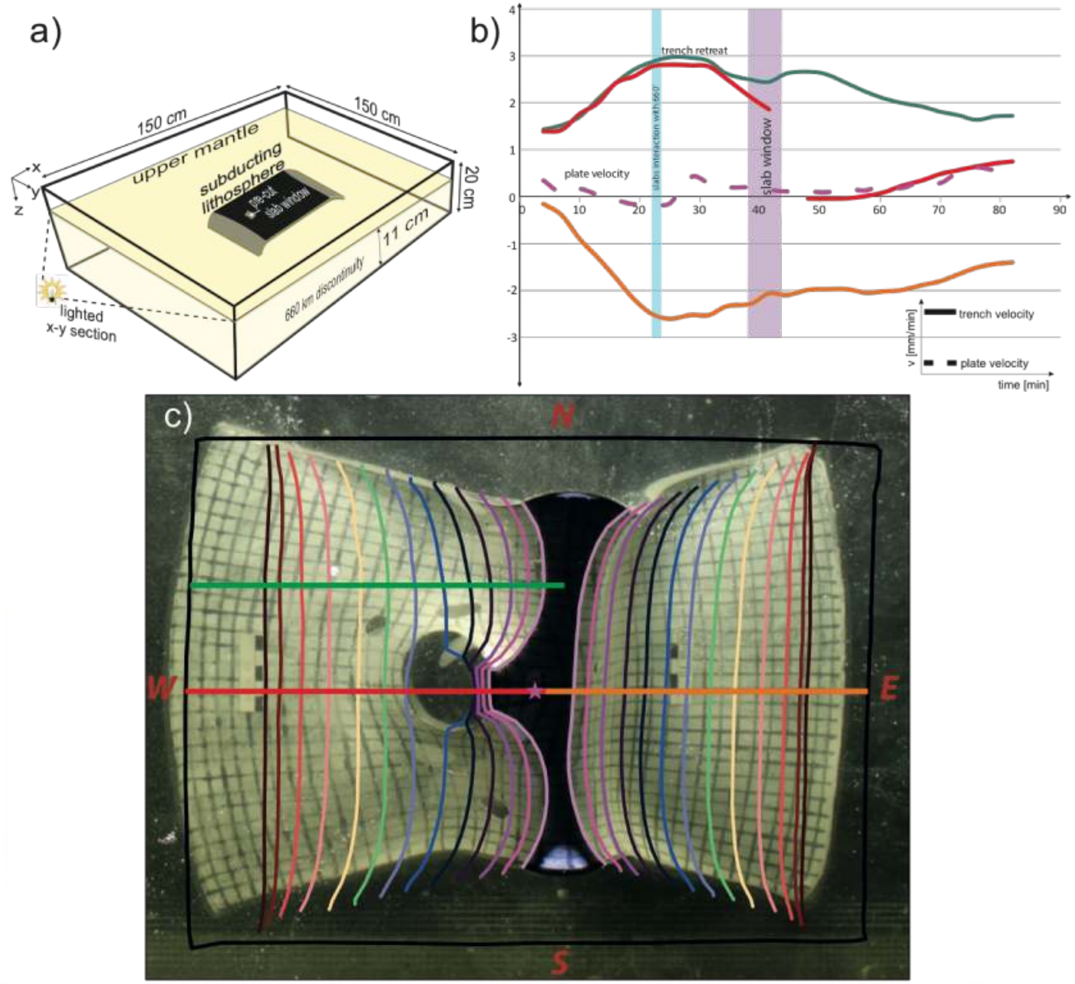


….due to overpressure beneath the slabs

Kiraly et al., 2017

DOUBLE SUBDUCTION AND SLAB WINDOW

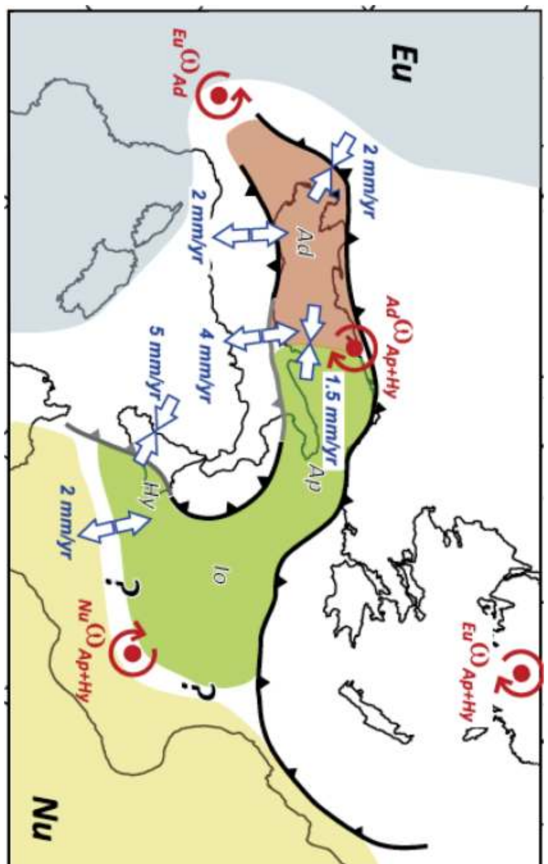


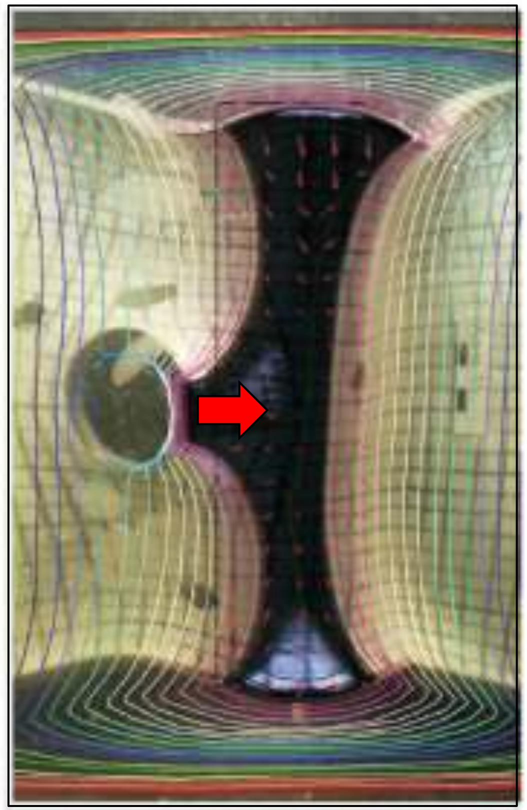


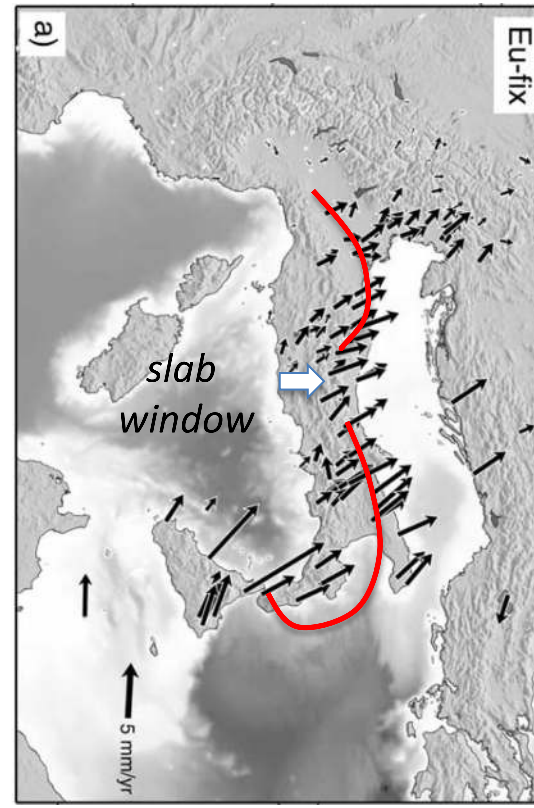
Kiraly et al., 2018

SLAB WINDOW AND ADRIA DEFORMATION

Previous model





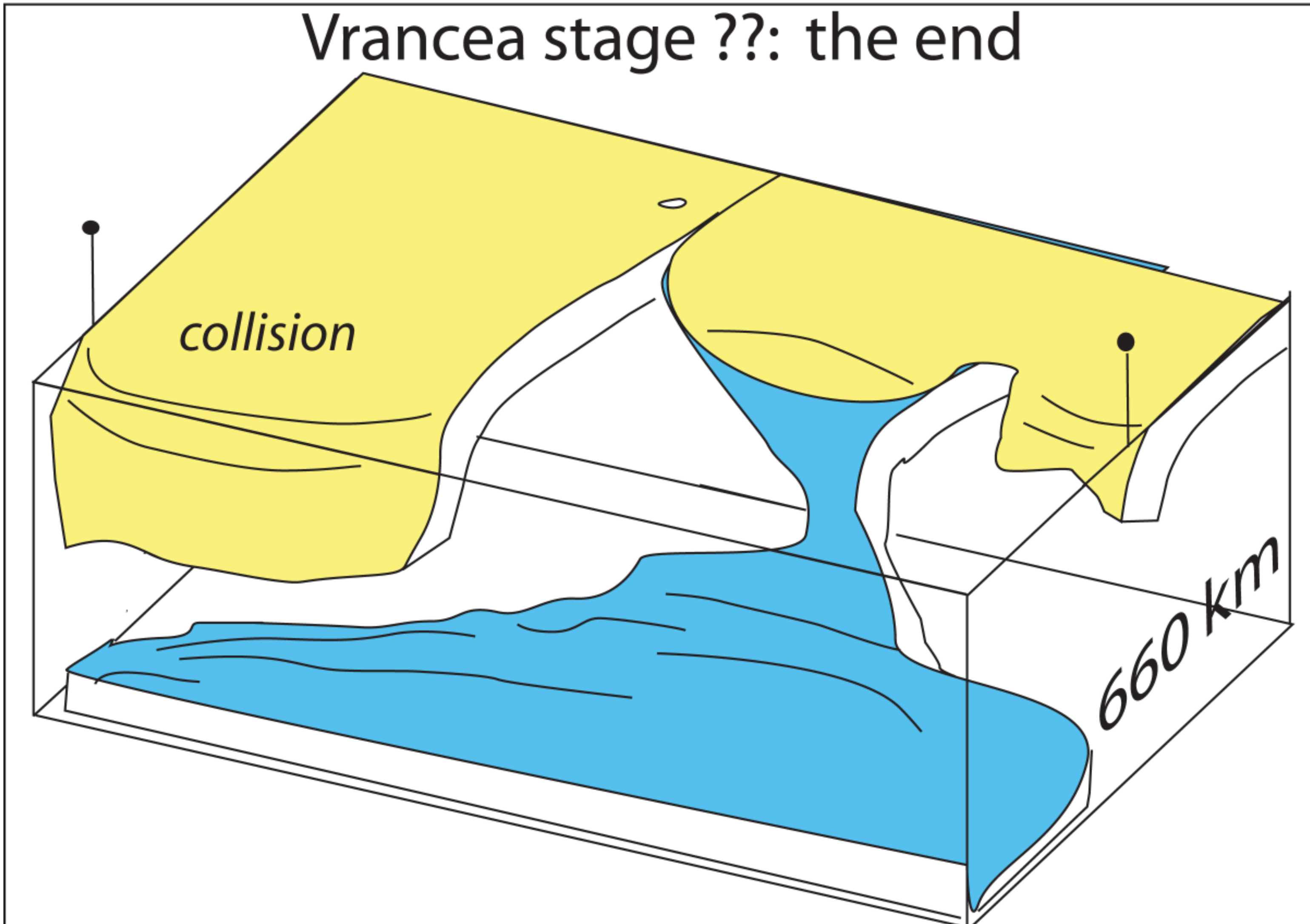


D'Agostino et al., 1998

...the formation of the arcs and motion of Adria emerges spontaneously in a asymmetric (slab windoww) opposite subducting system

Kiraly et al., 2018

Mediterranean-type subduction zone



