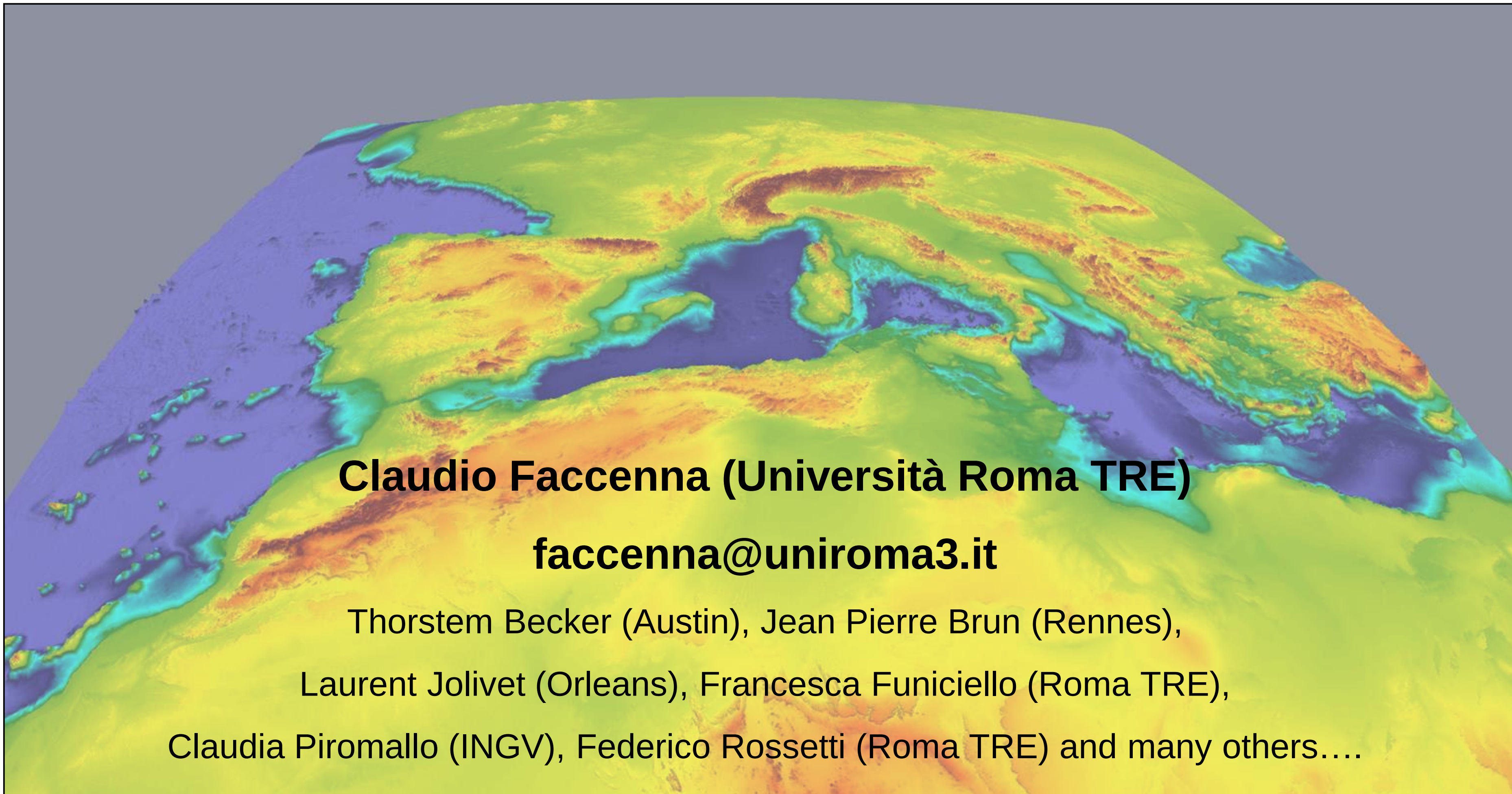
EGU, GIFT, 2017

SHAPING THE MEDITERRANEAN FROM THE INSIDE OUT



Claudio Faccenna (Università Roma TRE)

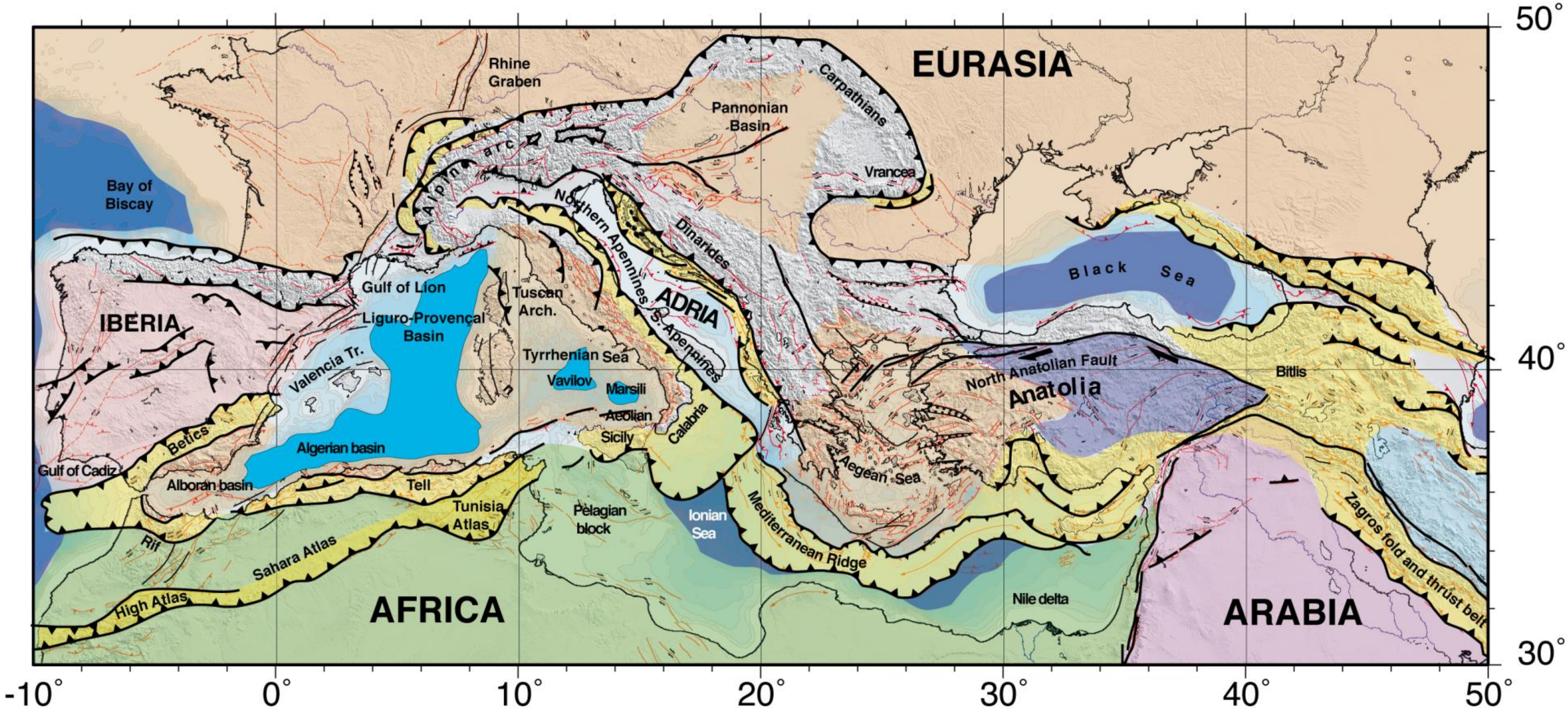
faccenna@uniroma3.it

Thorstem Becker (Austin), Jean Pierre Brun (Rennes),

Laurent Jolivet (Orleans), Francesca Funiciello (Roma TRE),

Claudia Piromallo (INGV), Federico Rossetti (Roma TRE) and many others….

THE MEDITERRANEAN TECTONICS PUZZLE



results of a relatively simple mantle convection pattern

OUTLINE OF THE TALK

- Fundaments of mantle dynamics
- Constraints on Mantle flow in the Mediterranean
- Modelling Mantle flow in the Mediterranean

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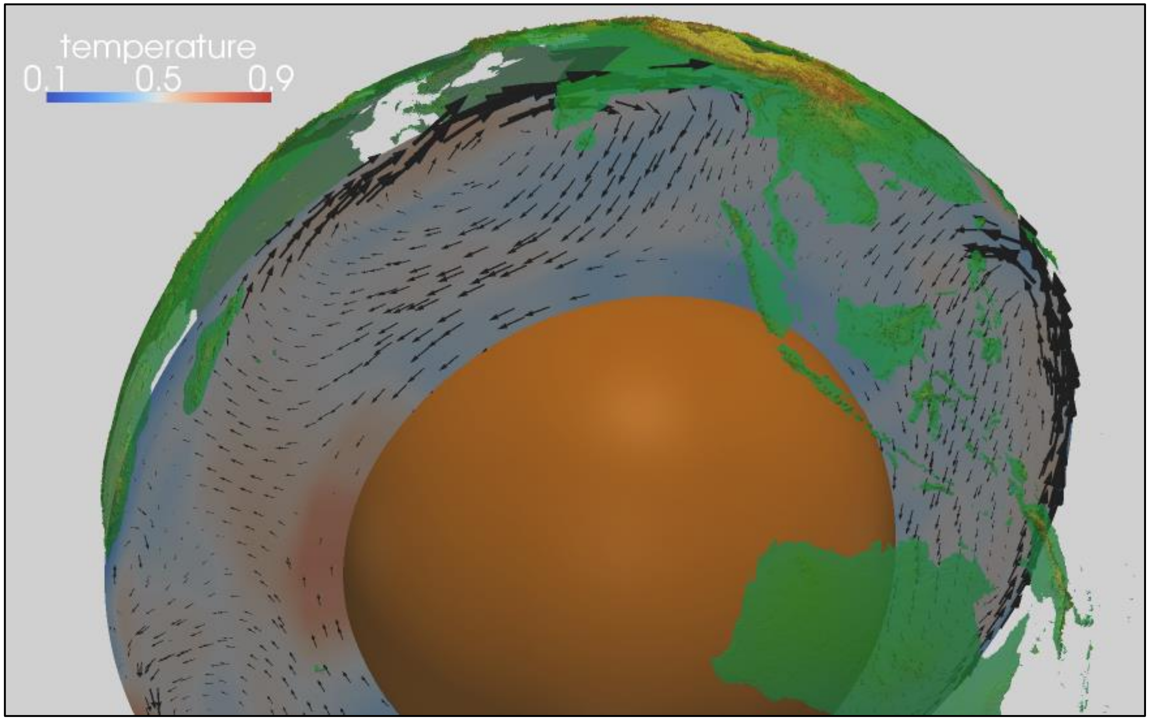
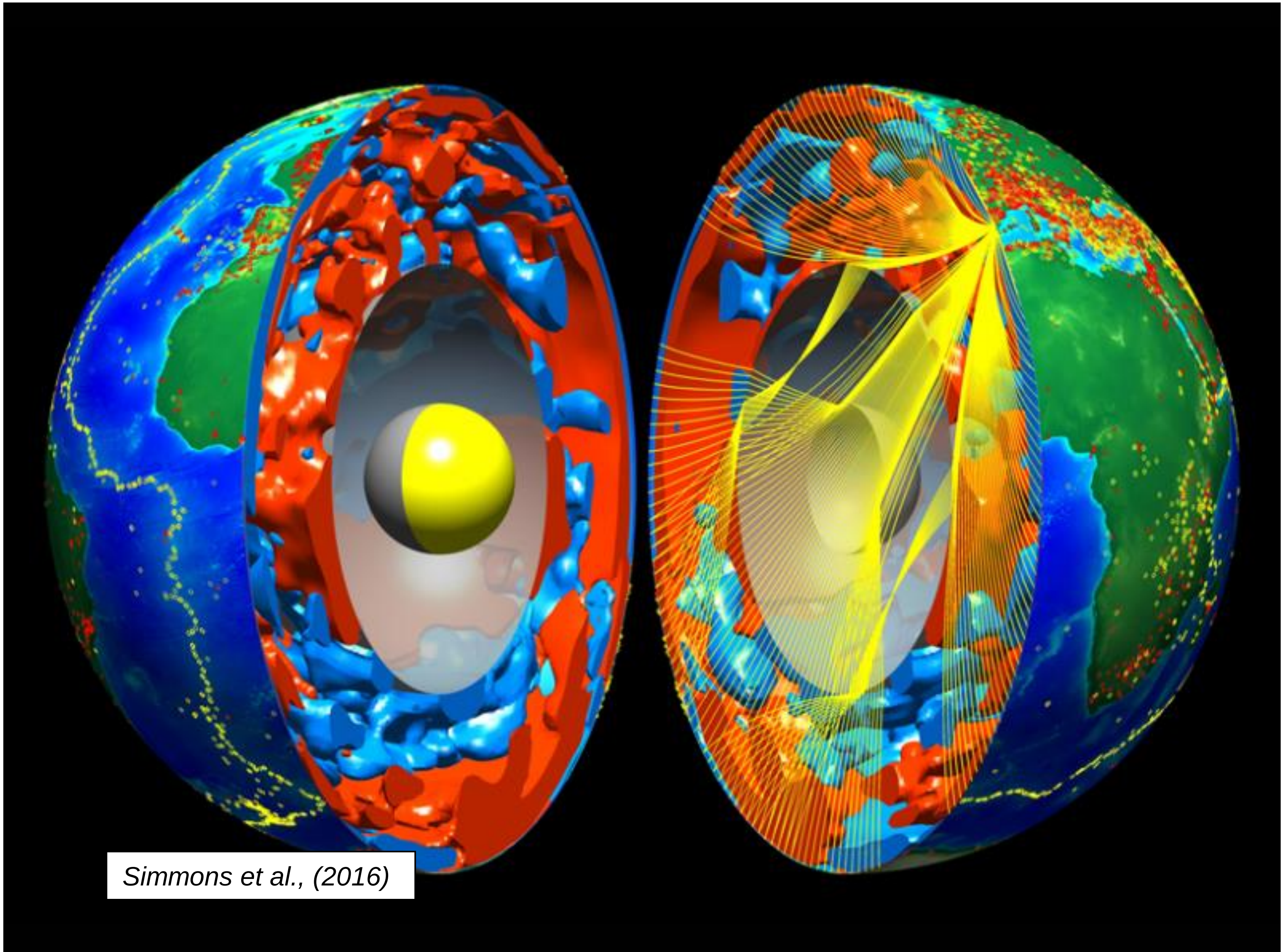
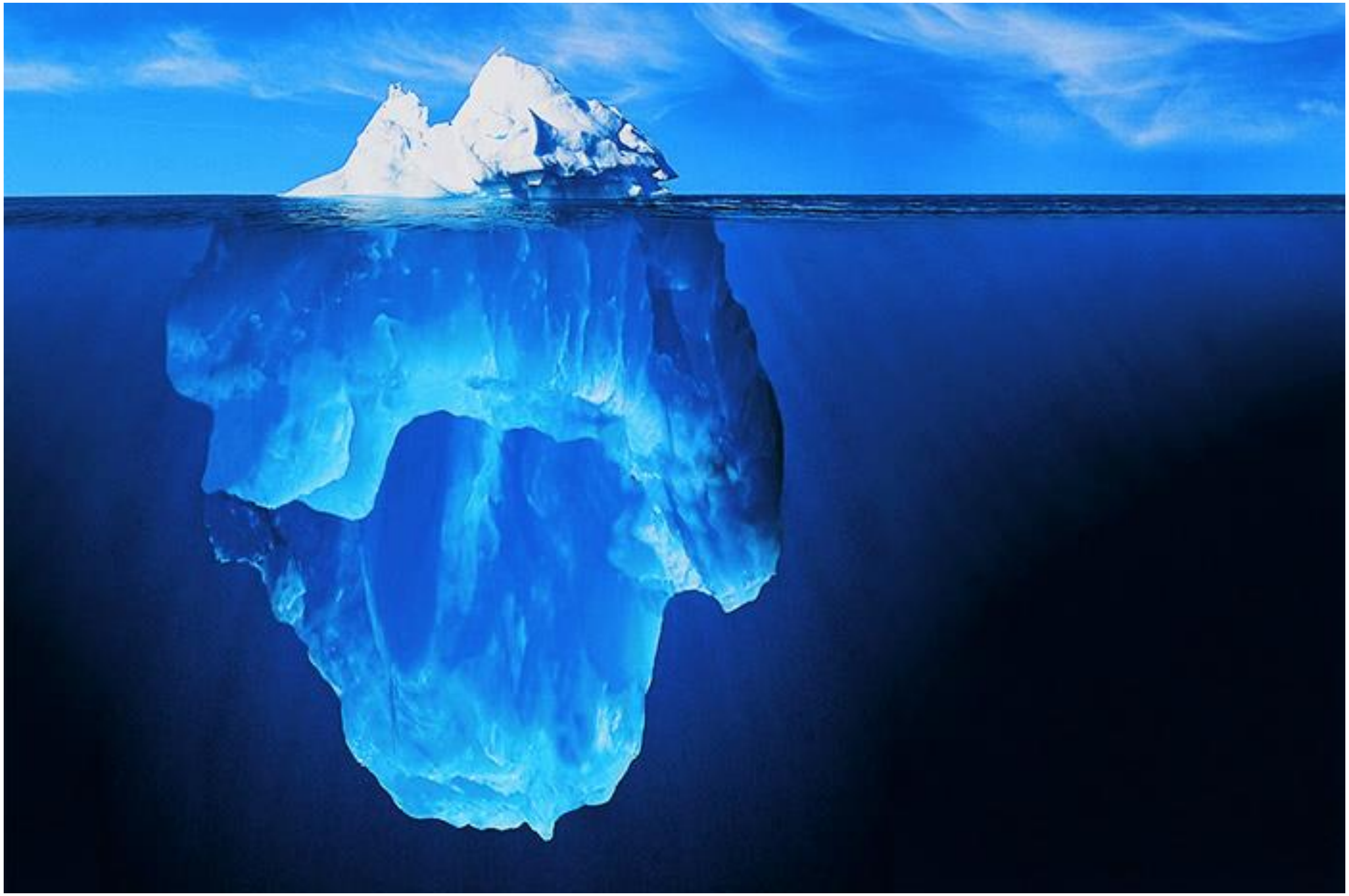