Modelling mantle flow at regionally high resolution

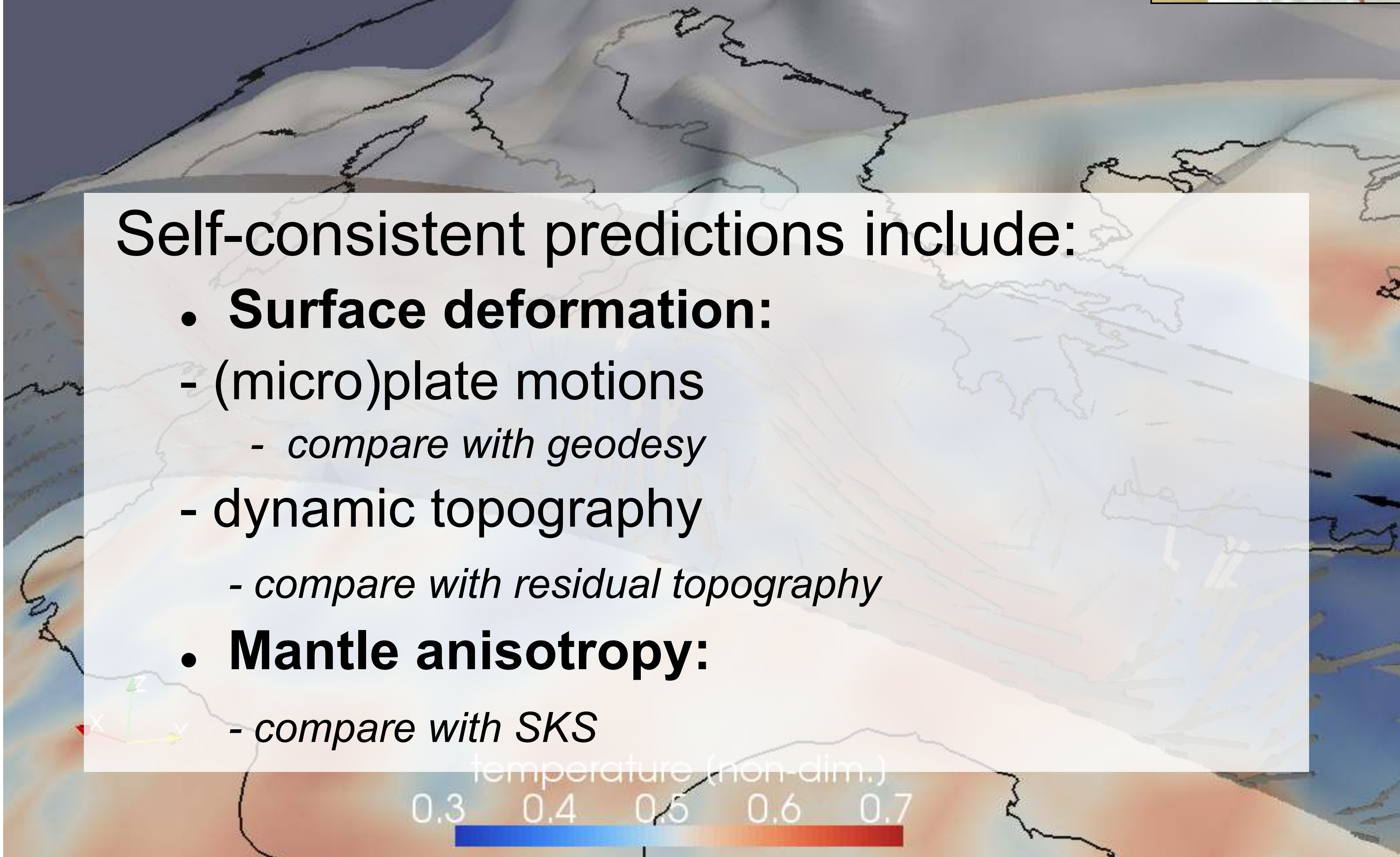
assuming:

Incompressible, laminar (Stokes) flow, surface and core free slip, CitcomS (*Zhong et al., 2000*), layered viscosity structure, Newtonian or not, lvv, low viscosity zone at boundary

and for density anomalies:

we assume simple scaling of velocity anomalies from *S* and *P* wave tomography to density, i.e. no chemical anomalies besides continental keels which are assumed neutrally buoyant


Thosrten W.Becker



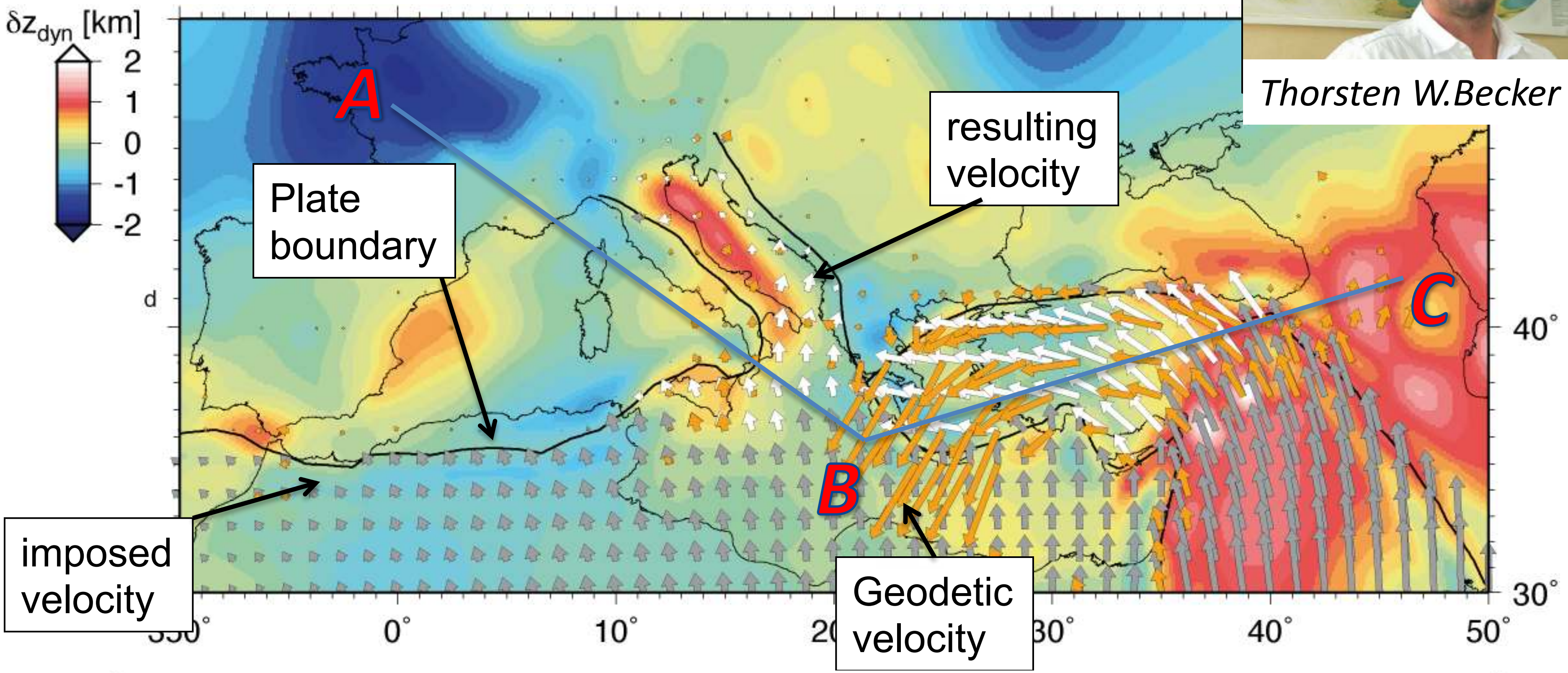
Self-consistent predictions include:

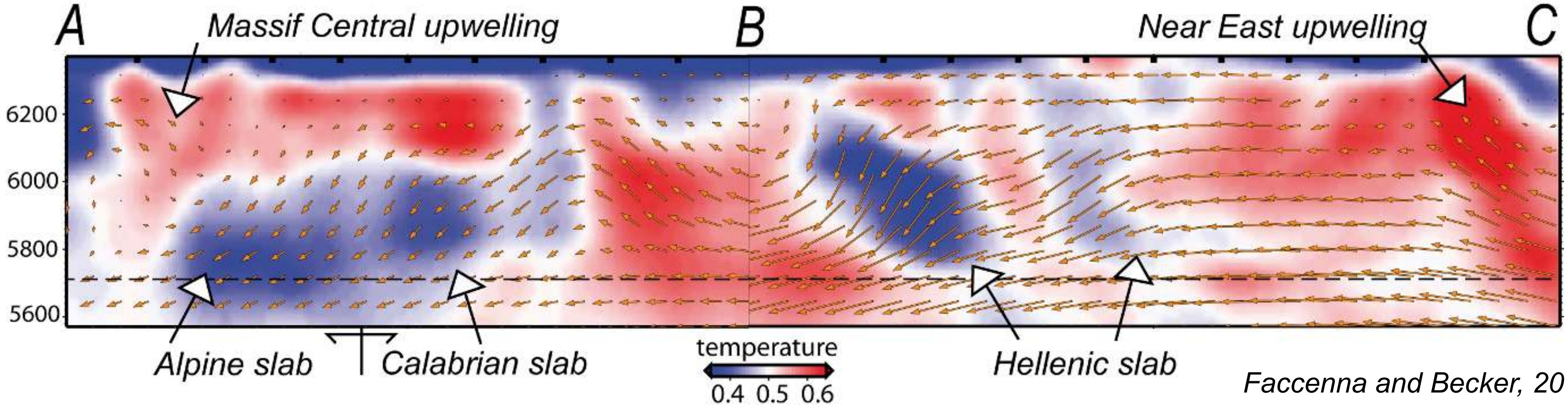
- **Surface deformation:**

  - (micro)plate motions
    - *compare with geodesy*
  - dynamic topography
    - *compare with residual topography*

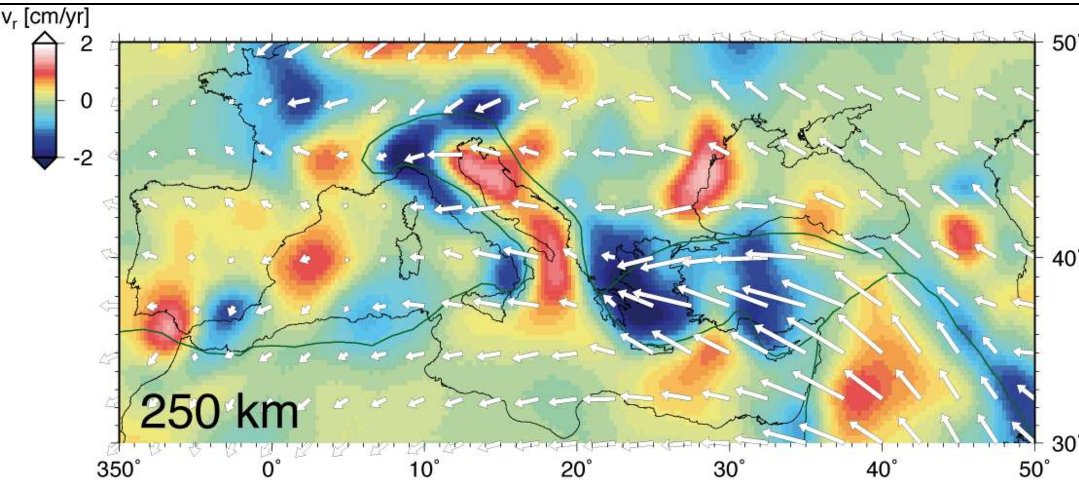
- **Mantle anisotropy:**
  - *compare with SKS*

SURFACE DEFORMATION

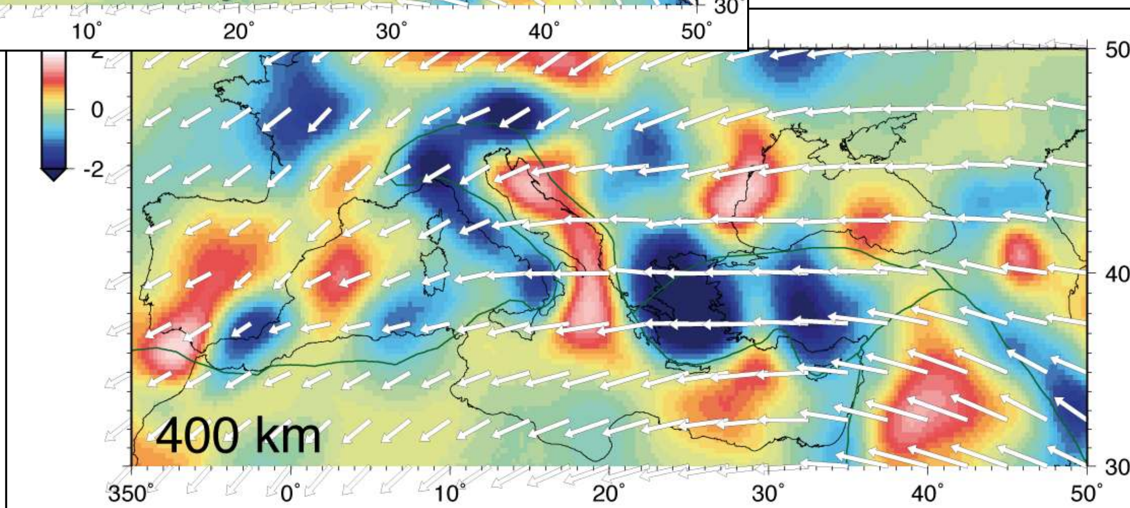


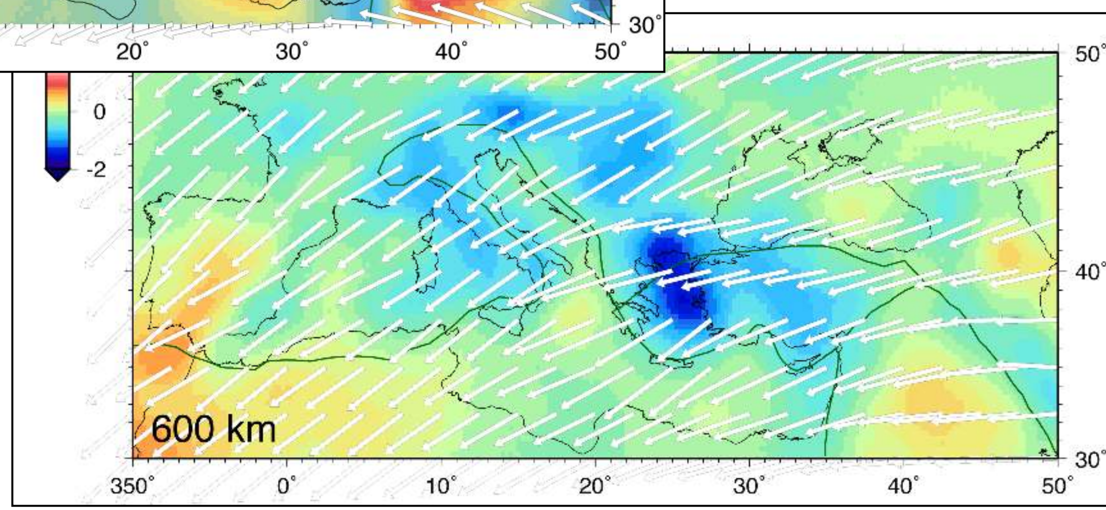


Faccenna and Becker, 2010



MANTLE FLOW SOLUTION

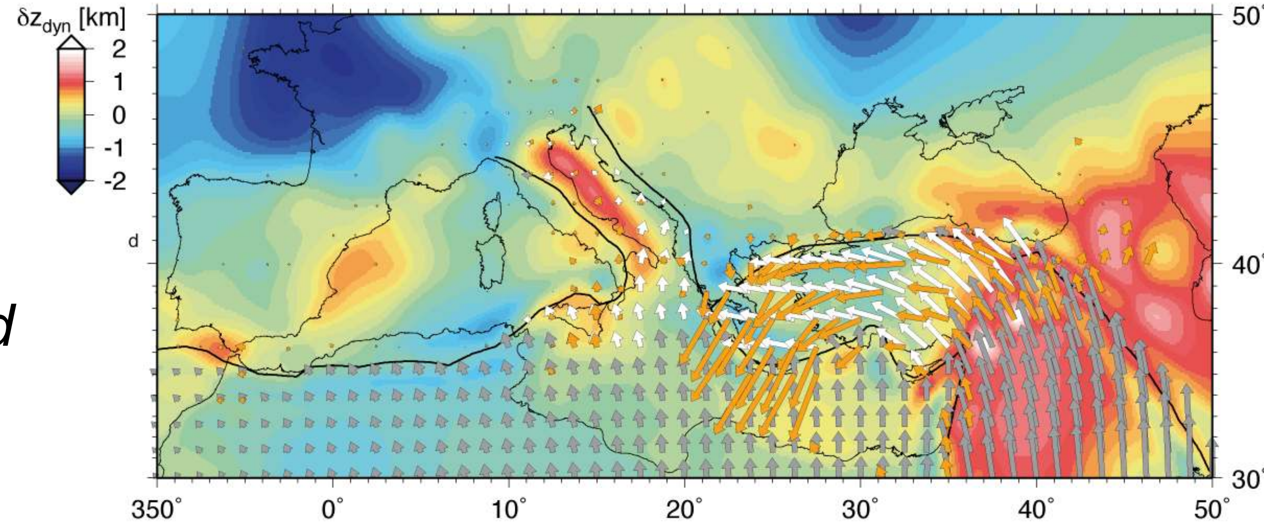




small scale upper mantle convection

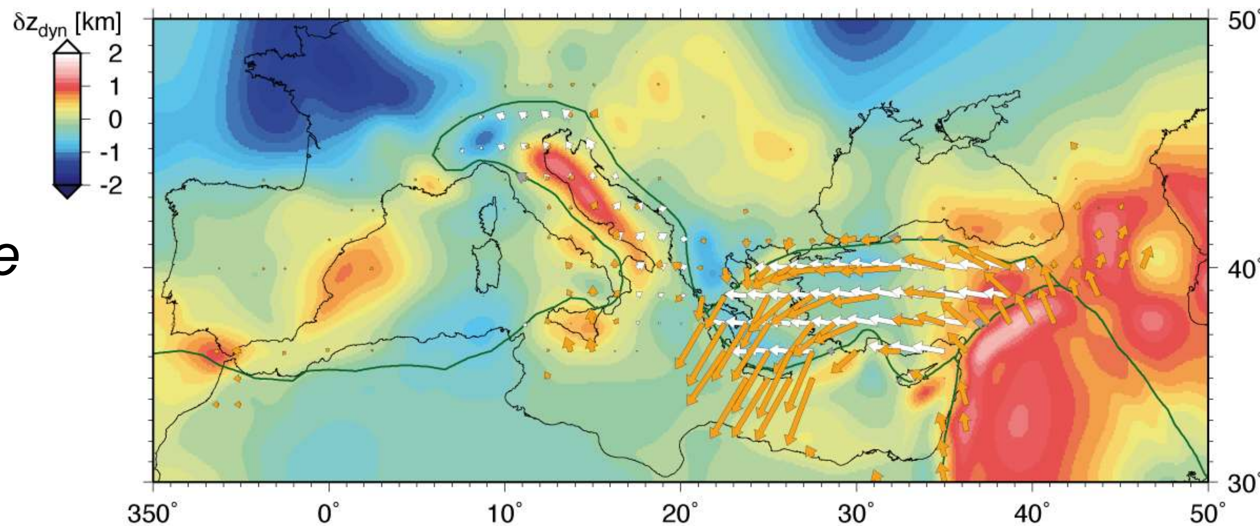
I° TEST: (MICRO)PLATE MOTION

Alps coupled



Alpine collision drives Adria correctly!