FUNDAMENTS OF MANTLE DYNAMICS

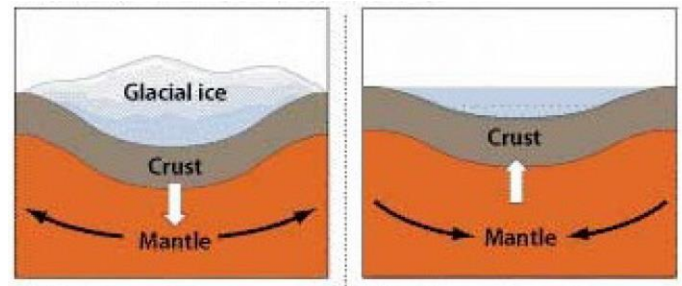


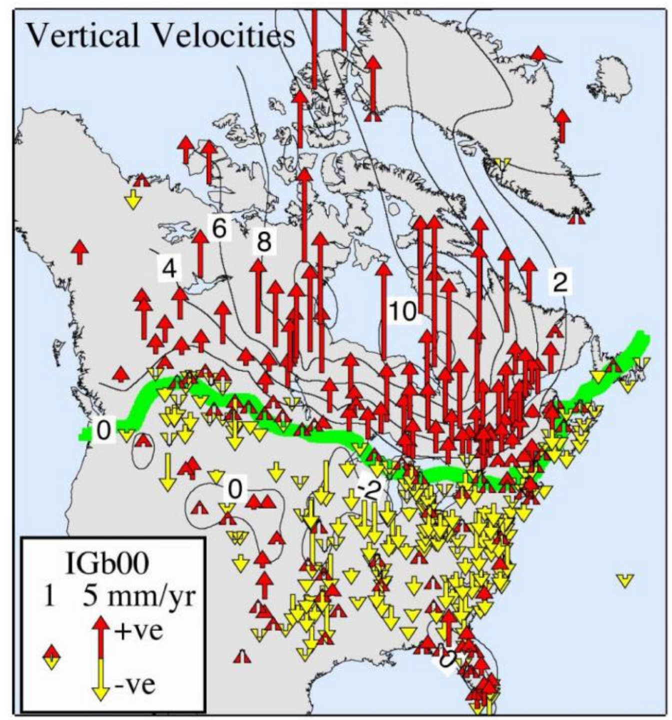
1) POST-GLACIAL REBOUND



From http://www.spindrift-racing.com

1) POST-GLACIAL REBOUND

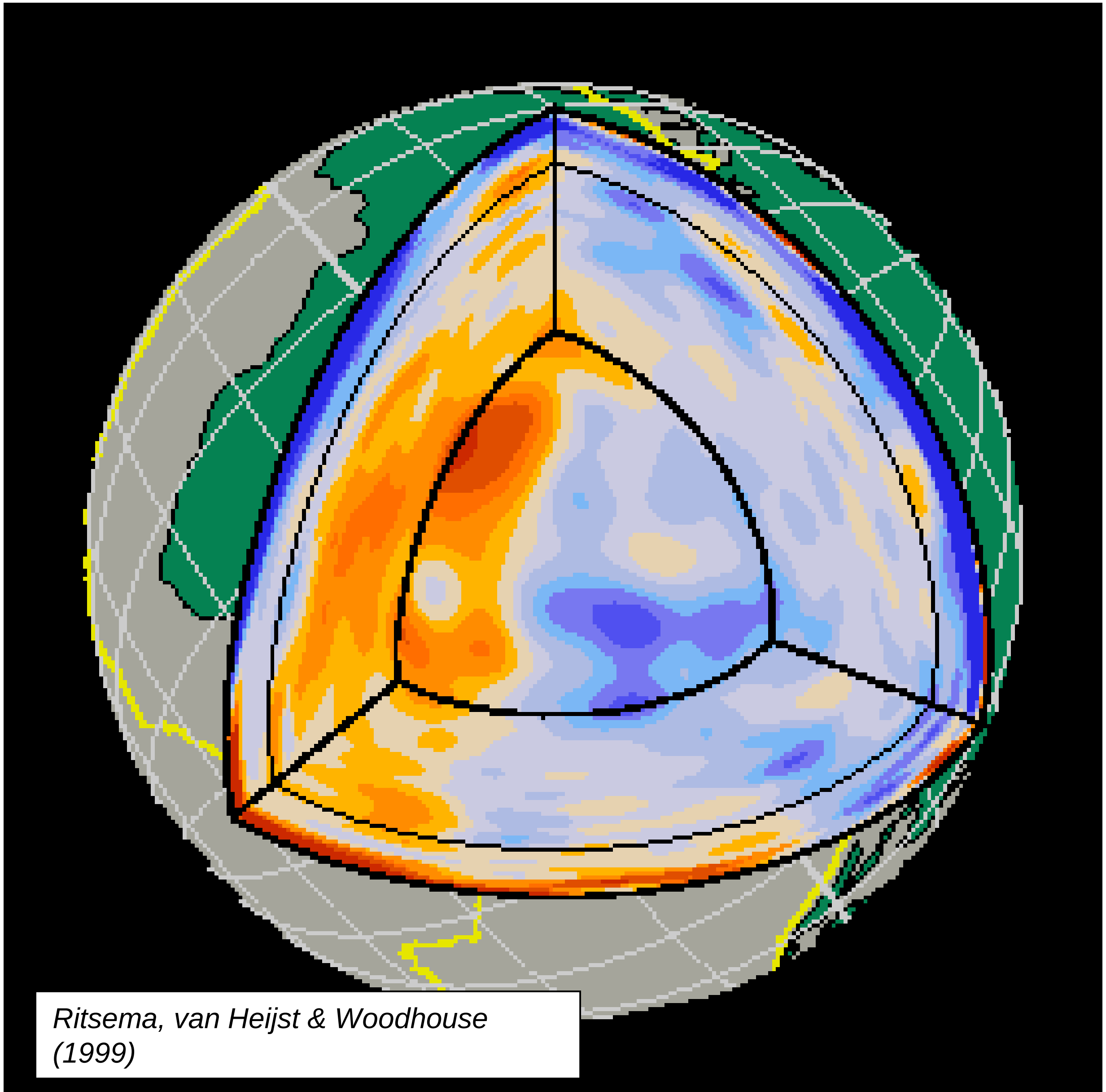




Sella et al, 2006

- Rebound of continents after melting of ice-caps after last ice age produces unloading and uplift.
- Mantle beahves as fluid (not melt) with Viscosity of 10^{22} Pa s (Haskell, 1935)

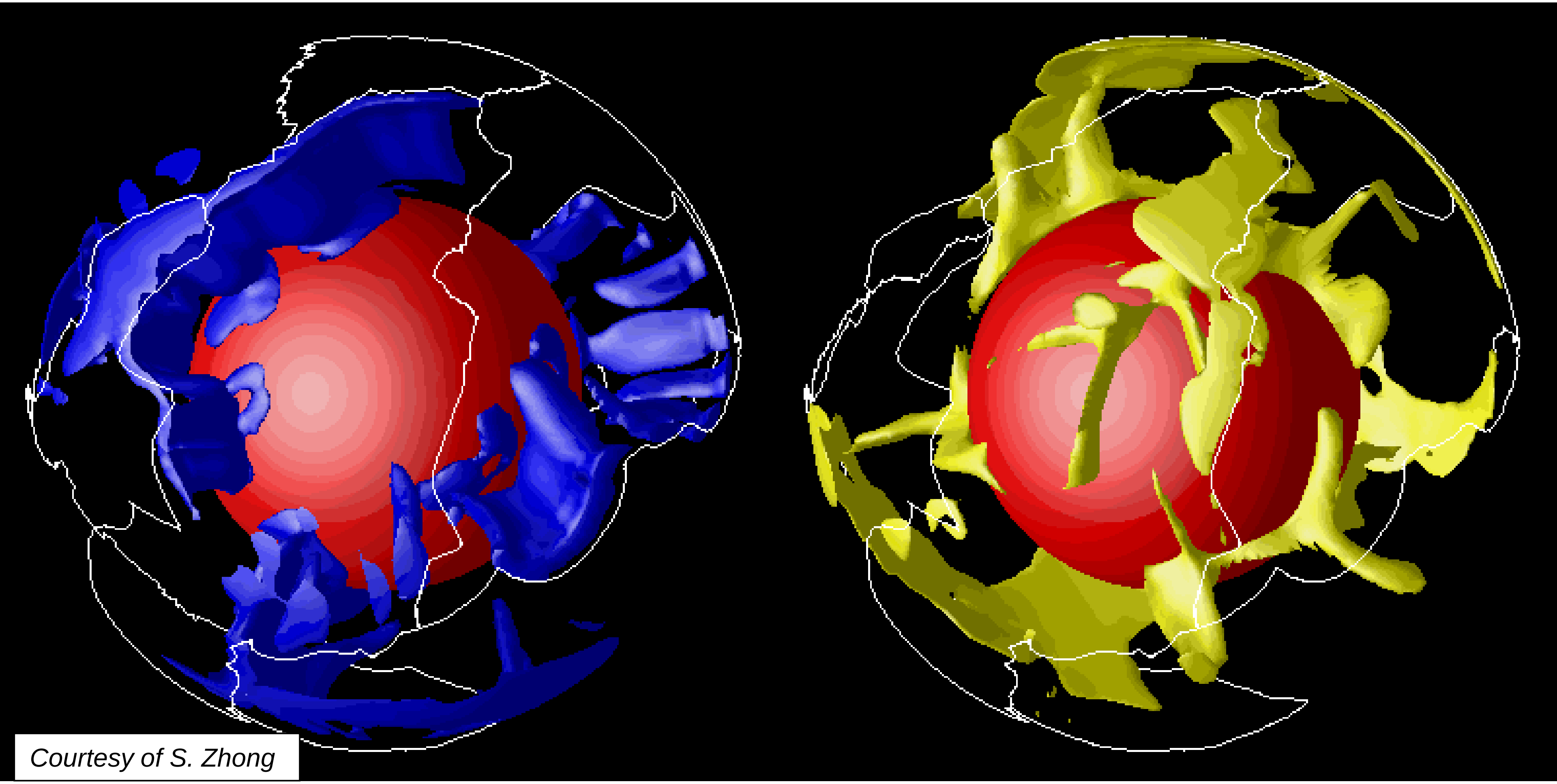
2) MANTLE CONVECTION



Ritsema, van Heijst & Woodhouse (1999)

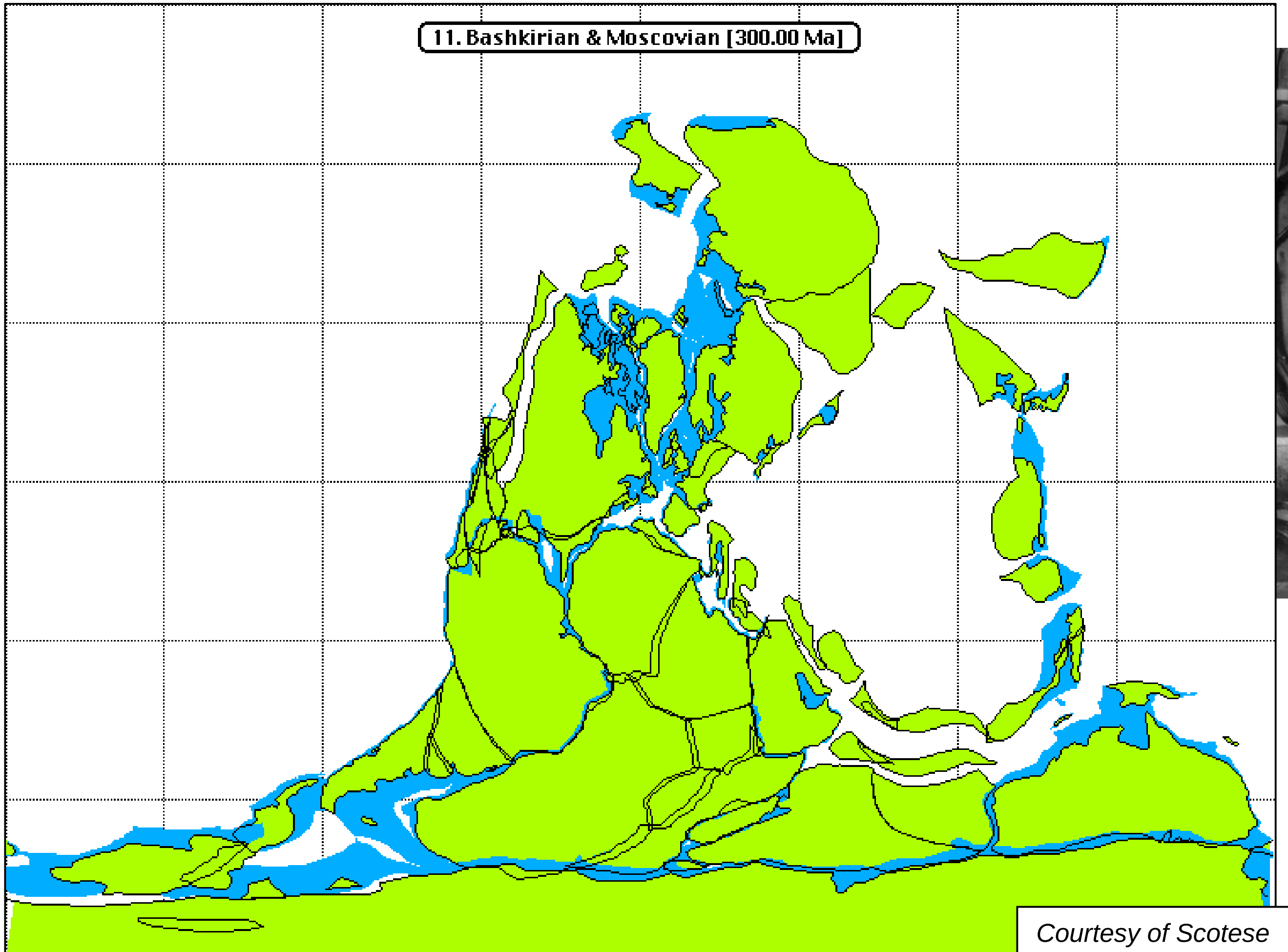
Arthur Holmes
“Principles of Physical Geology”

2) MANTLE CONVECTION



blue downwelling, yellow upwelling

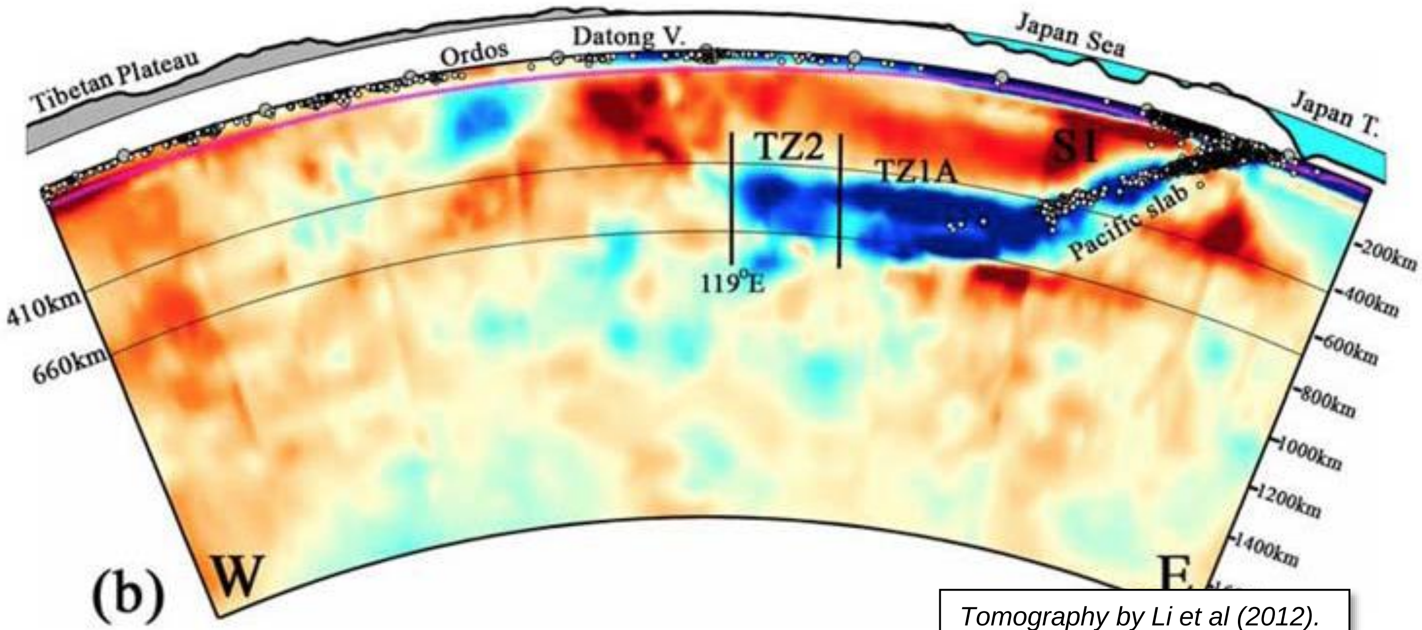
3) CONTINENTAL DRIFT



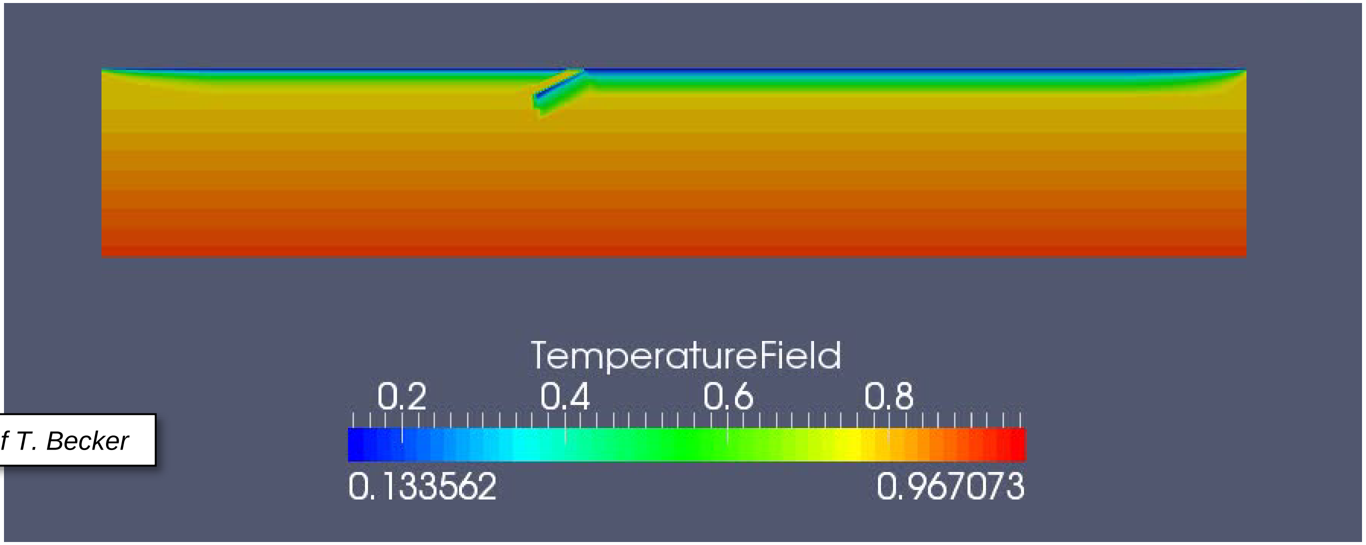
Alfred Wegener

Alfred Wegner (1915)
«The Origin of Continents and Oceans"