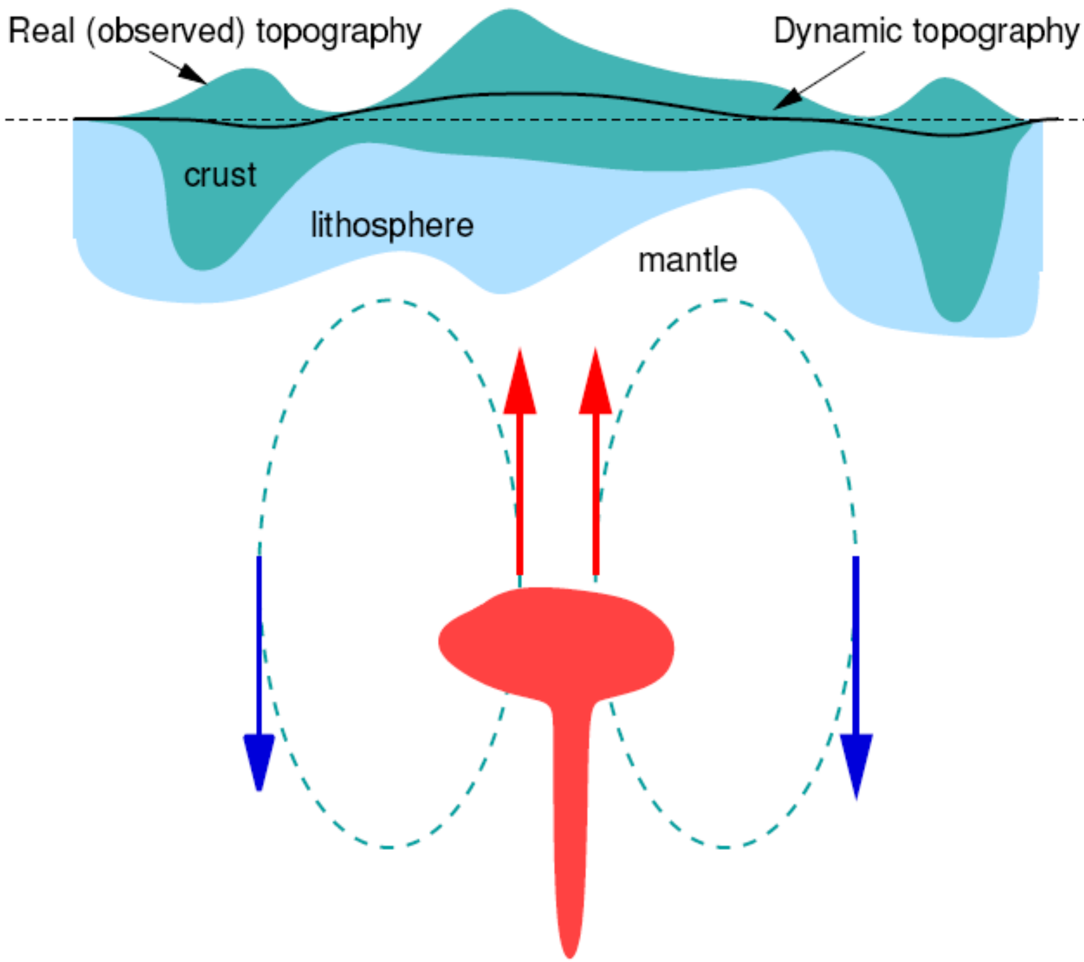
No plate motion



How mantle drives Anatolia and Adria

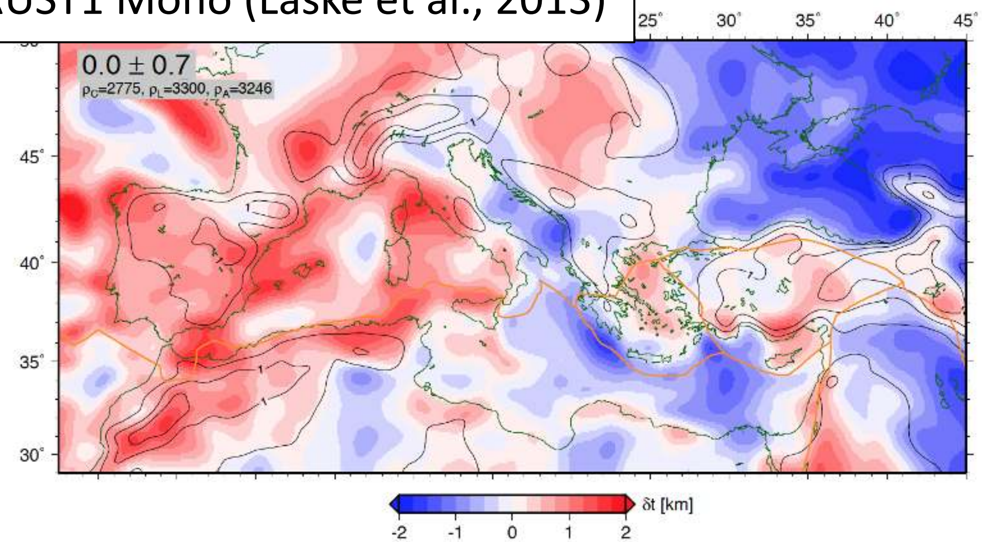
II° TEST : DYNAMIC TOPOGRAPHY

Topography= Dynamic topography + Isostatic topography

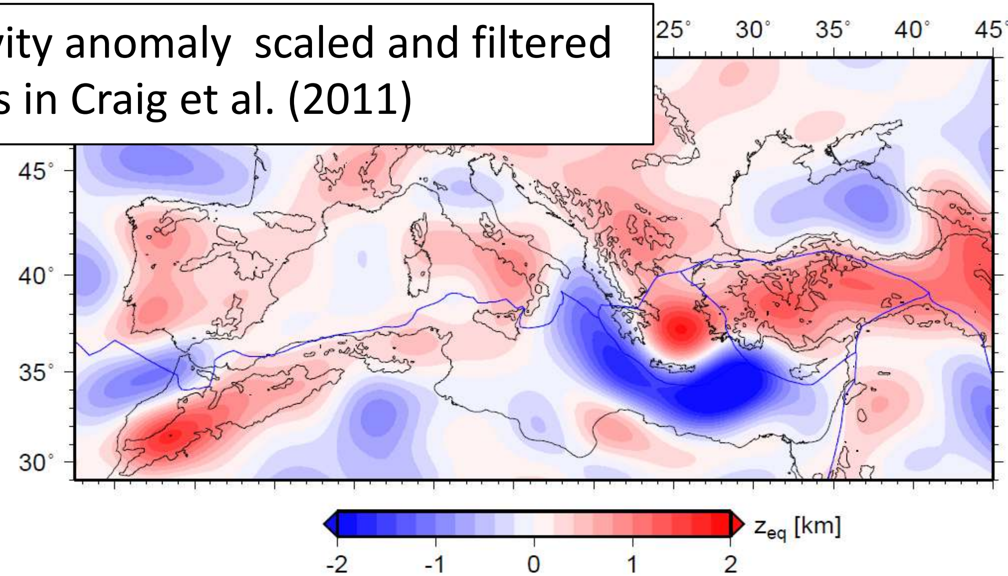


RESIDUAL TOPOGRAPHY

Based on CRUST1 Moho (Laske et al., 2013)

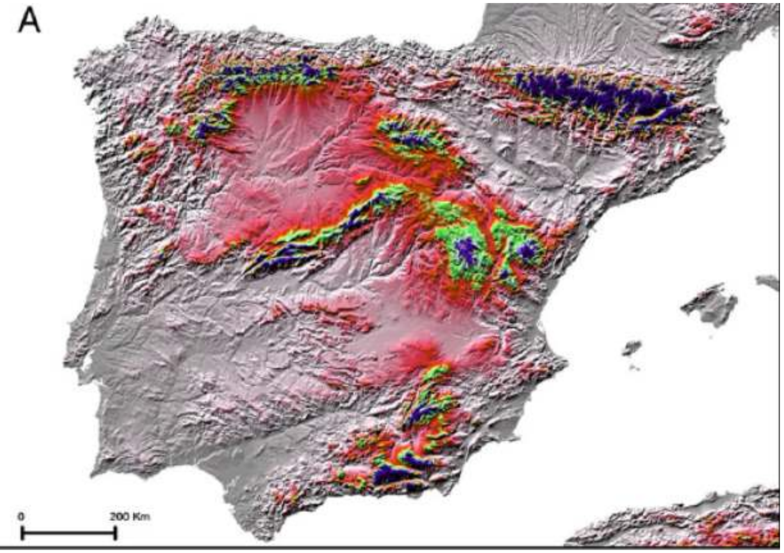


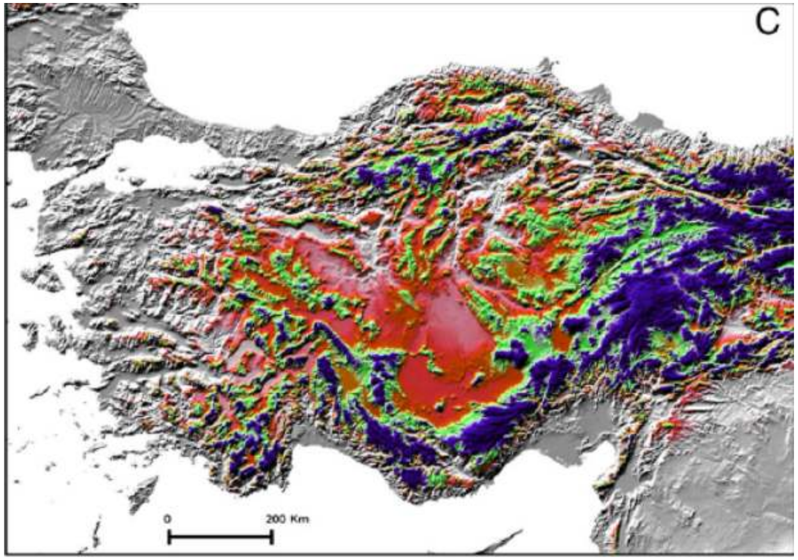
free air gravity anomaly scaled and filtered as in Craig et al. (2011)



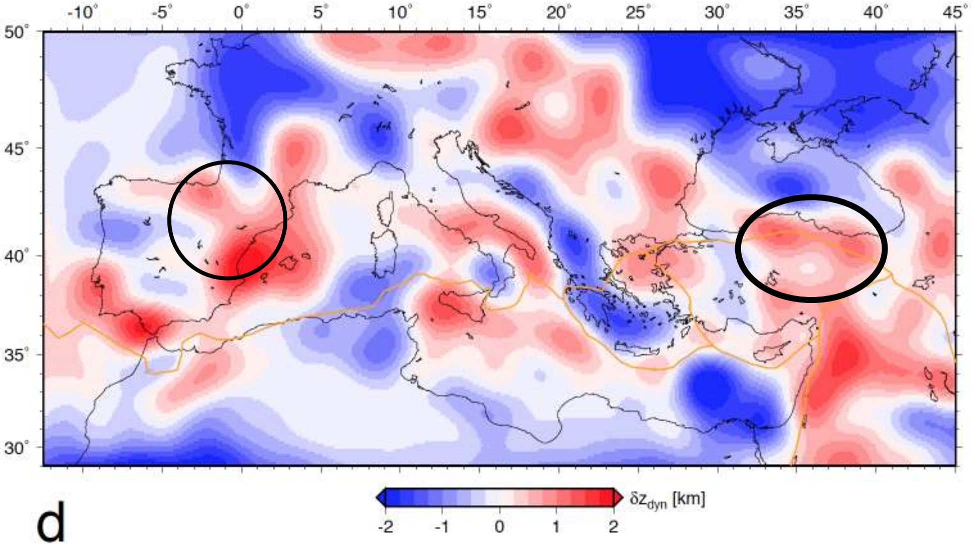
Faccenna and Becker, 201; Boschi et al., 2010

DYNAMIC TOPOGRAPHY



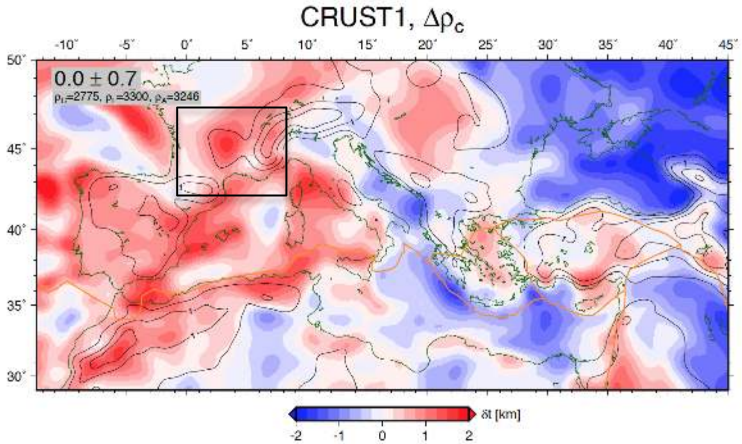


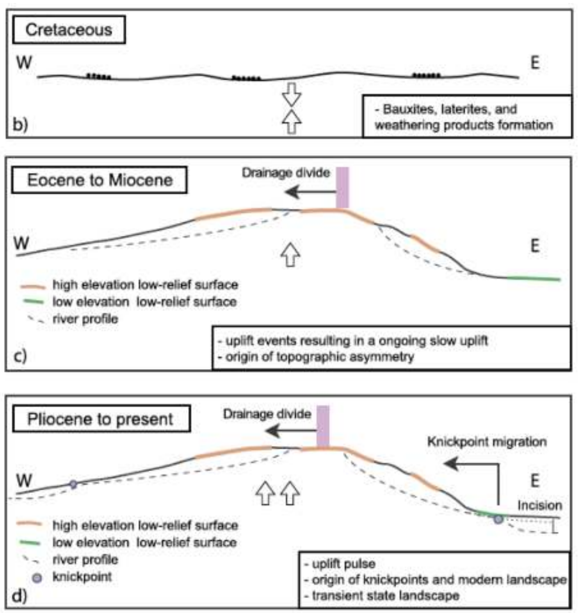
Dynamic Topography

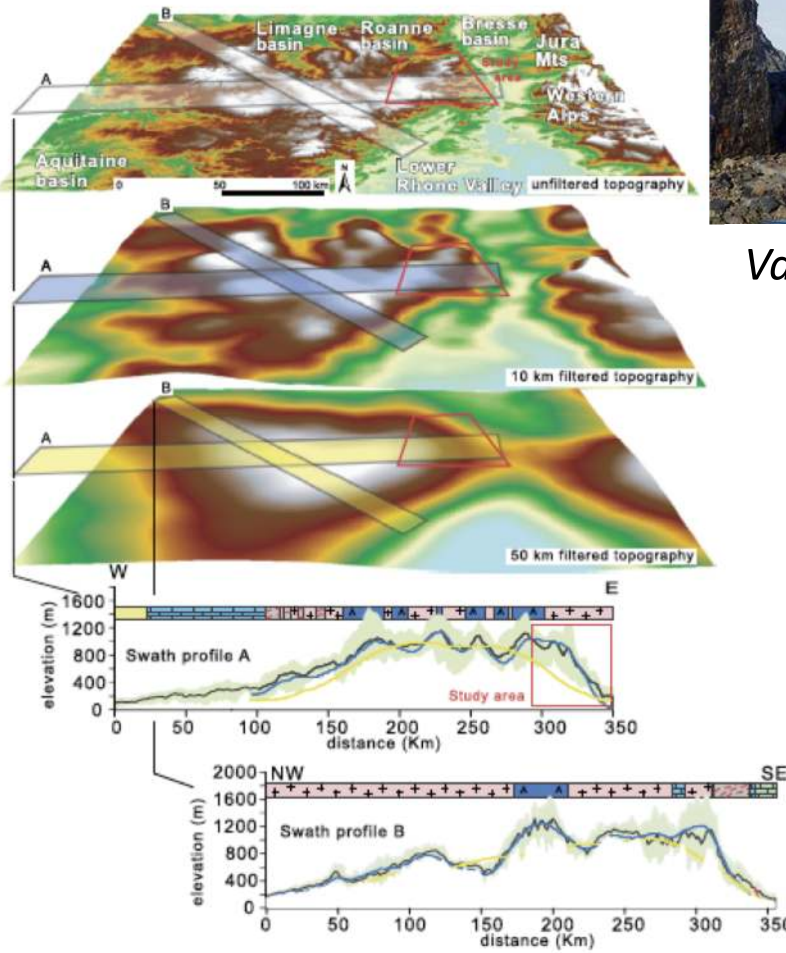


Faccenna and Becker, 2014; Boschi et al., 2010

Massif Central : baby plume







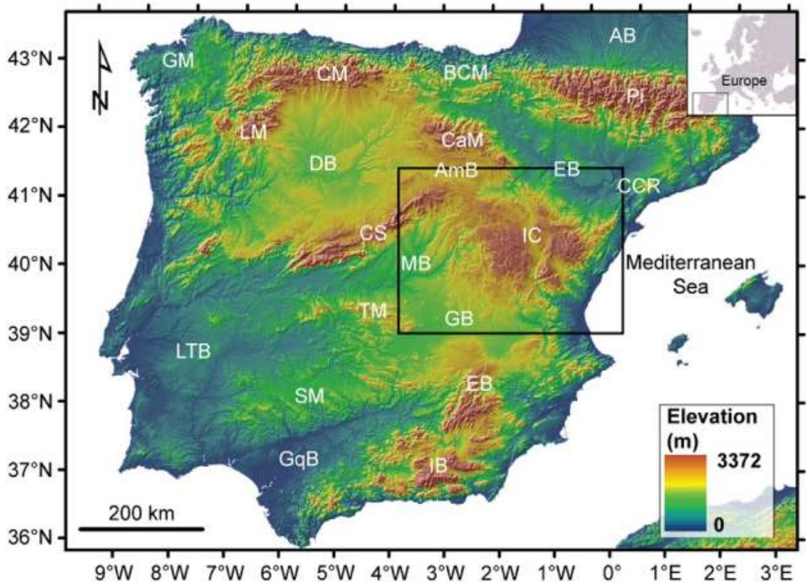
Valerio Olivetti

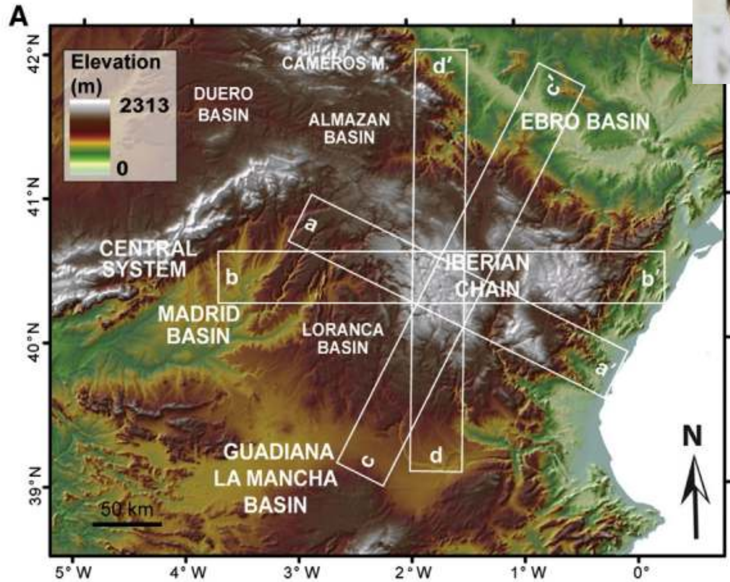
Residual: 500 m
Uplift of 250 m last 2 Ma