4) SUBDUCTION

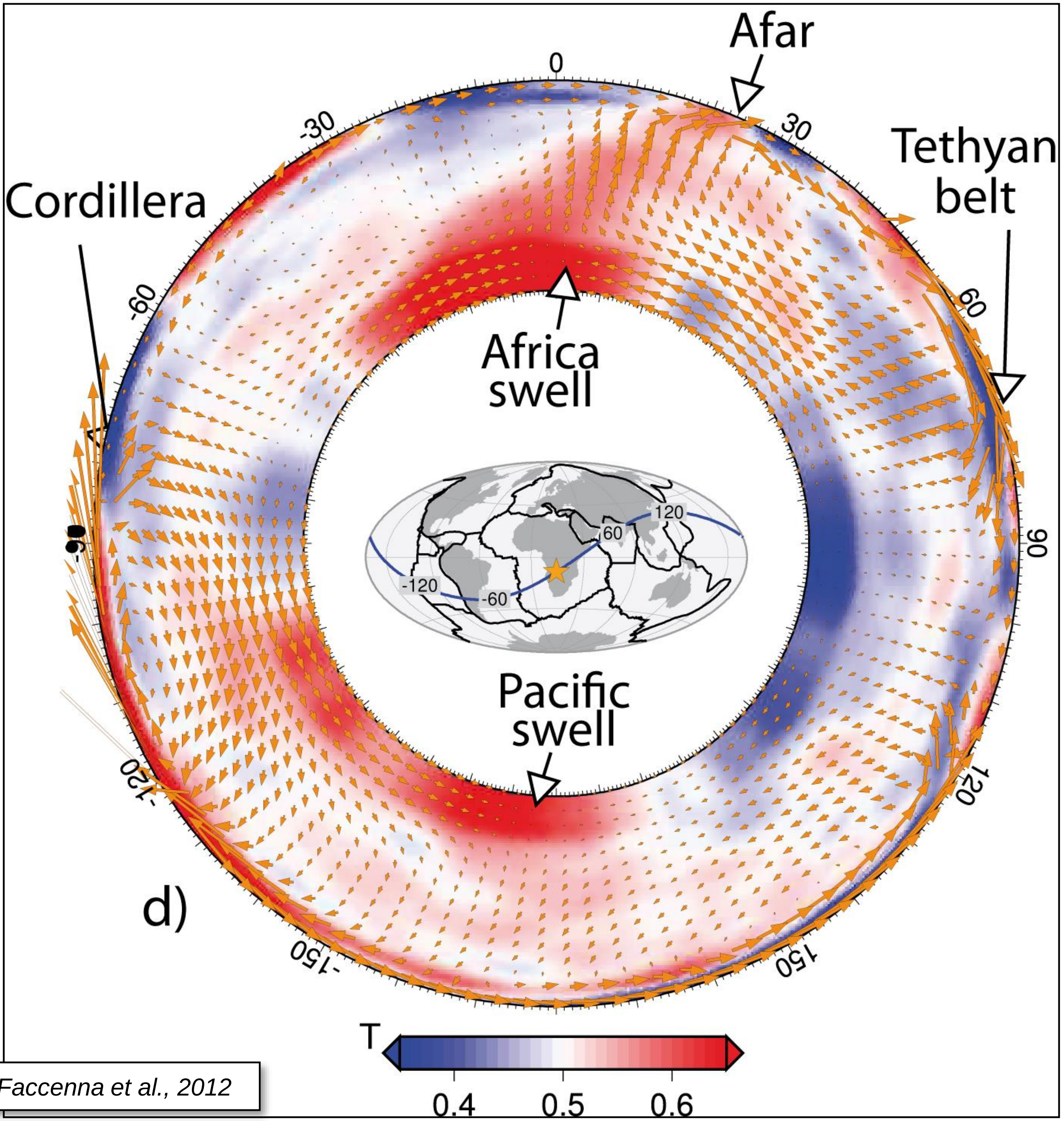


Tomography by Li et al (2012).



Courtesy of T. Becker

summary



Faccenna et al., 2012

- Earth cools to space
Total heat output from Earth about 46TW (1 TeraWatt = 1 trillion Watts) (½ from primordial and ½ from radioactive decay, e.g., of Uranium, Thorium)

Mantle behaves as a viscous fluid over geological time scale, convecting at slow rate cm/yr

The present-day pattern shows a symmetric, four convective cells

Lithosphere (outer portion of the mantle and the crust) behaves as rigid outer shell.

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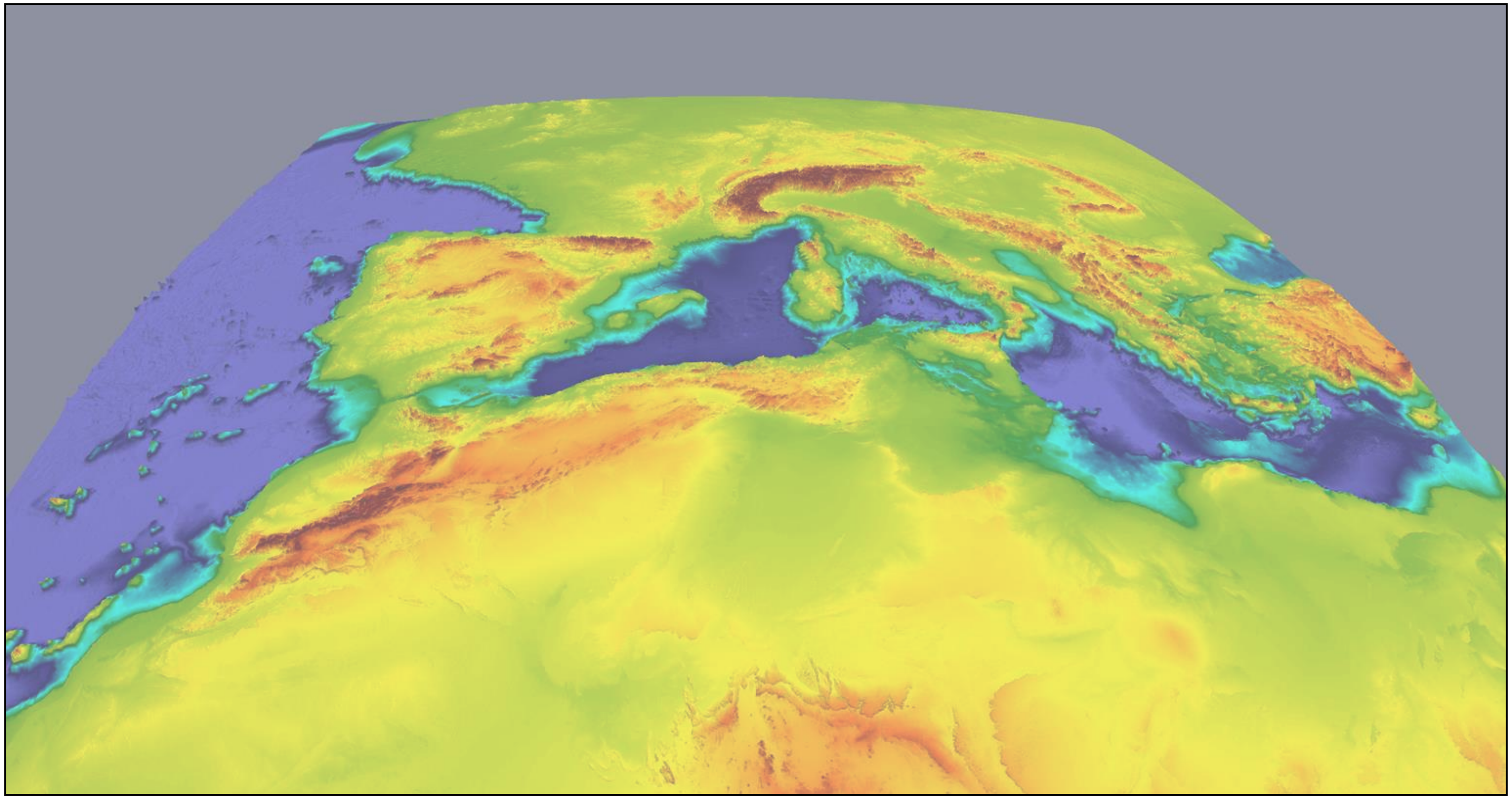
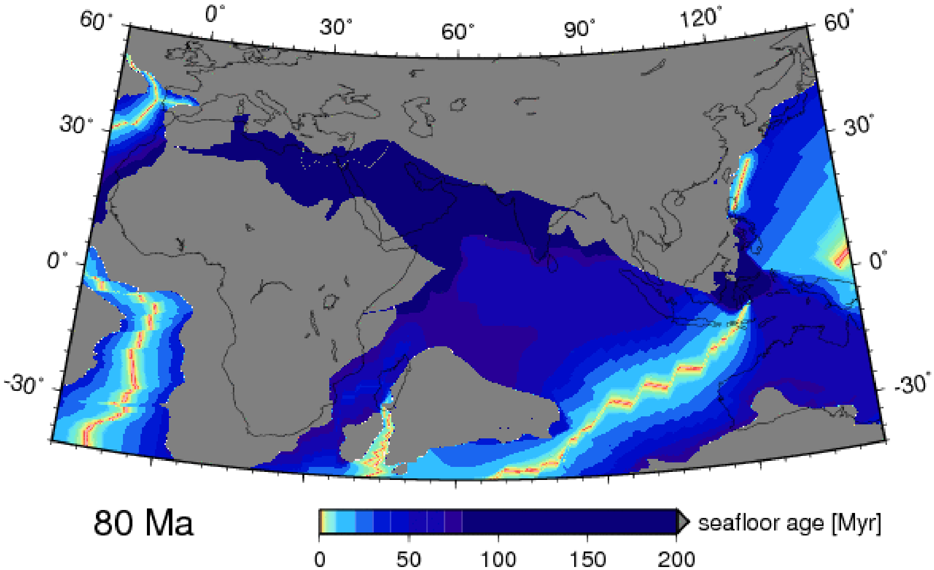
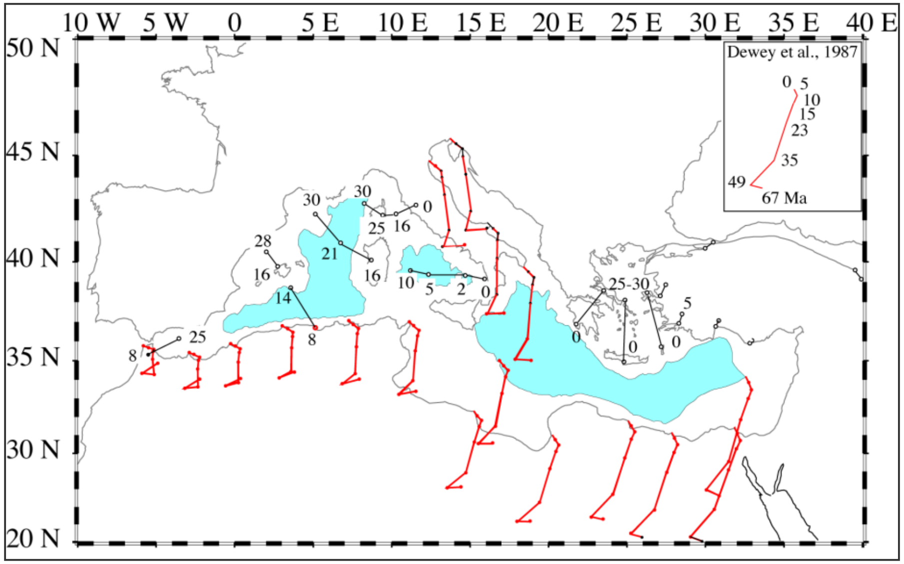