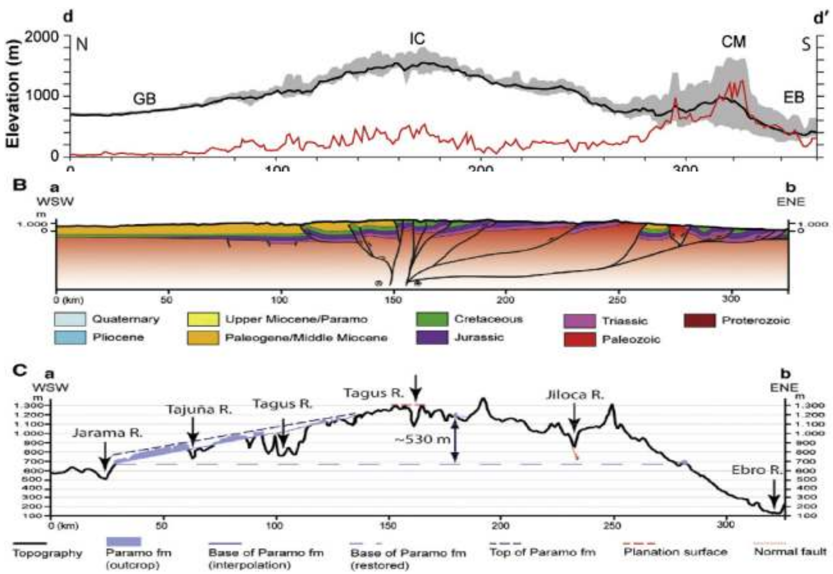
Olivetti et al., 2016

Iberian chain

Valentina Scotti





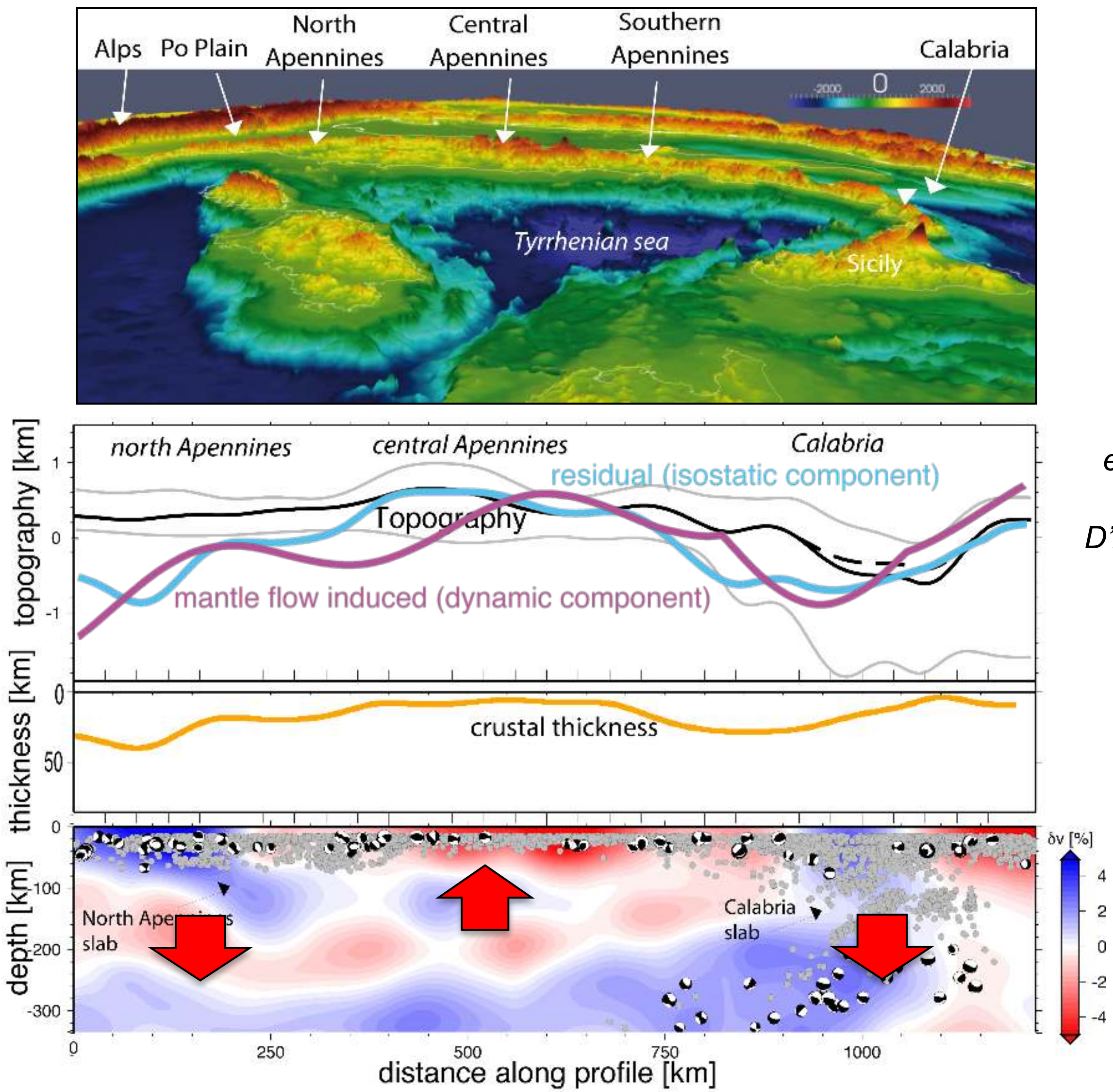


UPLIFT:

- 530 meters
- average 0.6 mm/yr
- From Middle Pliocene

Scotti et al., 2015; Giachetta et al., 2015

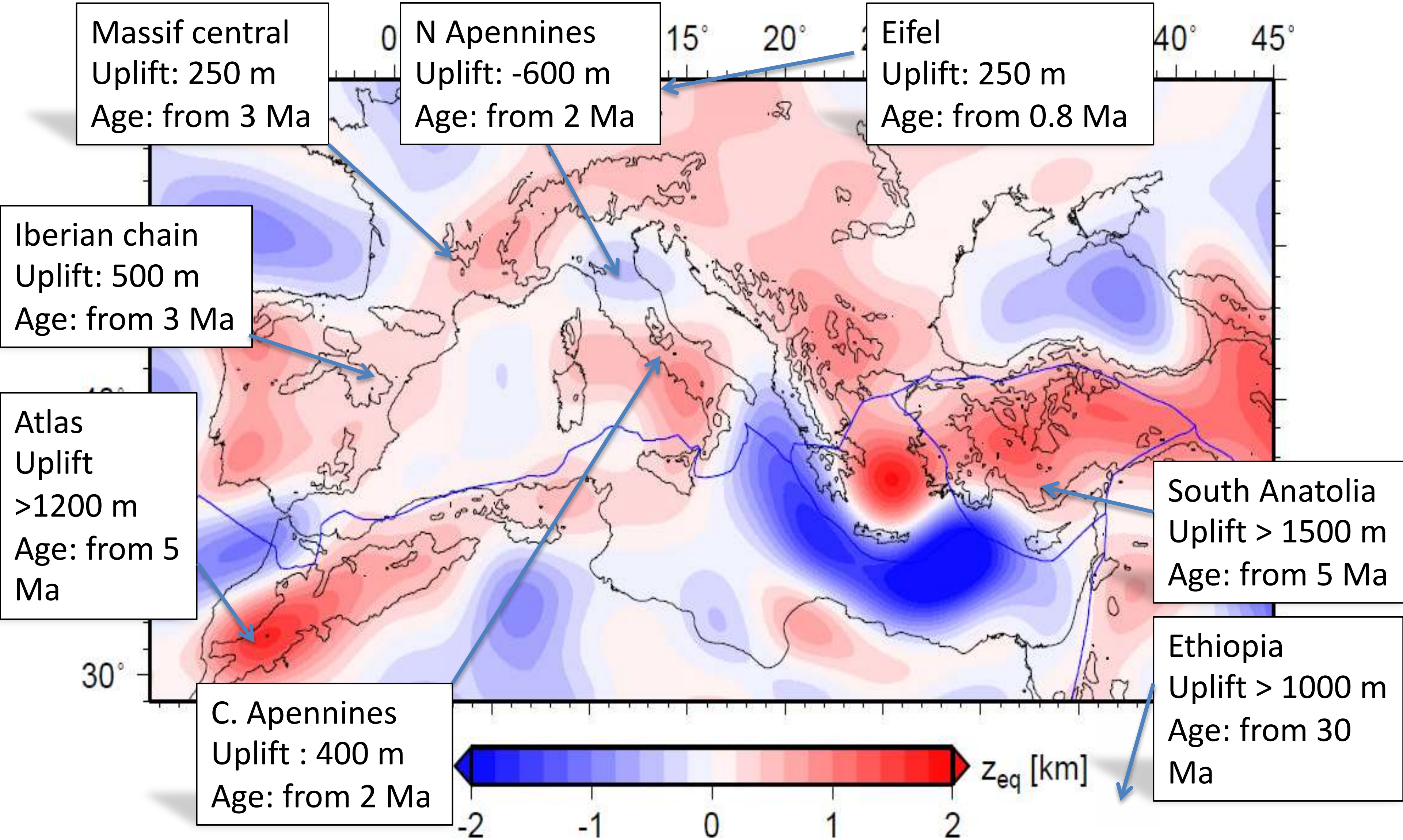
Apennines



contribution of subduction/mantle dynamics on the Apennines topography

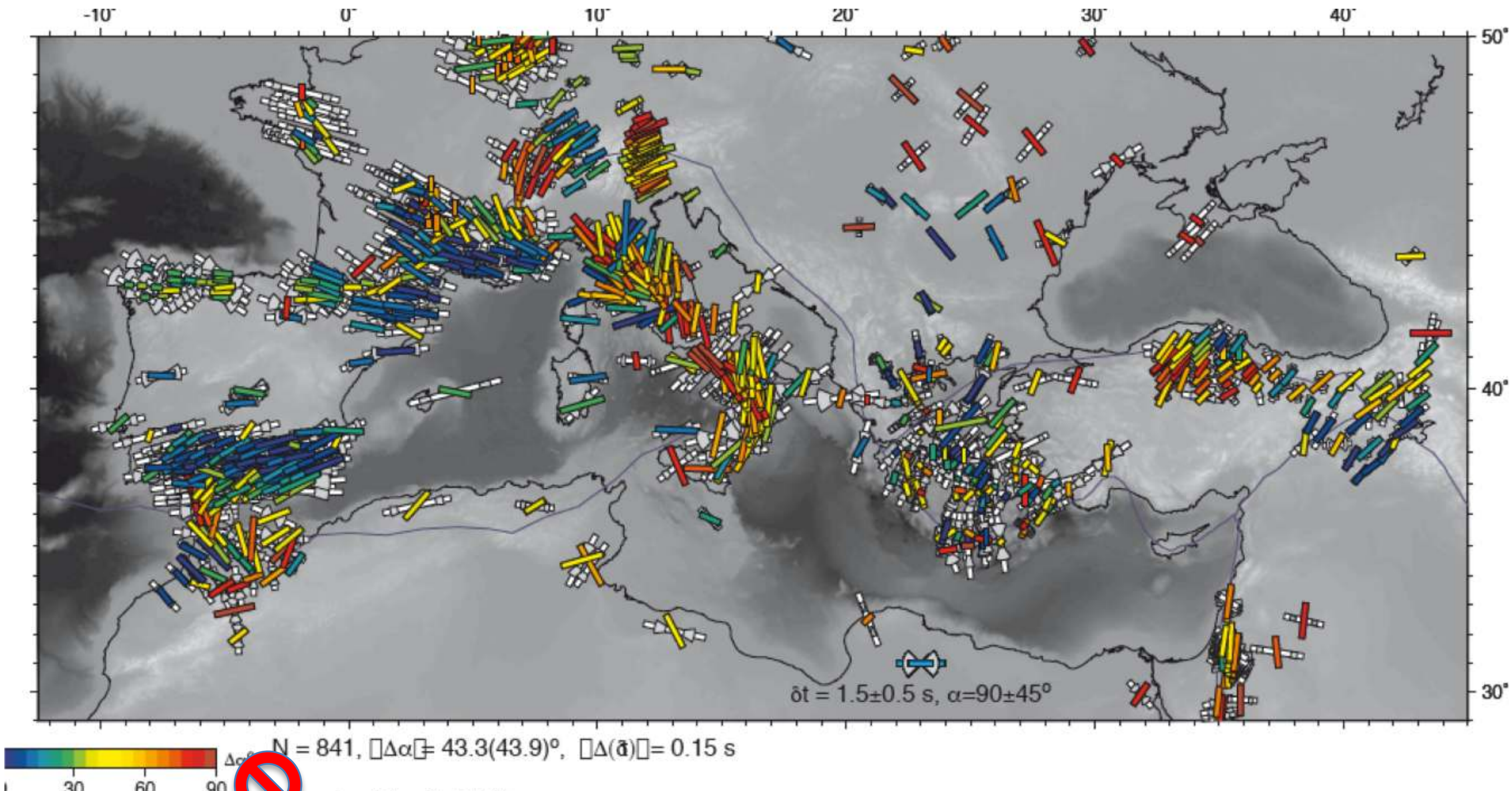
e.g., Royden, 1993; Buiter et al.,1998; Wortel and Spakman, 2000; Gvirtzman and Nur, 2001; D'Agostino et al., 2001; Shaw and Pysklywec, 2010; Carminati and Doglioni, 2012

RESIDUAL TOPOGRAPHY VS. GEOL. ESTIMATES

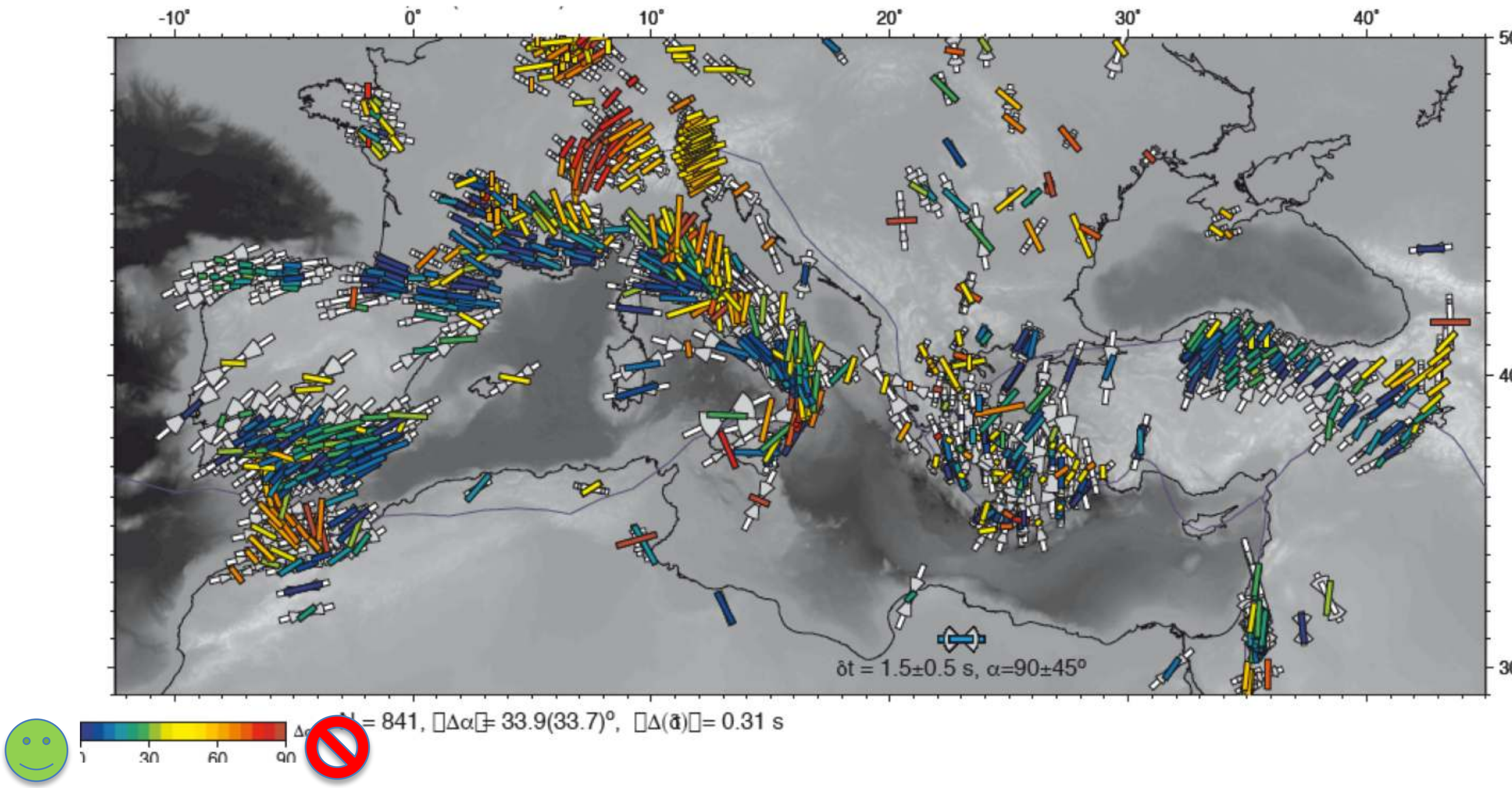


Geological information over residual topography calculated from the free air gravity anomaly (scaled and filtered as in Craig et al., 2011)

III° TEST: MANTLE ANISOTROPY
LARGE SCALE TOMOGRAPHY (SMEAN)