AFRICA, ARABIA AND INDIA KINEMATICS

- AF/EU convergence velocity

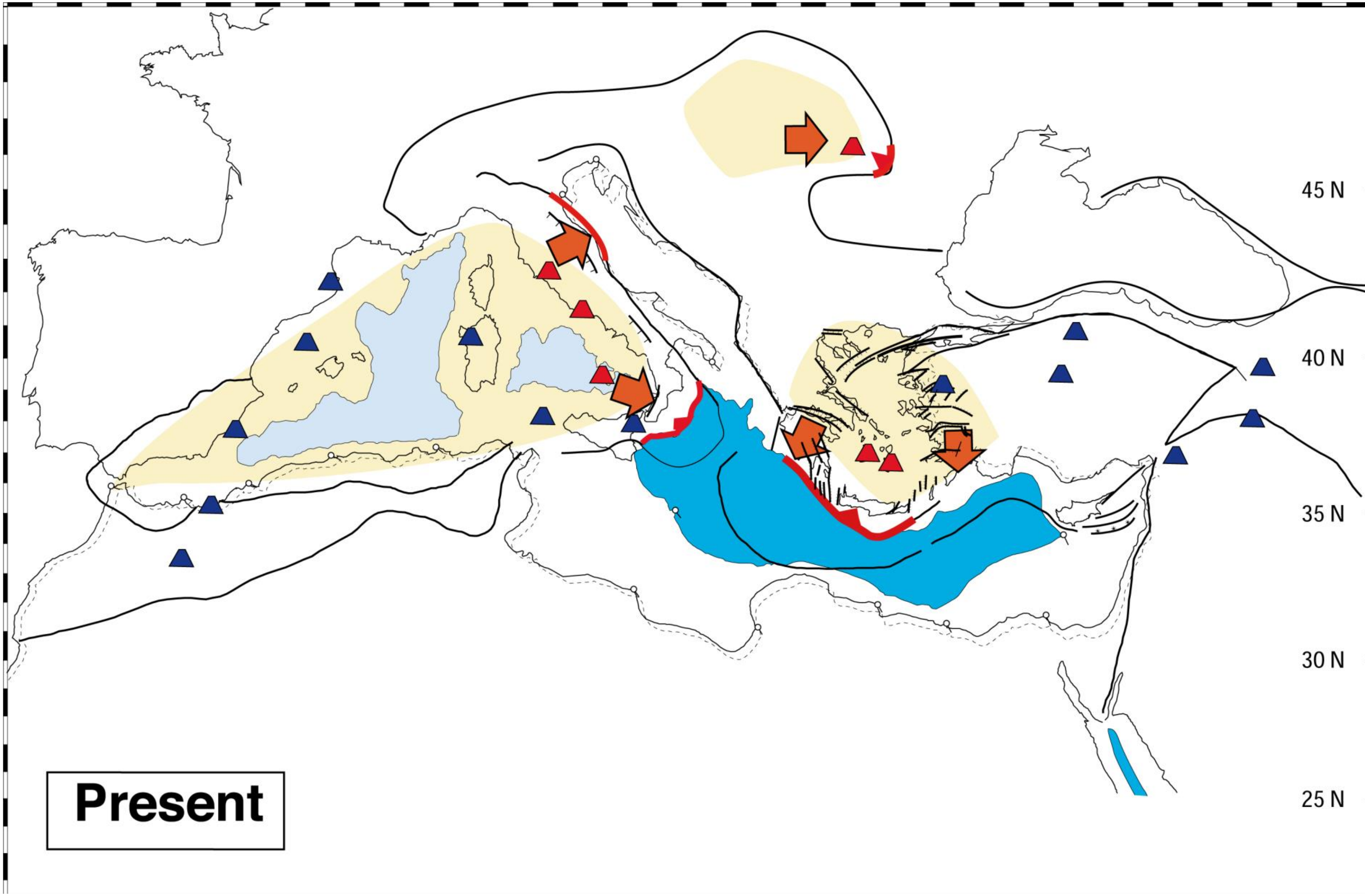


Müller et al., 2008; Torsvik et al., 2008



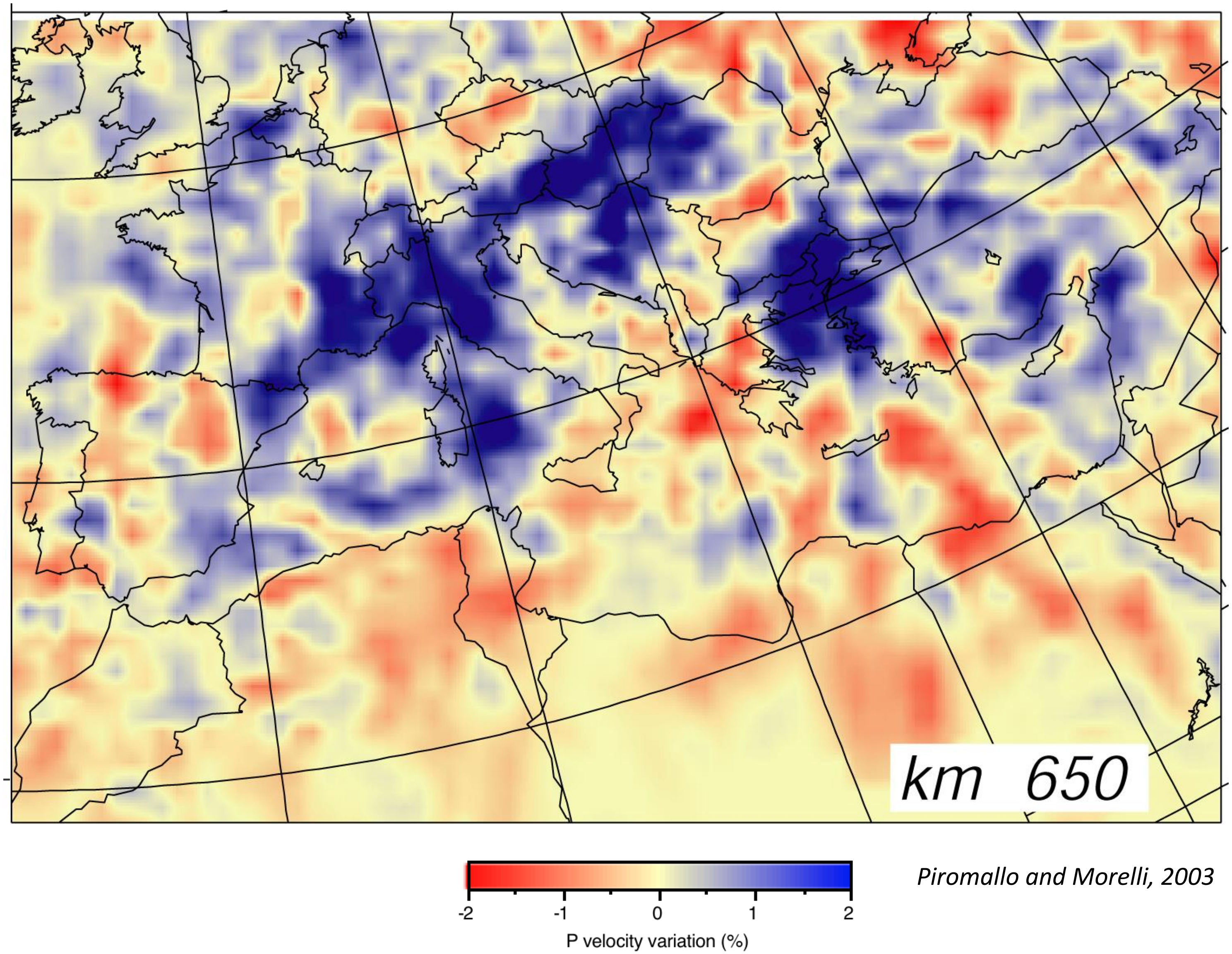
……a slow convergence

THE MEDITERRANEAN EVOLUTION



Subduction zones retreating towards the Central Mediterranean

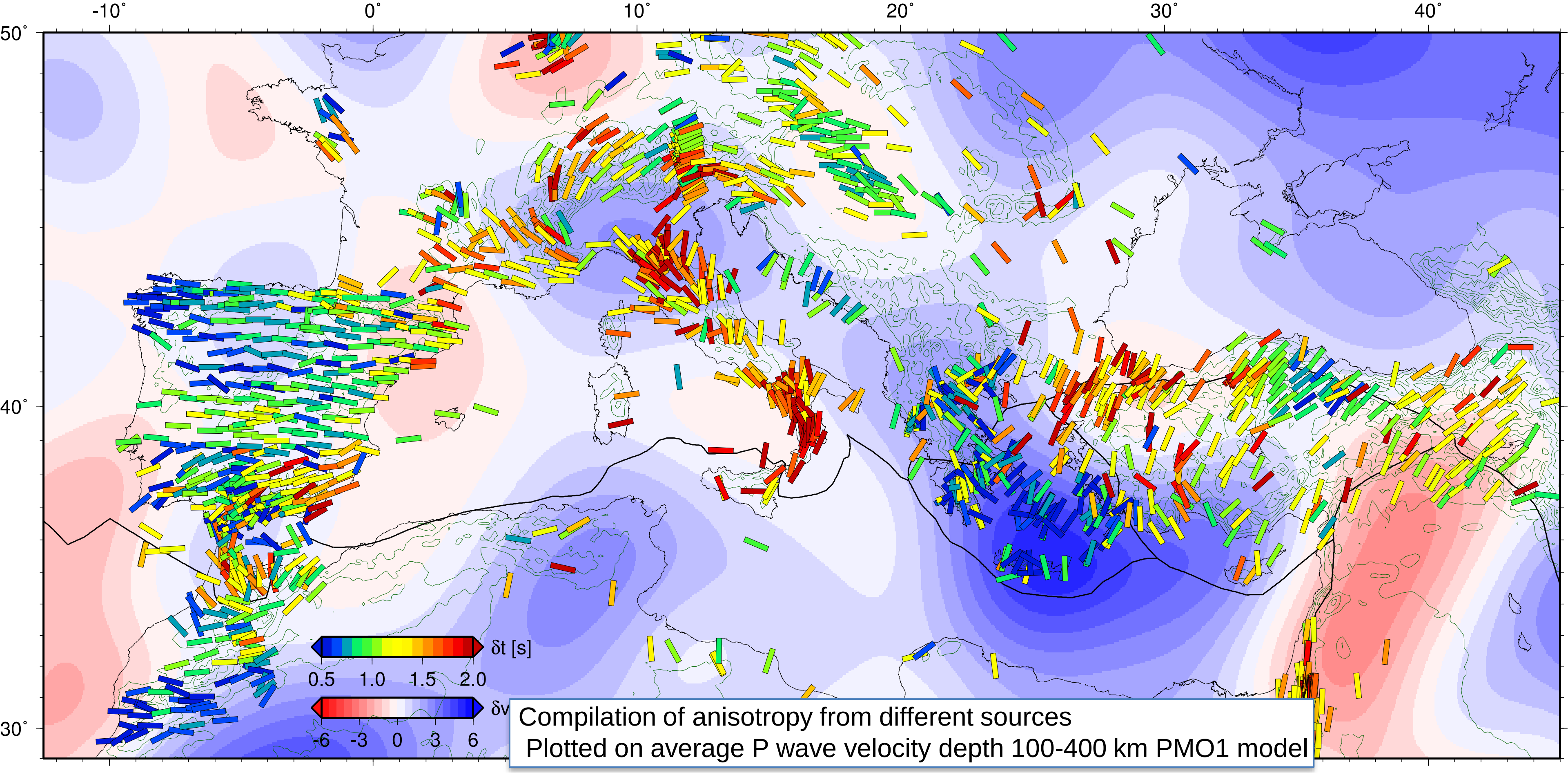
THE MEDITERRANEAN MANTLE STRUCTURE



Piromallo and Morelli, 2003

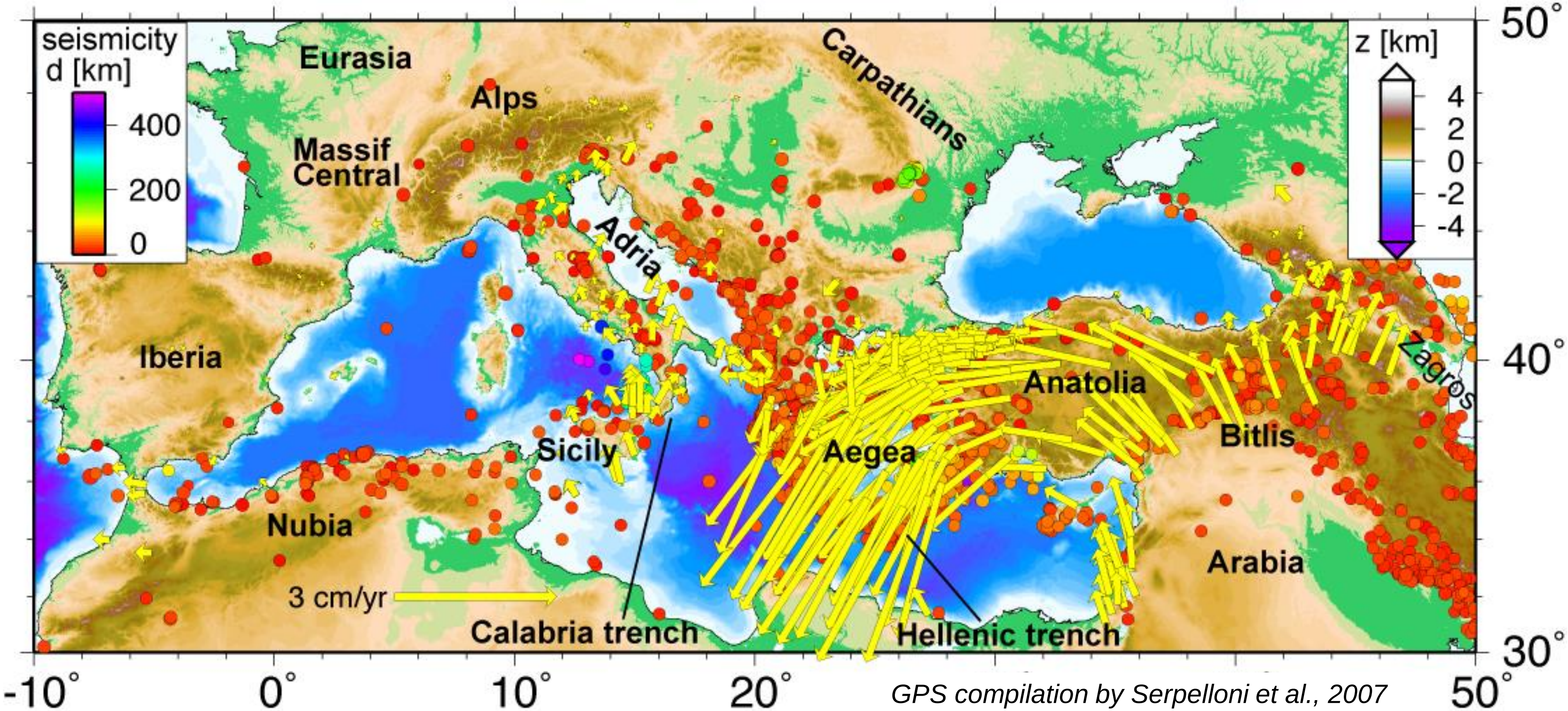
an almost restricted upper mantle …

SEISMIC ANISOTROPY



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

THE MEDITERRANEAN



GPS compilation by Serpelloni et al., 2007

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

OUTLINE OF THE TALK

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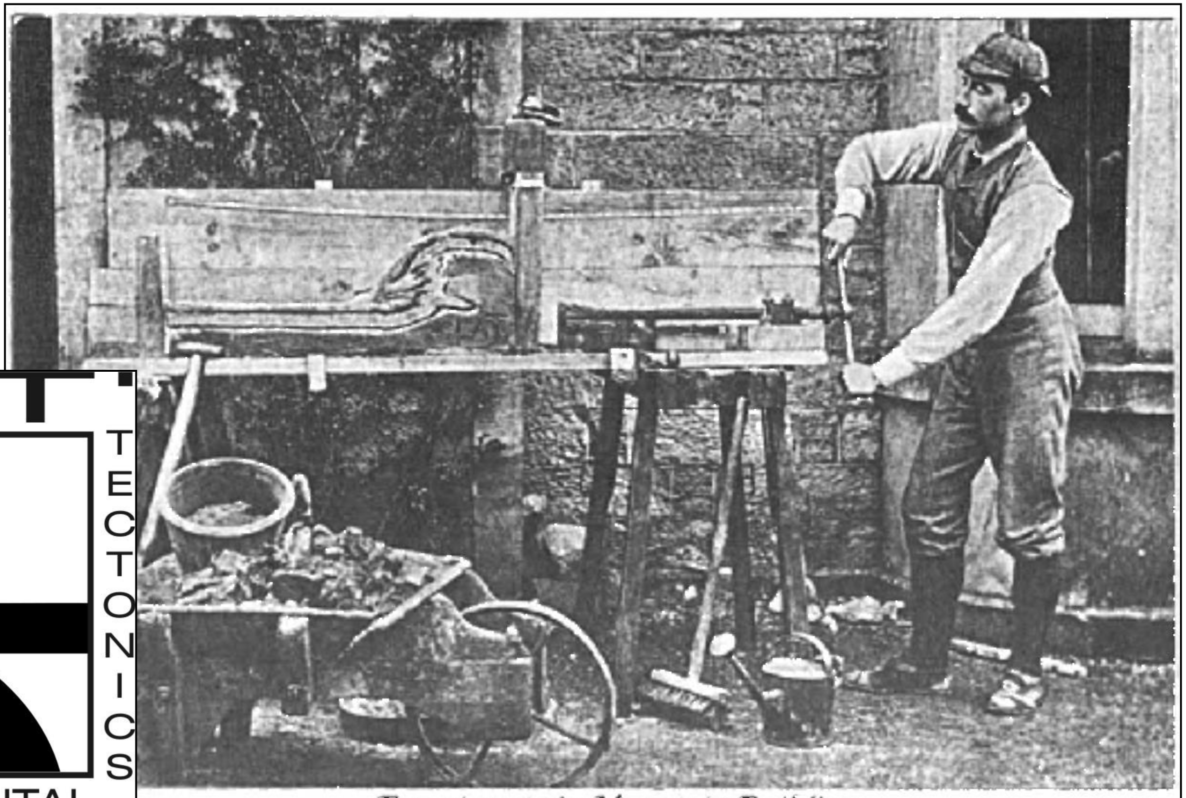
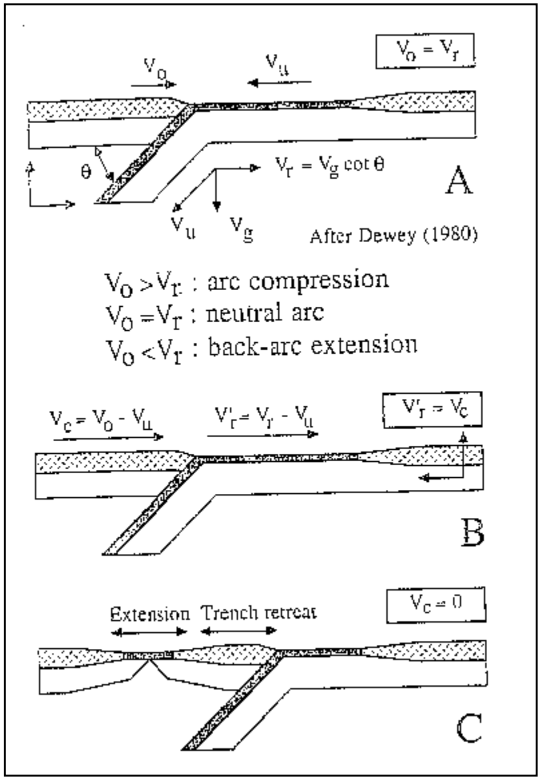


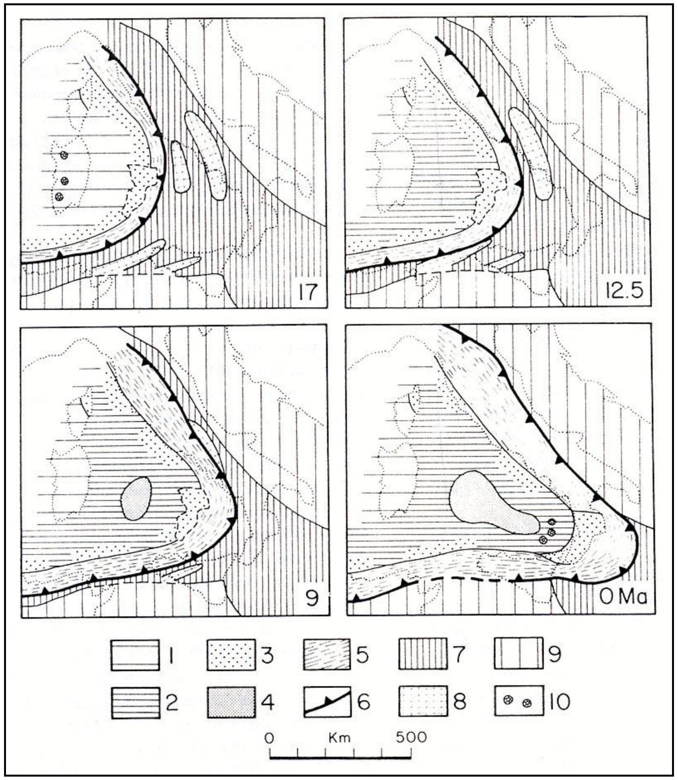
Experiments in Mountain Building

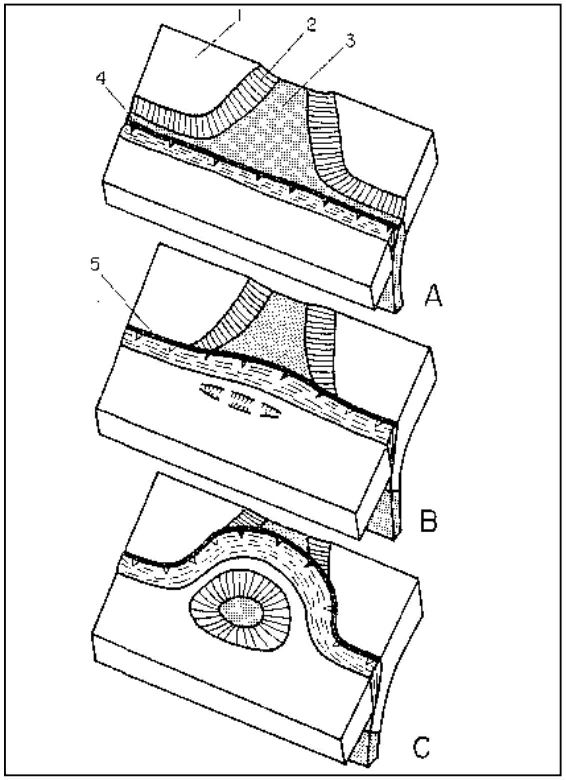
LET
ROMA TRE UNIVERSITÀ DEGLI STUDI
LABORATORY EXPERIMENTAL TECTONICS

THE SLAB ROLLBACK MODEL

(Dewey et al., 1980)

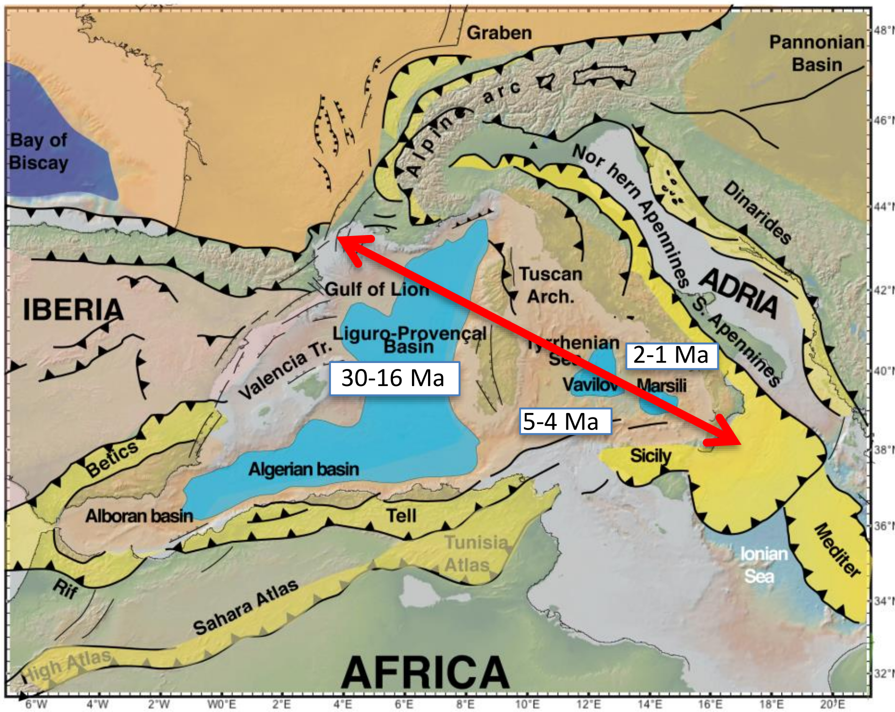


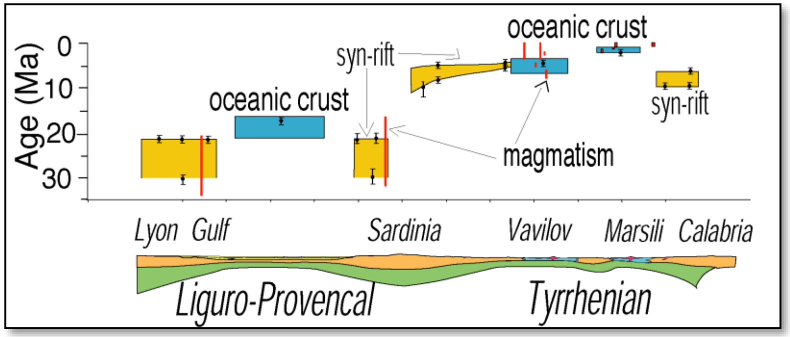


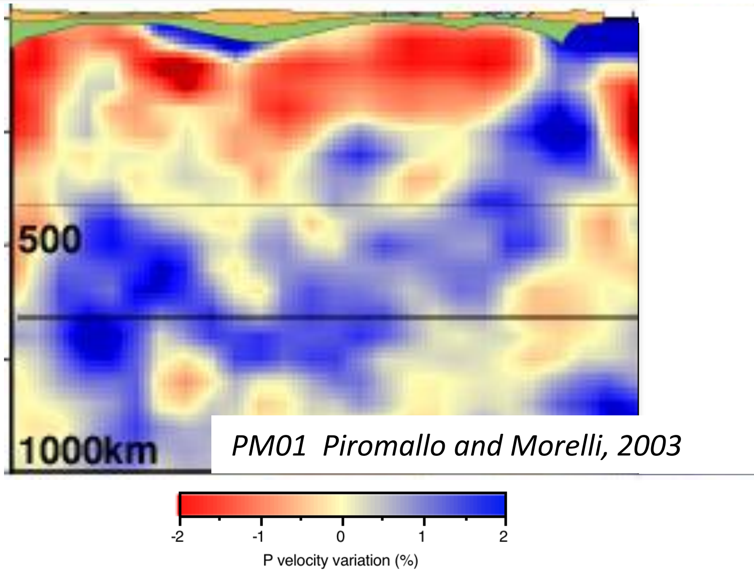


Malinverno and Ryan (1986)

SUBDUCTION AND BACK-ARC EXTENSION



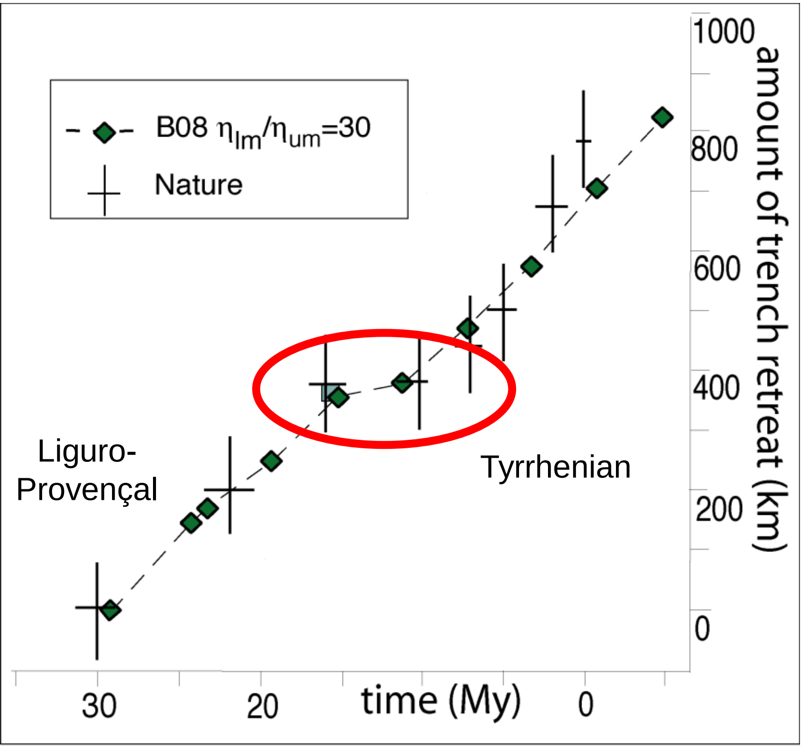


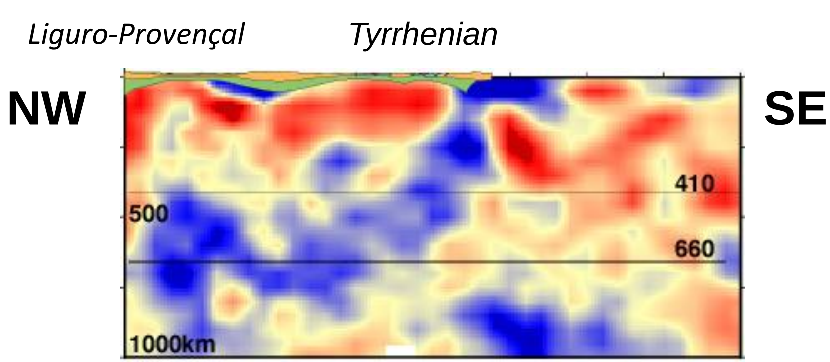


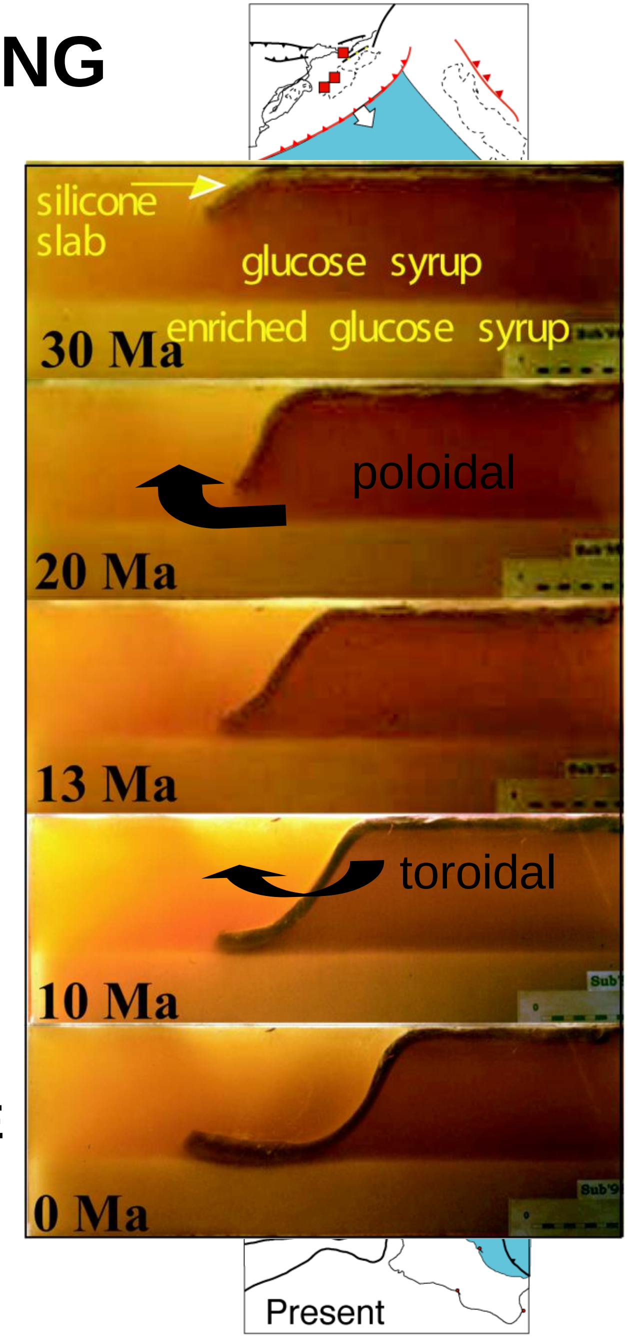
PM01 Piromallo and Morelli, 2003

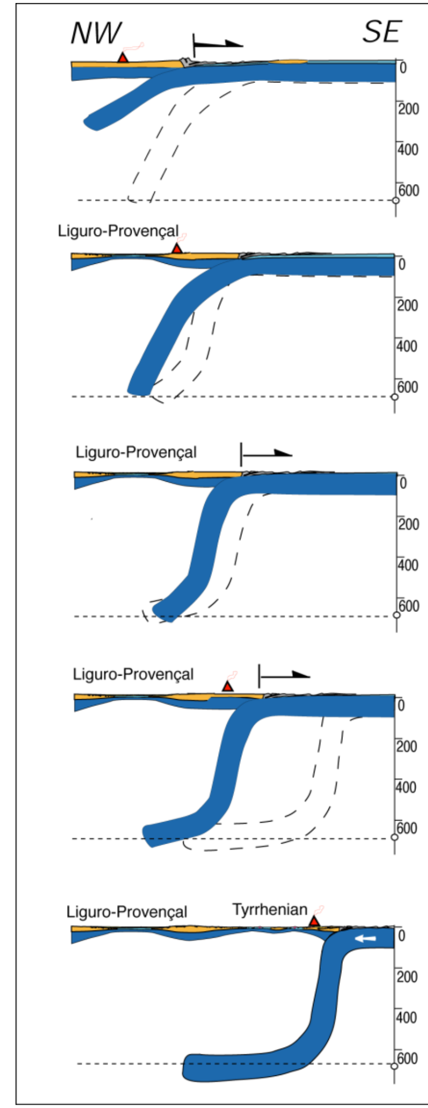
- **more than 800 km of back-arc extension;**
- **three pulses of spreading.**

ANALOGUE MODELLING





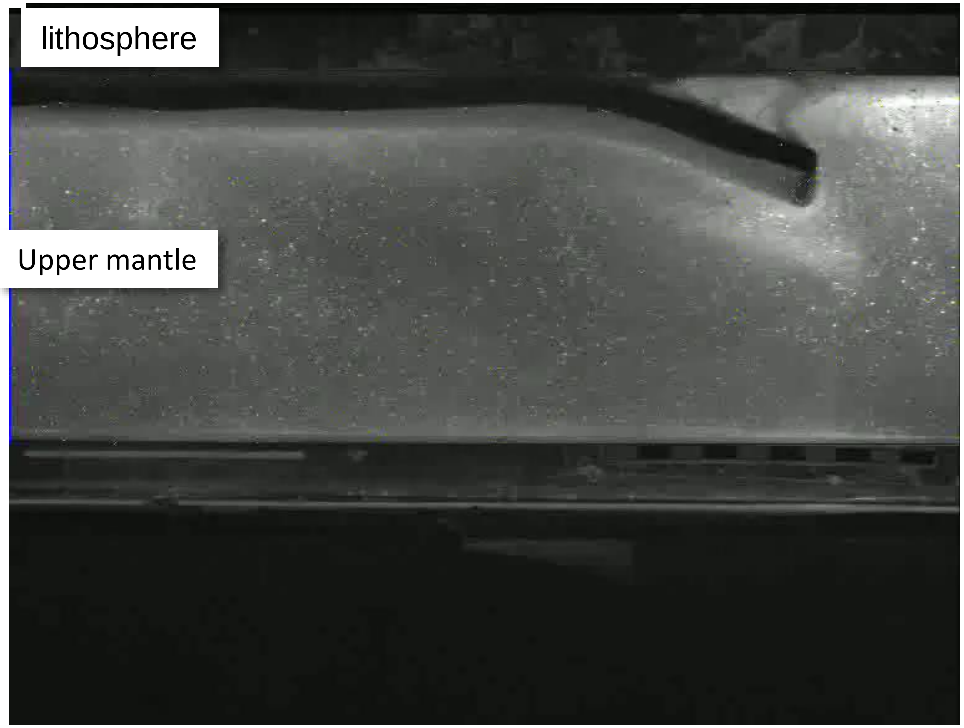




Faccenna et al., 2001

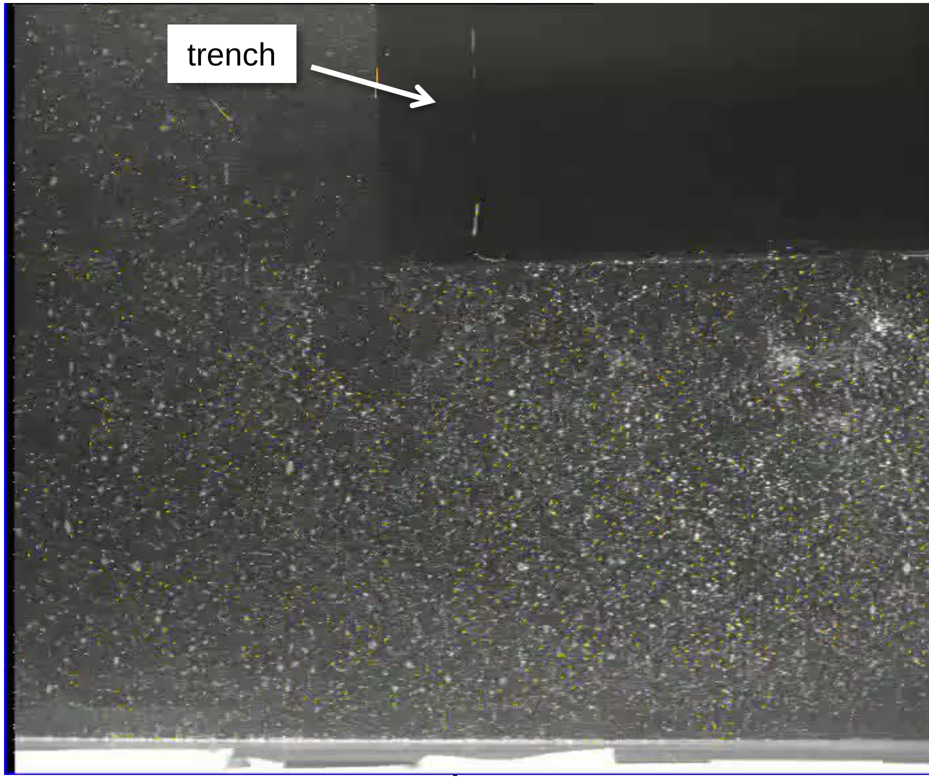
MANTLE CIRCULATION DURING RETREAT OF A NARROW SLAB
(LABORATORY MODELS)