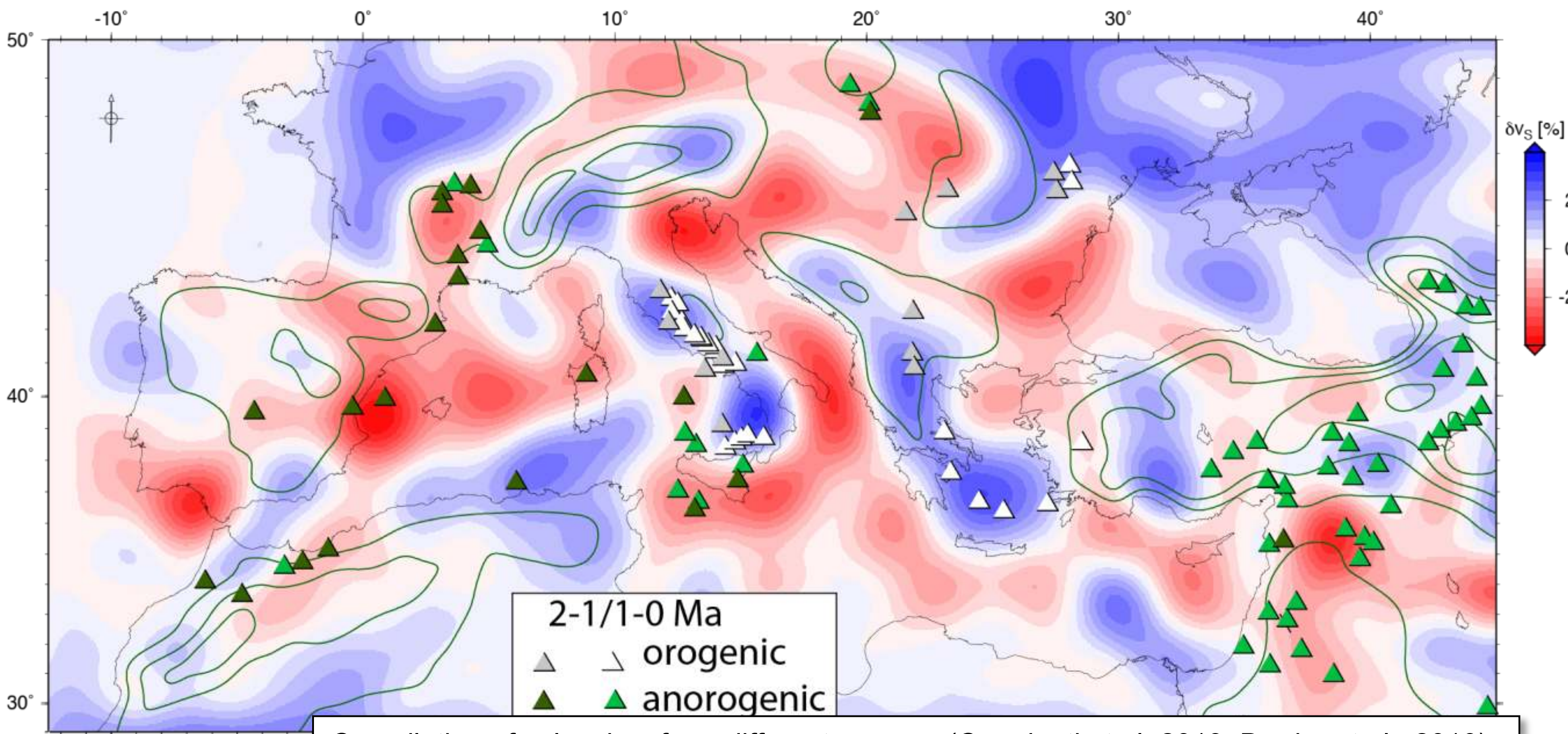


LARGE SCALE TOMOGRAPHY (SMEAN) AND SUBDUCTION ZONES



Back-arc basin: good fit with return flow related to the retreating slab

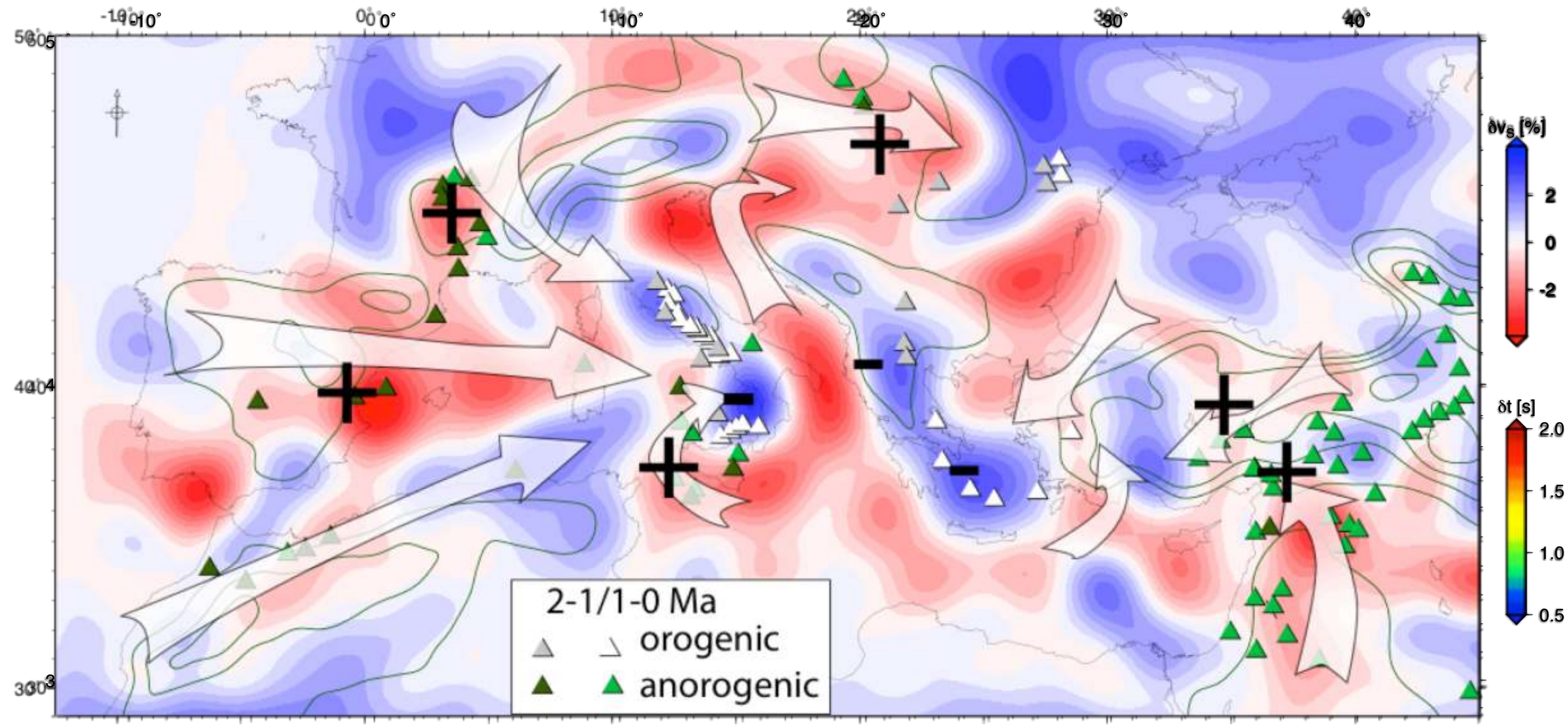
IV TEST: MEDITERRANEAN VOLCANISM



Compilation of volcanism from different sources (Carminati et al. 2013; Barrier et al., 2010)
Plotted on average P wave velocity depth 100-400 km PMO1 model.

Anorogenic volcanoes plot on low velocity anomalies
Orogenic volcanoes plot on high velocity anomalies

MANTLE FLOW PATTERN



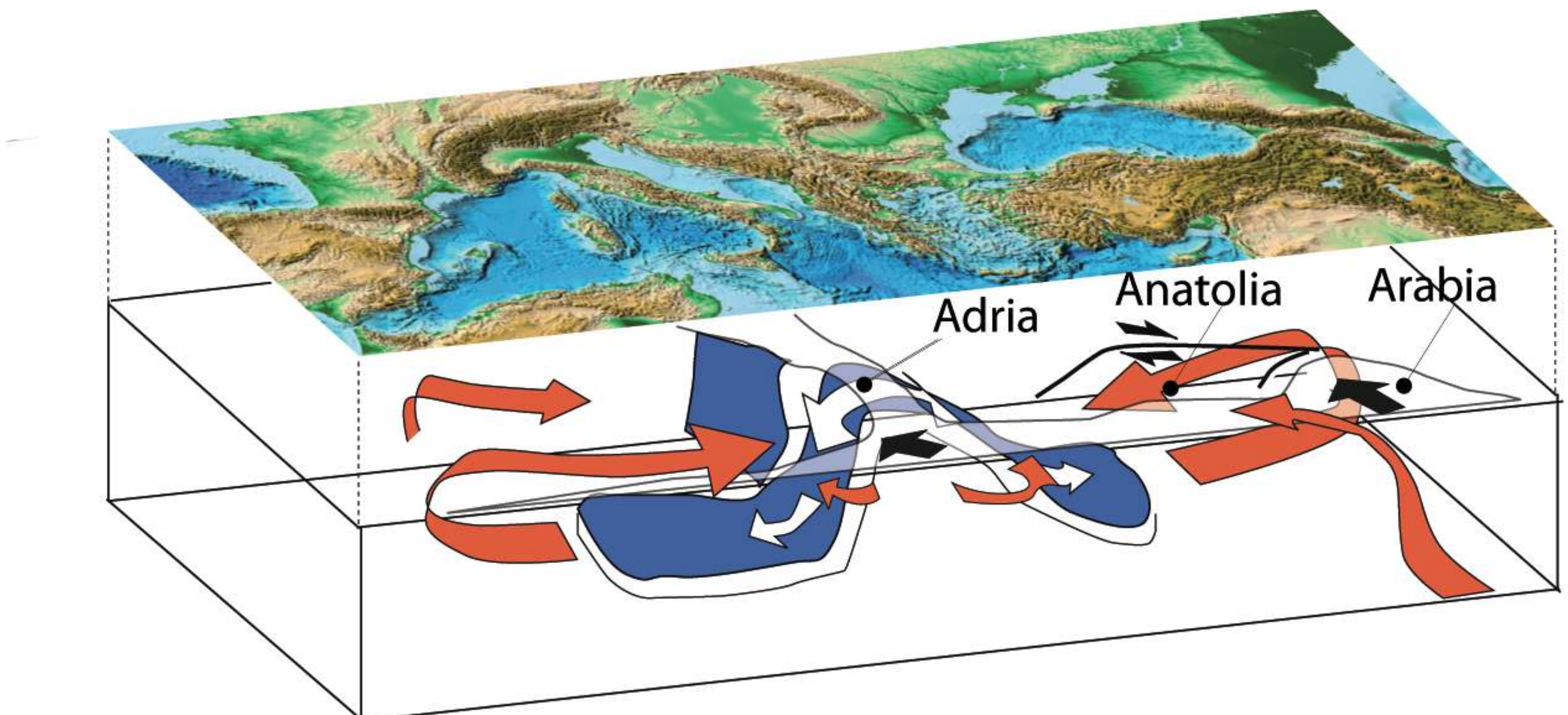
Large scale return flow: upwelling beneath Iberia and Anatolia due to downwelling in Central Mediterranean (Tyrrhenian and Aegean).

REMARKS

- Subduction/slab pull dominated system localized in the Central Mediterranean
- flow restricted in the shallow upper mantle -horizontal and vertical surface deformation
- Return flow with upwelling beneath Anatolia, souther France and Iberia
- Small-scale toroidal flow at slab edges

Open questions

- Lateral connection with Arabia (probable) and Atlantic (?)
- Better definition of crustal deformation
- Better definition of dynamic contribution to topo with field studies



THANKS

is talk is also at : https://www.youtube.com/watch?v=UEy1pybi3oI

ry short list of references from our group on Mediterranean subduction and convection

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