Poloidal Flow



lateral view

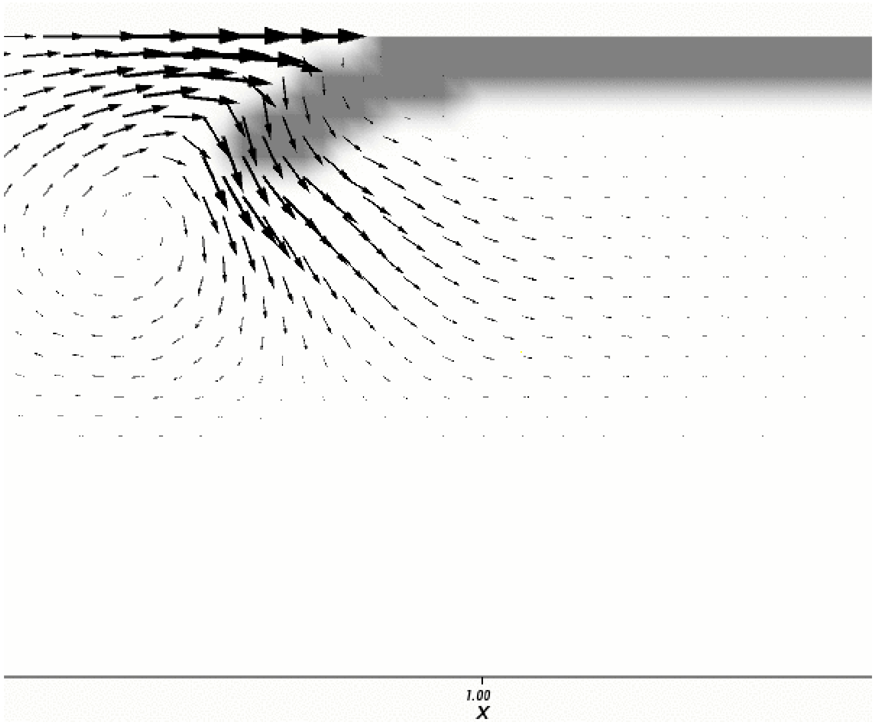
Toroidal Flow



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

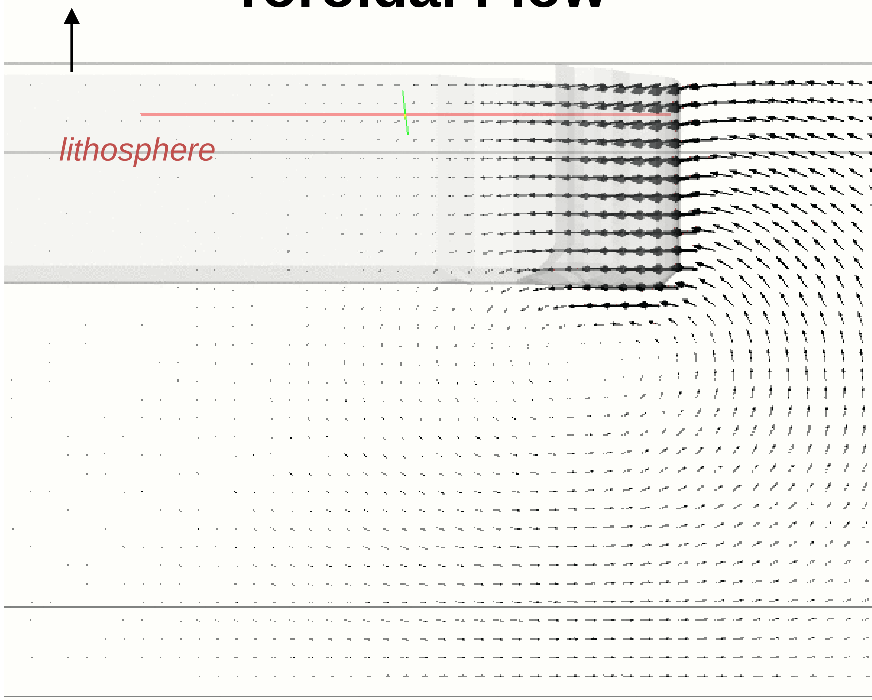
MANTLE CIRCULATION DURING RETREAT OF A NARROW SLAB
(NUMERICAL MODELS)

Poloidal Flow



lateral view

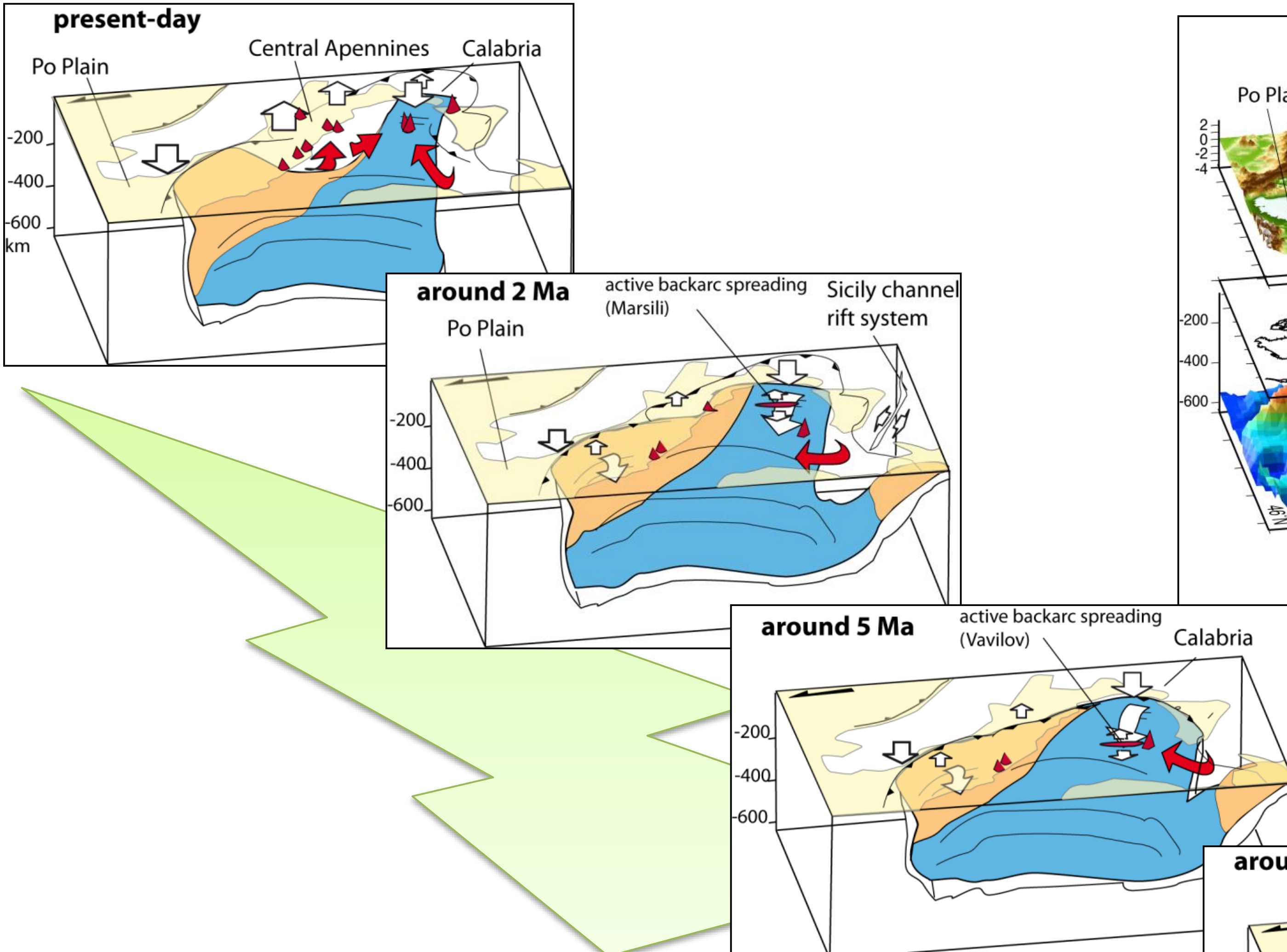
Toroidal Flow

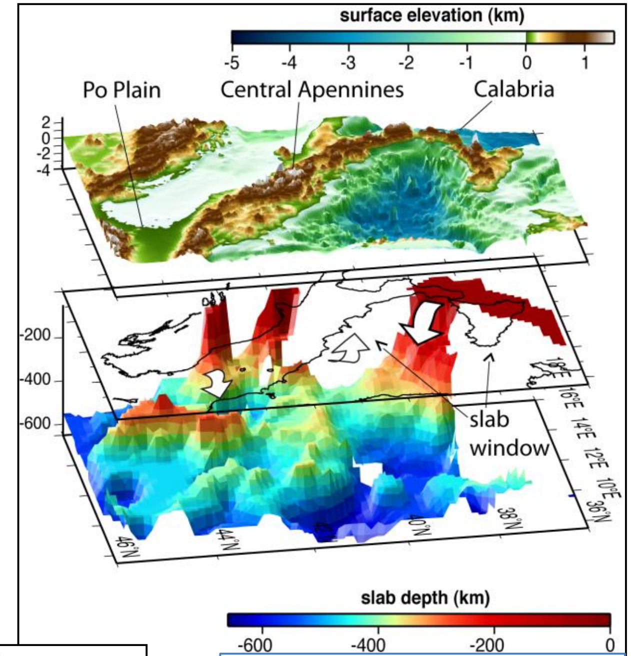


top view

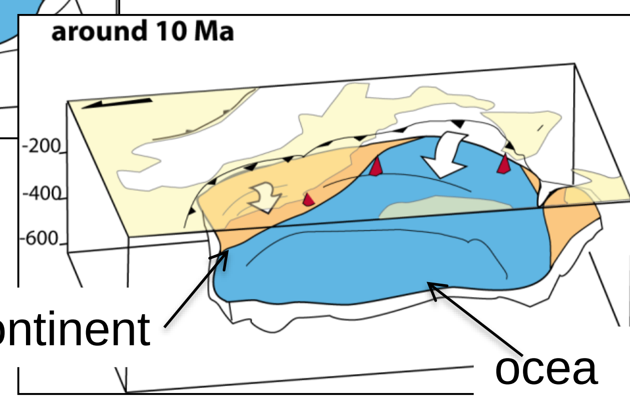
Piromallo et. al, 2006

DISRUPTION OF THE TYRRHENIAN SLAB





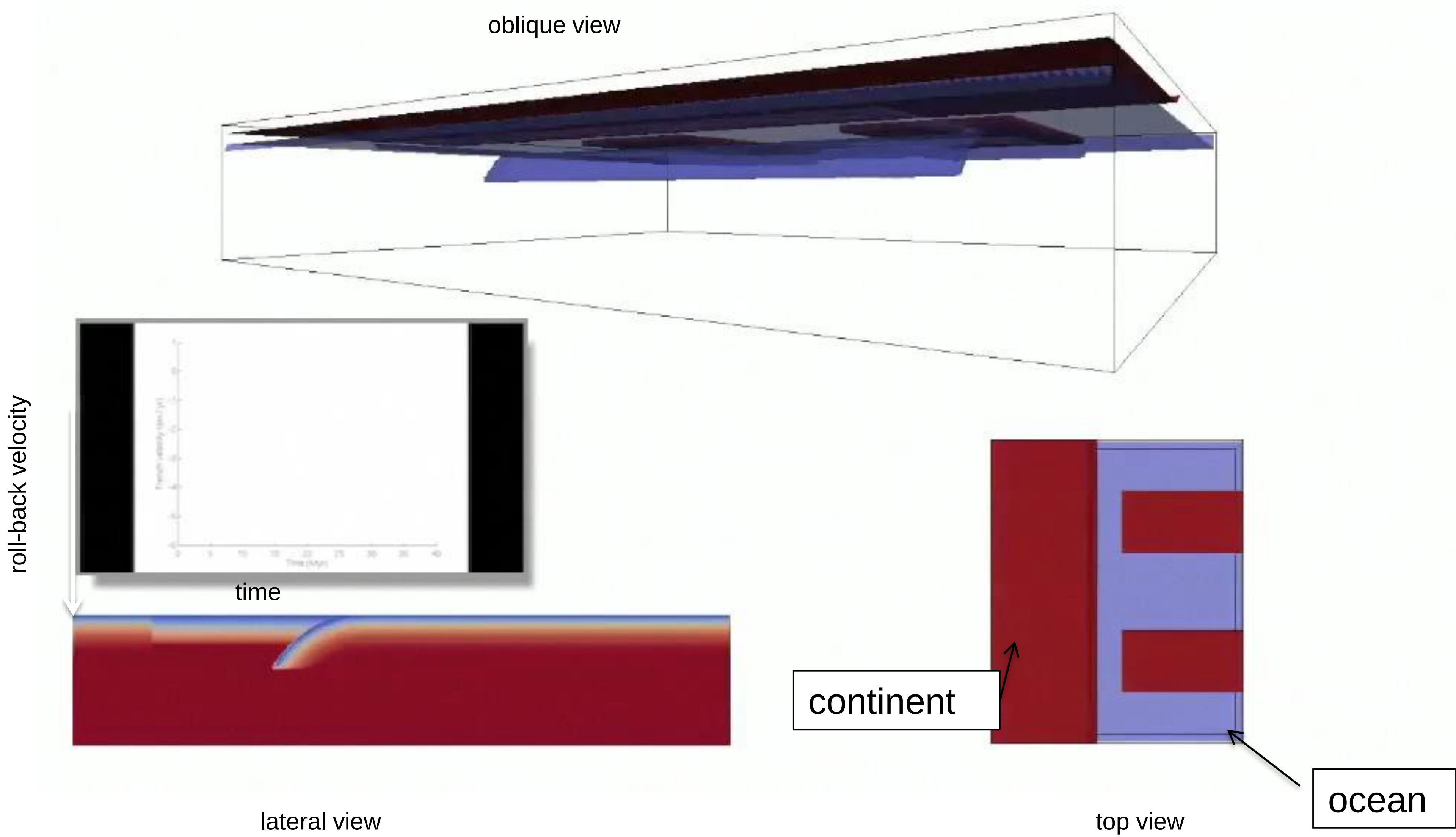
Isosurface of the >0,8 % P wave anomalies from Piromallo and Morelli (2003) model



short-lived catastrophic events of slab disruption

Faccenna et al., 2005; 2007

BACKARC EXTENSIONAL MODELS



collision, backarc extension and slab disruption

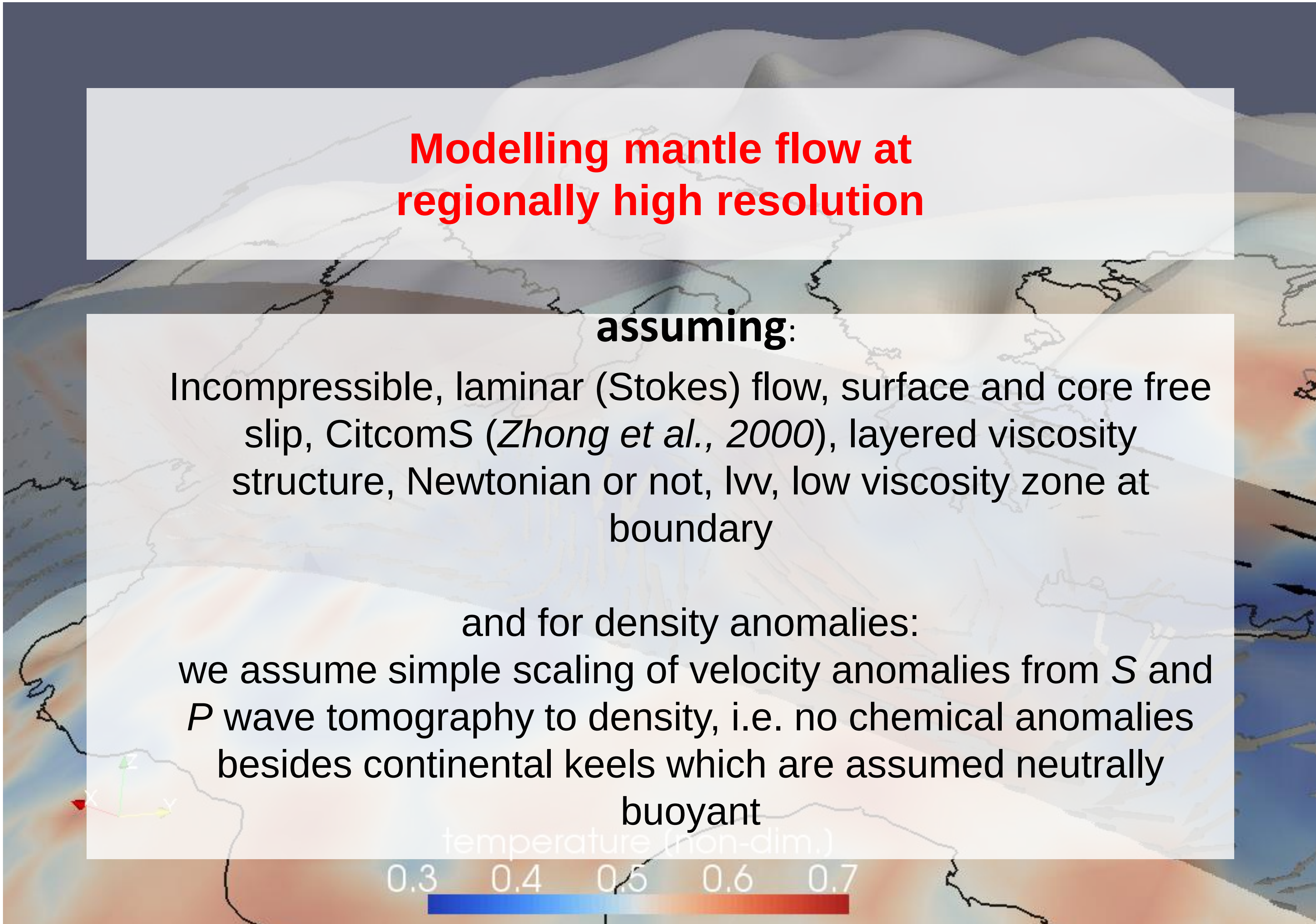
Magni et al., 2014

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



Self-consistent predictions include:

- **Surface deformation:**

- (micro)plate motions

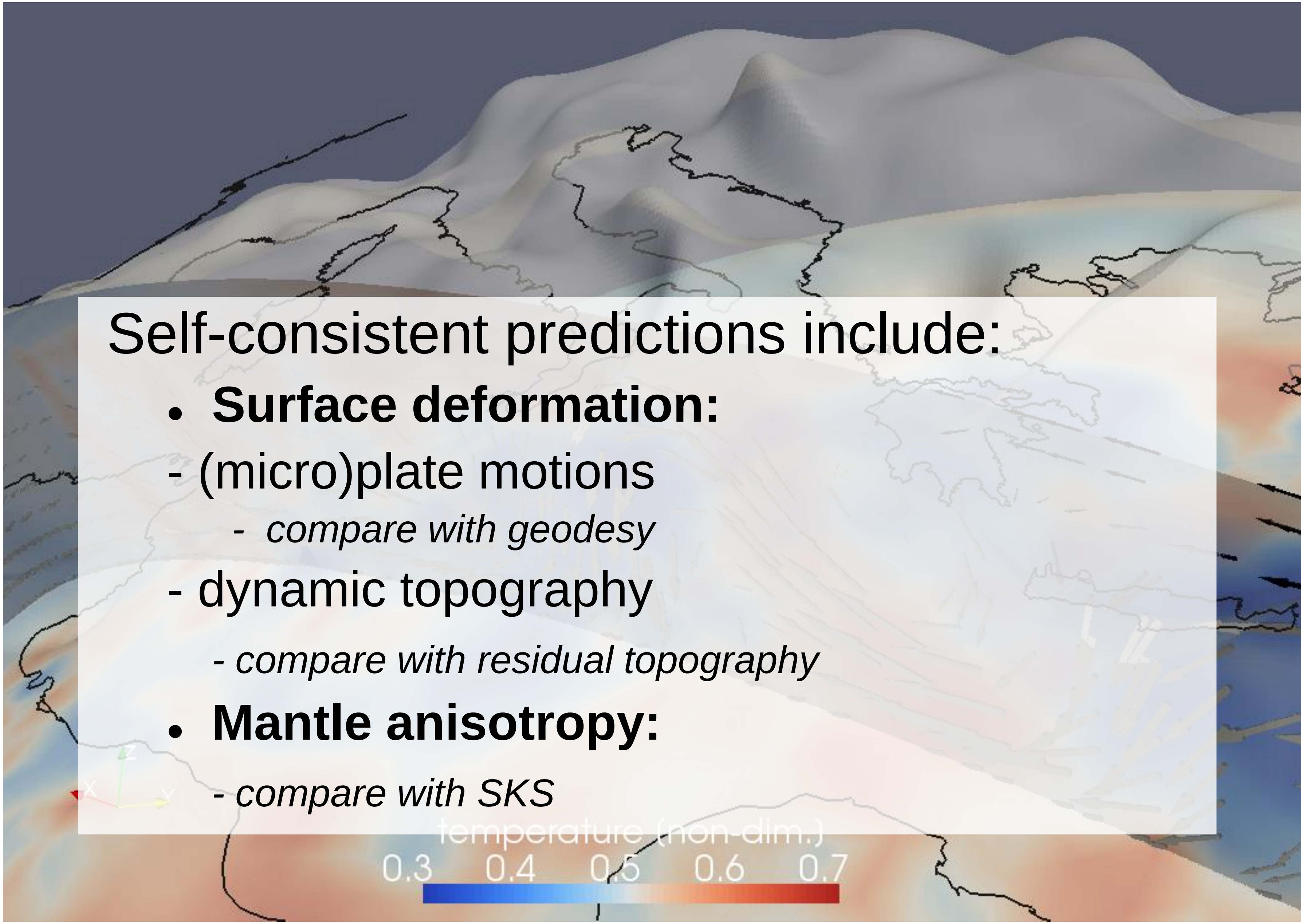
    - *compare with geodesy*

- dynamic topography

    - compare with residual topography

- **Mantle anisotropy:**

    - compare with SKS



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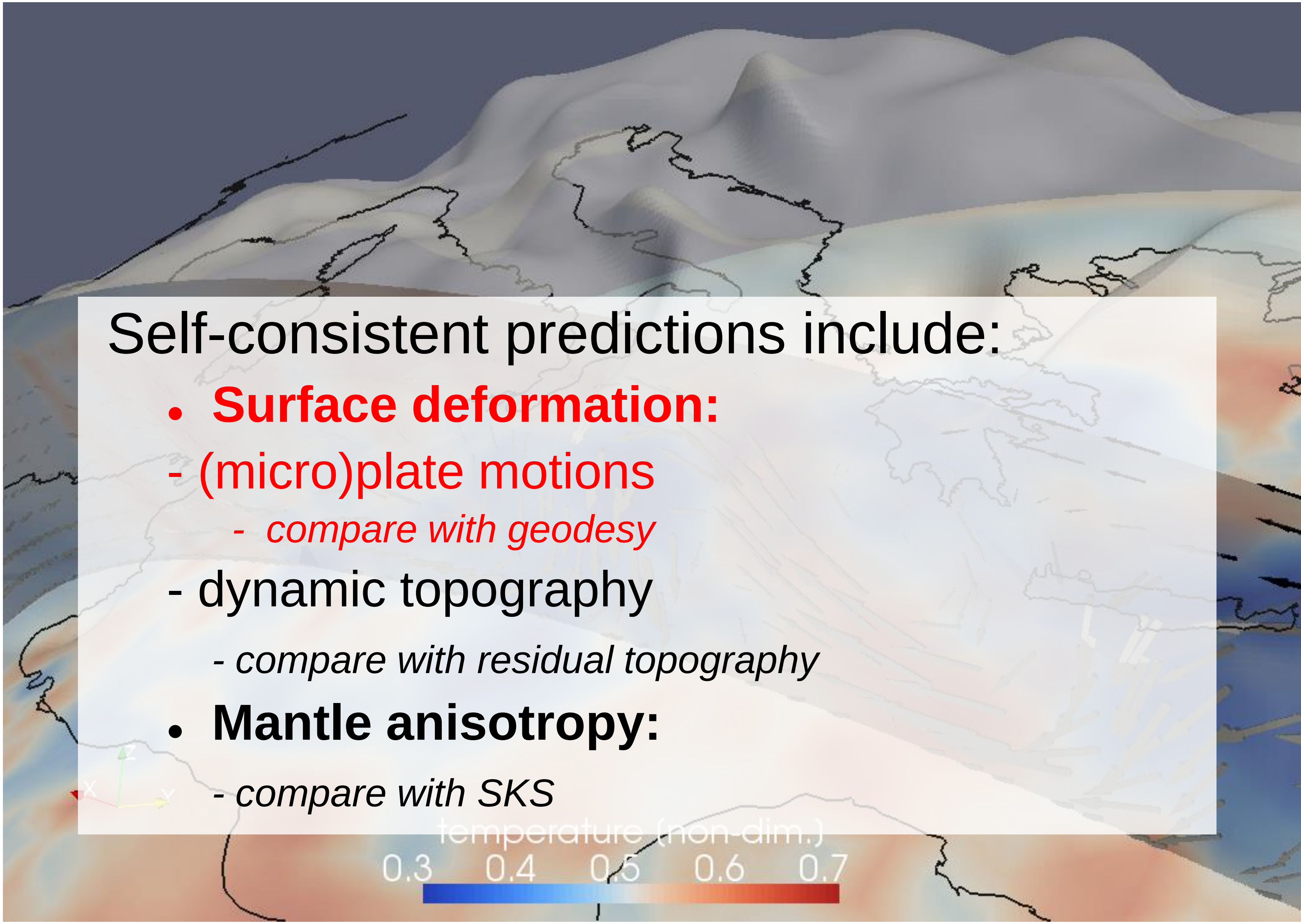
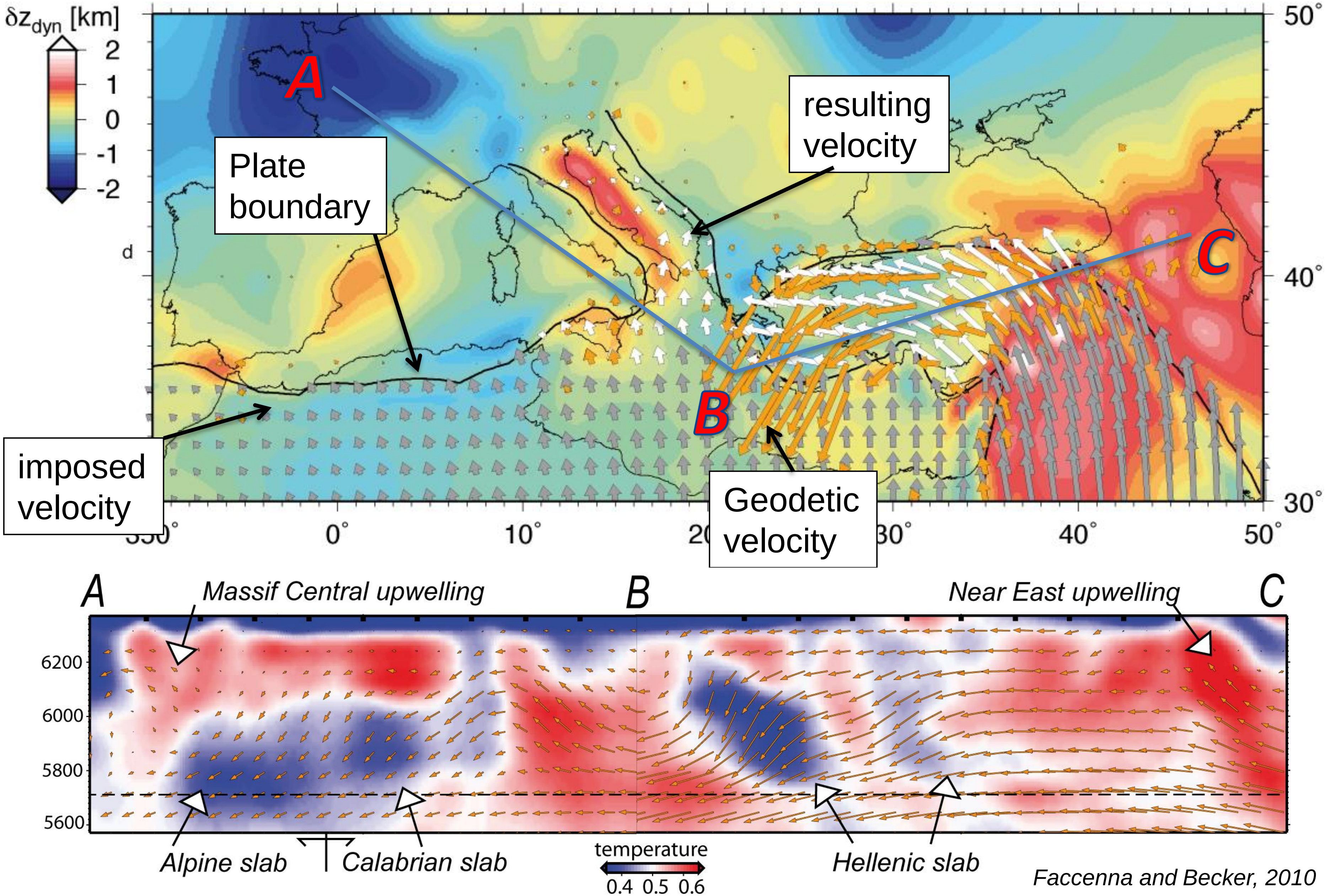
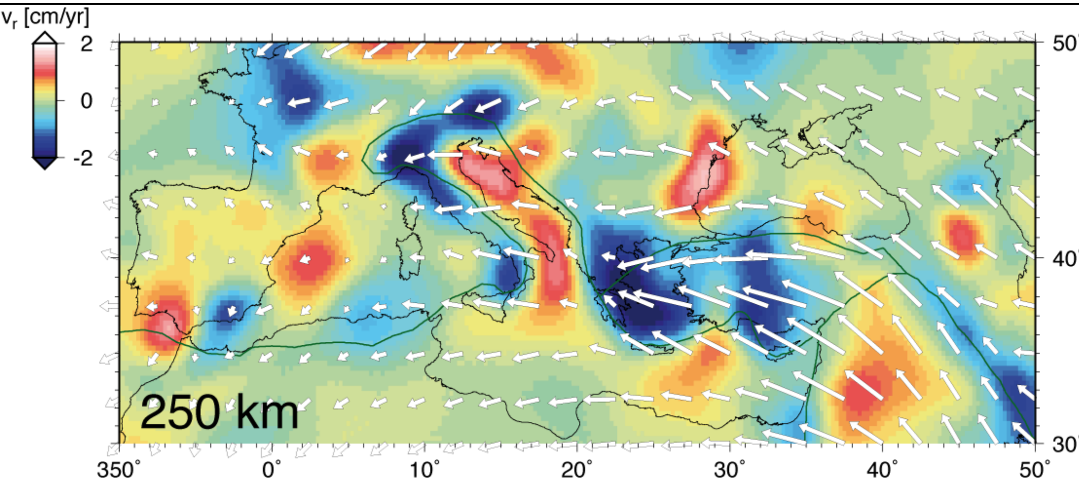


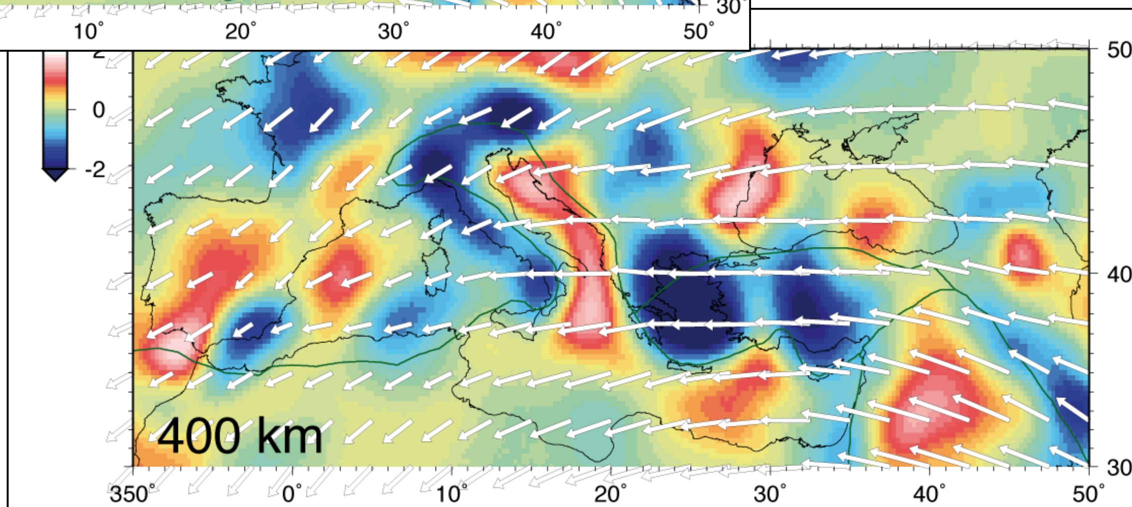
I TEST: PLATE MOTION

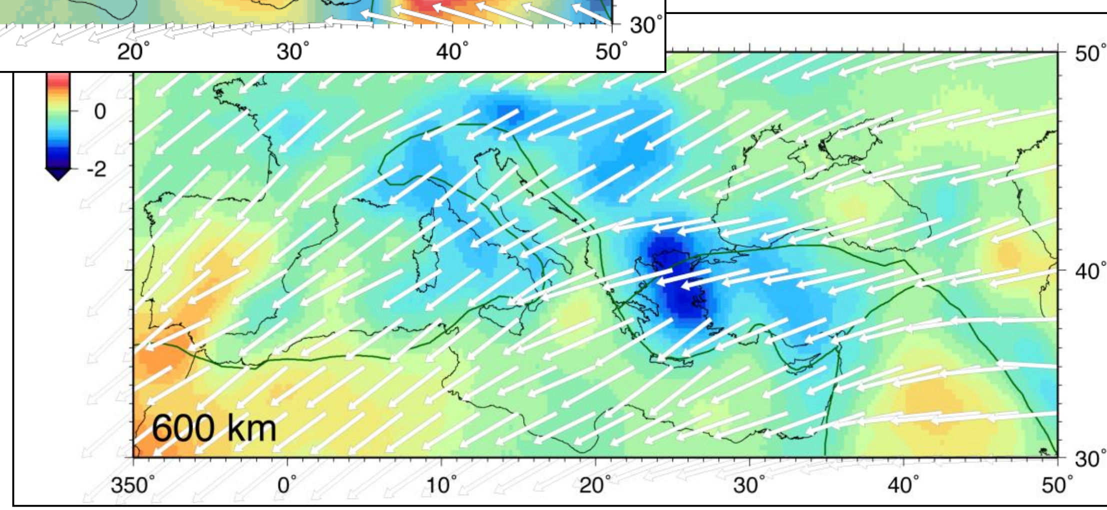


Faccenna and Becker, 2010

MANTLE FLOW SOLUTION

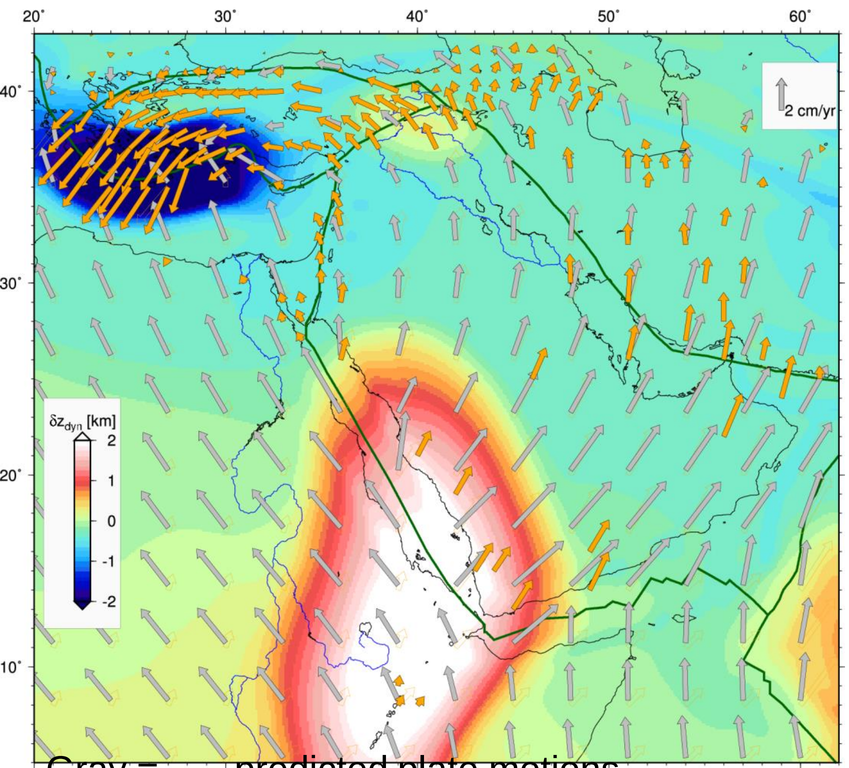




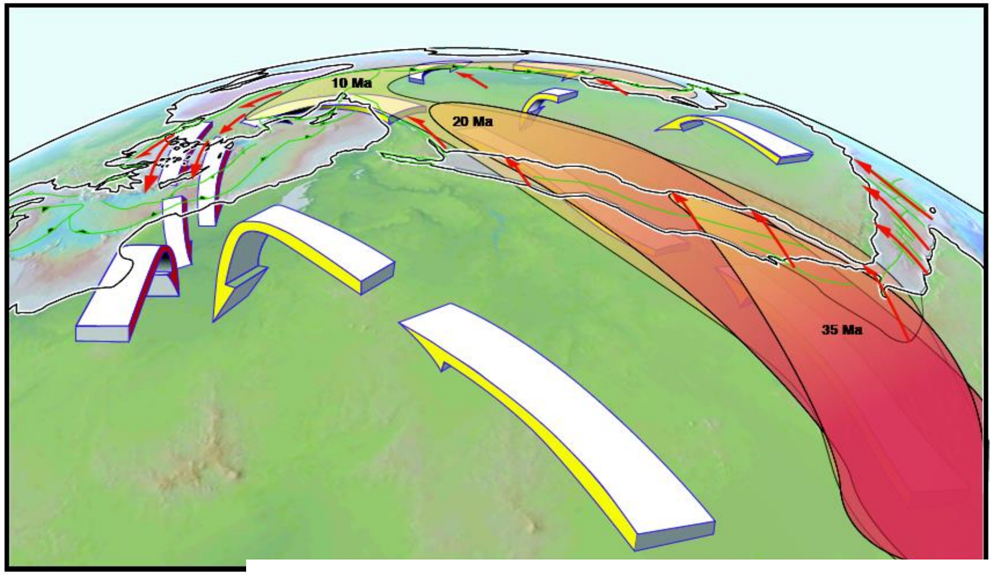


small scale upper mantle convection

THE MEDITERRANEAN - ARABIA CIRCUIT



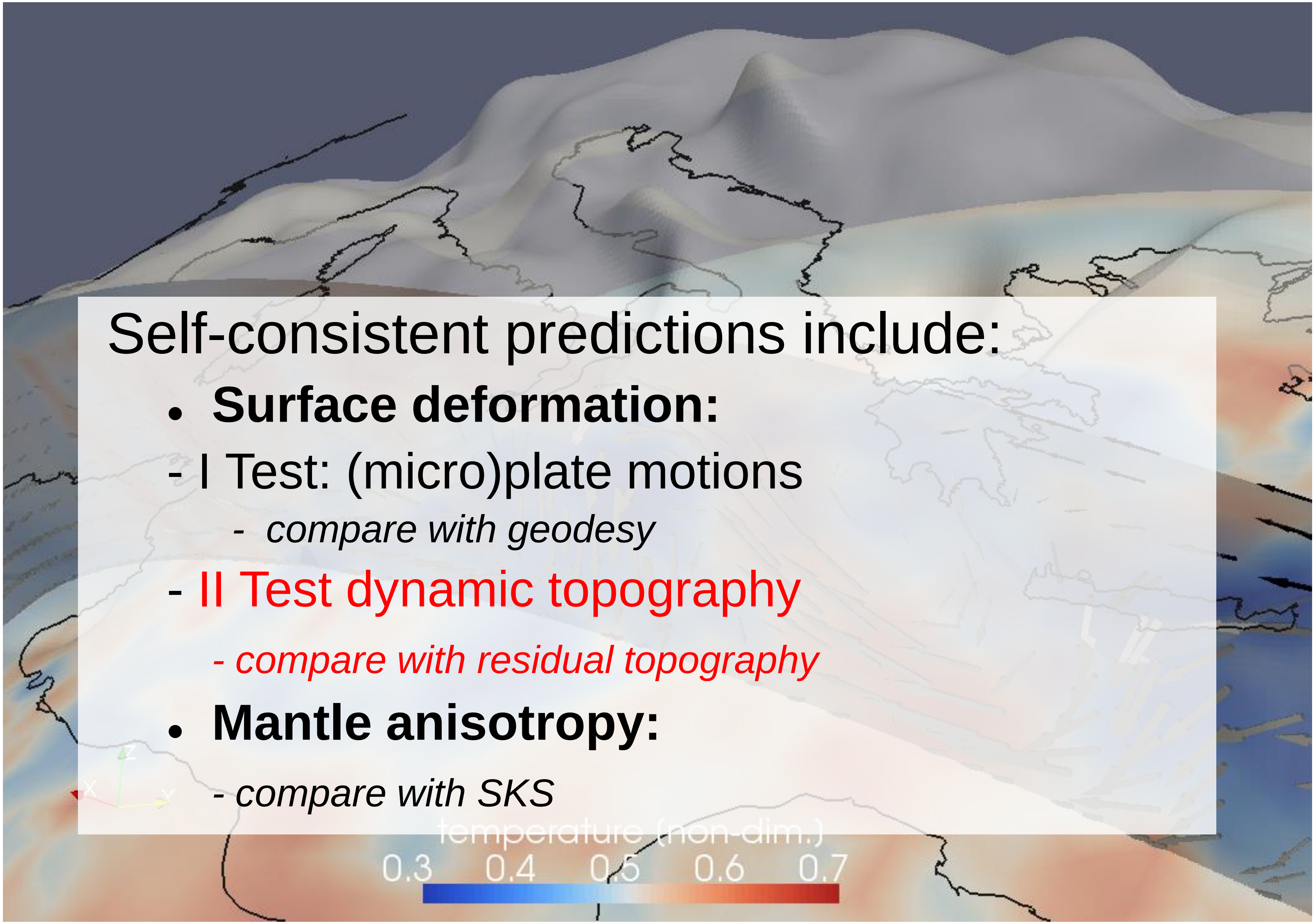
Gray = predicted plate motions
Orange = interpolate GPS



mantle flow reconstruction from volcanic age progression *(Ershov and Nikishin, 2004; Krienitz et al., 2009; Keskin et al., 2012)*

hot mantle flowing from Arabia inside Anatolia:
can this flow explain the uplift and extrusion of Anatolia?

Faccenna et al. (2013)



Self-consistent predictions include:

- **Surface deformation:**

- I Test: (micro)plate motions

  - *compare with geodesy*

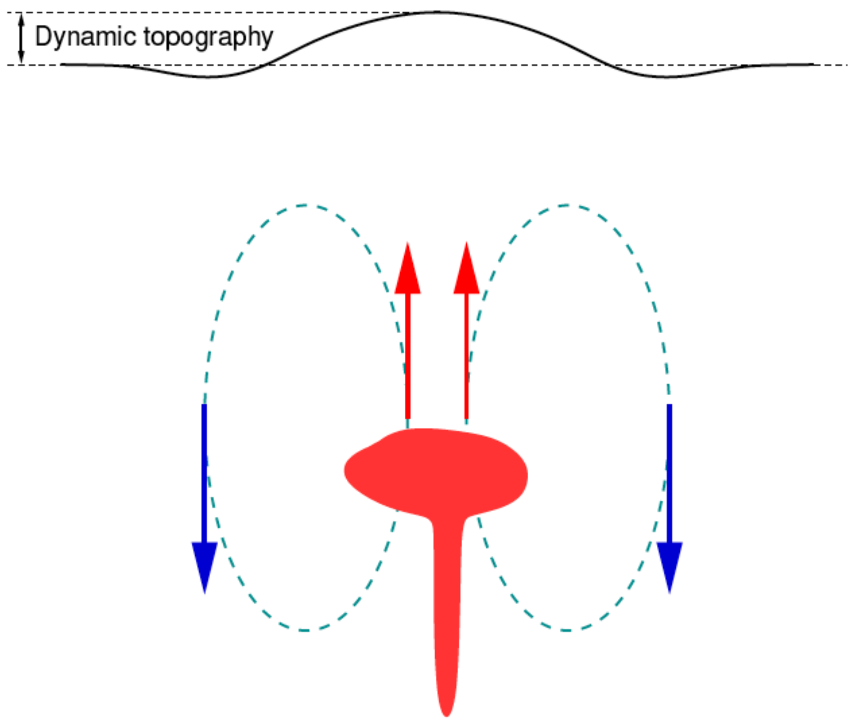
- II Test dynamic topography

  - compare with residual topography

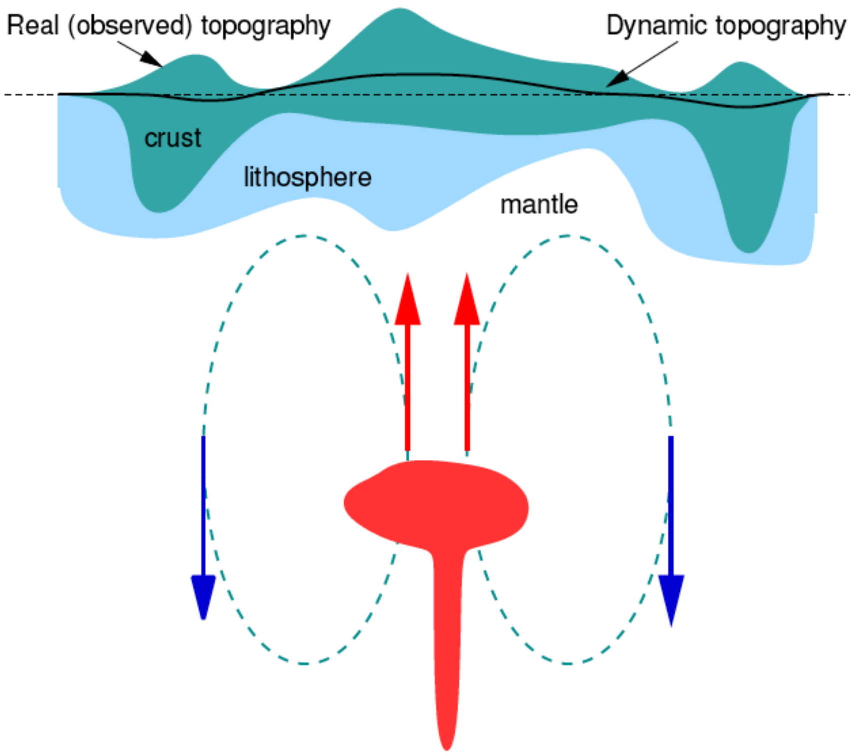
- **Mantle anisotropy:**

  - compare with SKS

DYNAMIC TOPOGRAPHY



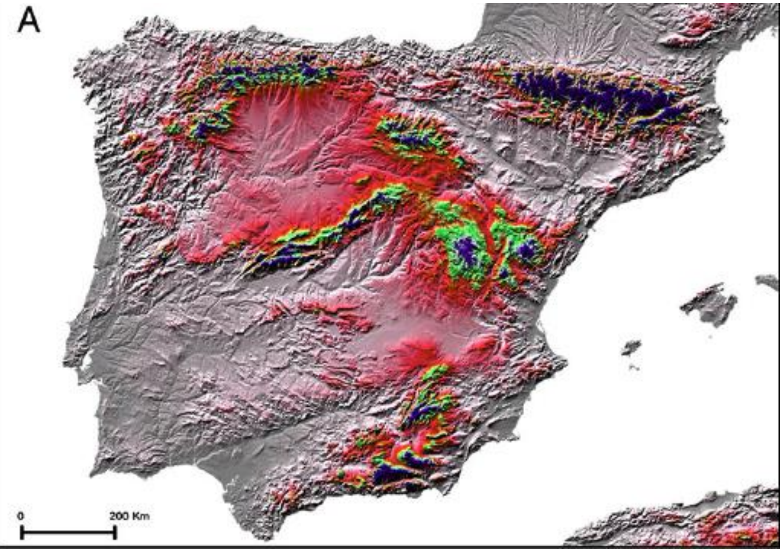
Theory

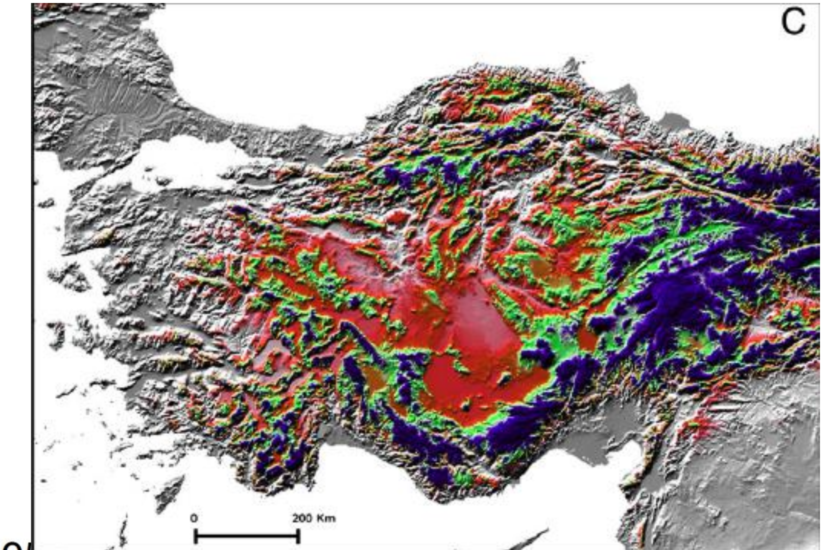


Real Earth

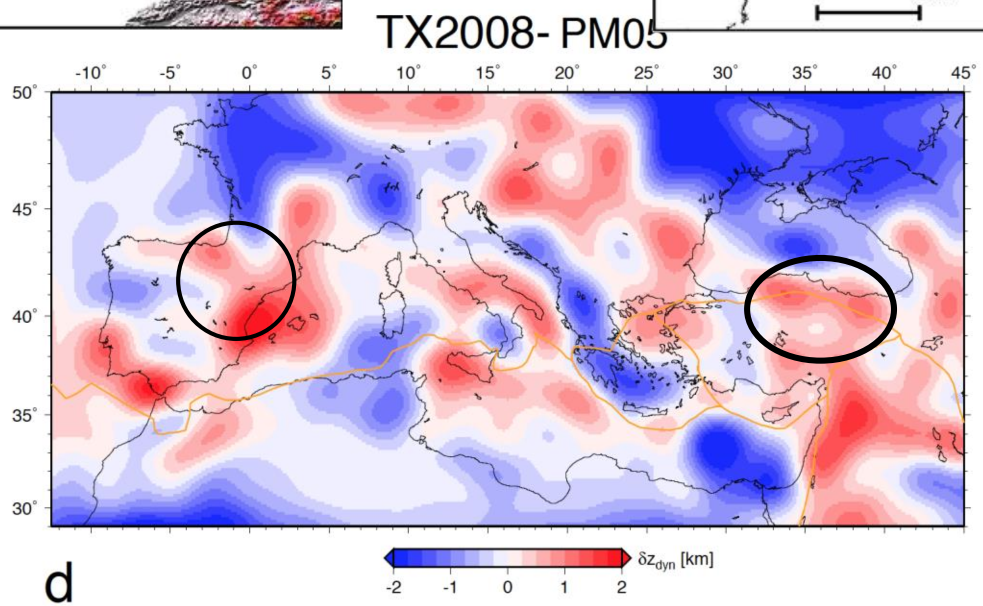
(from O. Cadek)

DYNAMIC TOPOGRAPHY





Dynamic Topography



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

Self-consistent predictions include:

- **Surface deformation:**

- (micro)plate motions

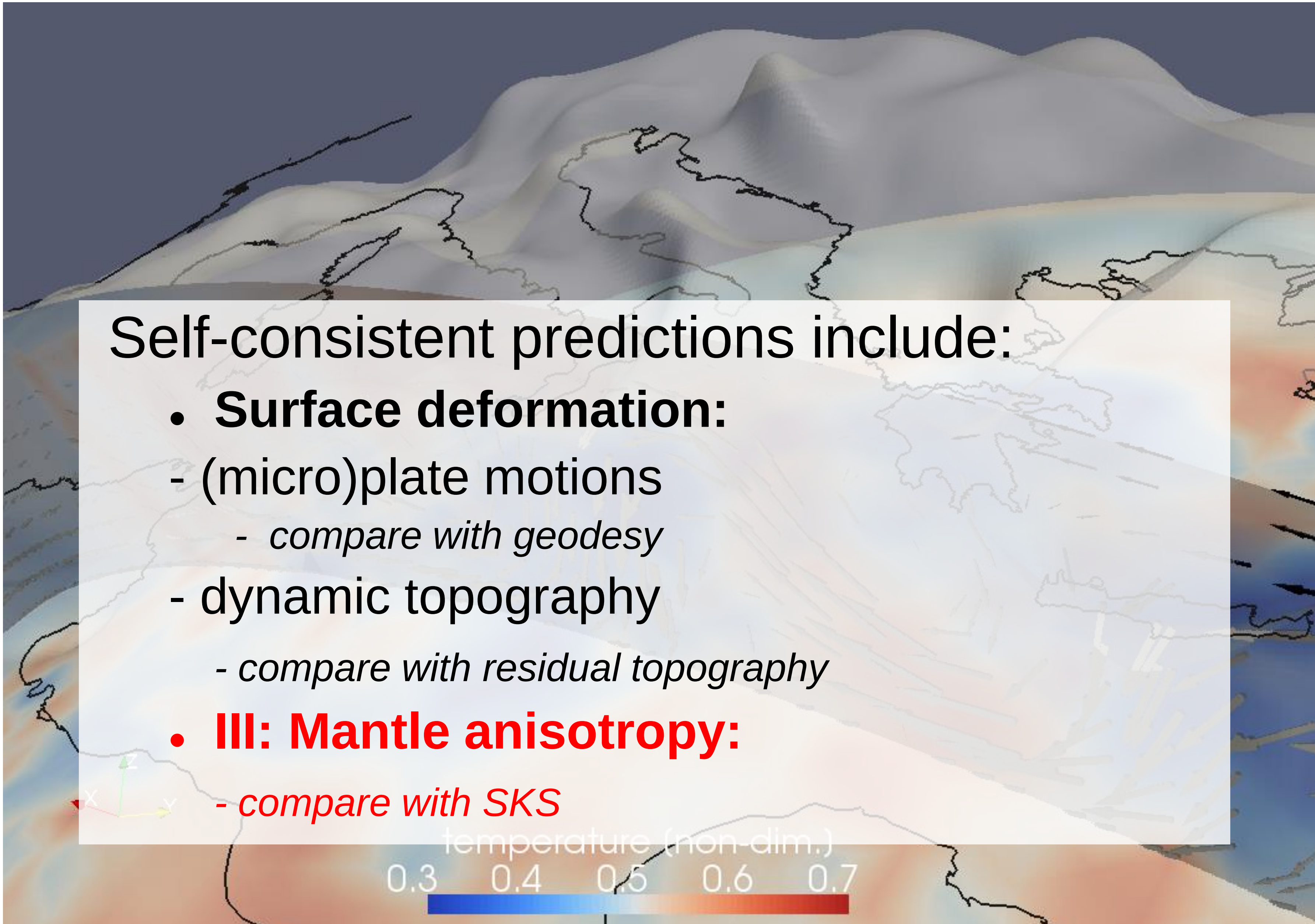
  - *compare with geodesy*

- dynamic topography

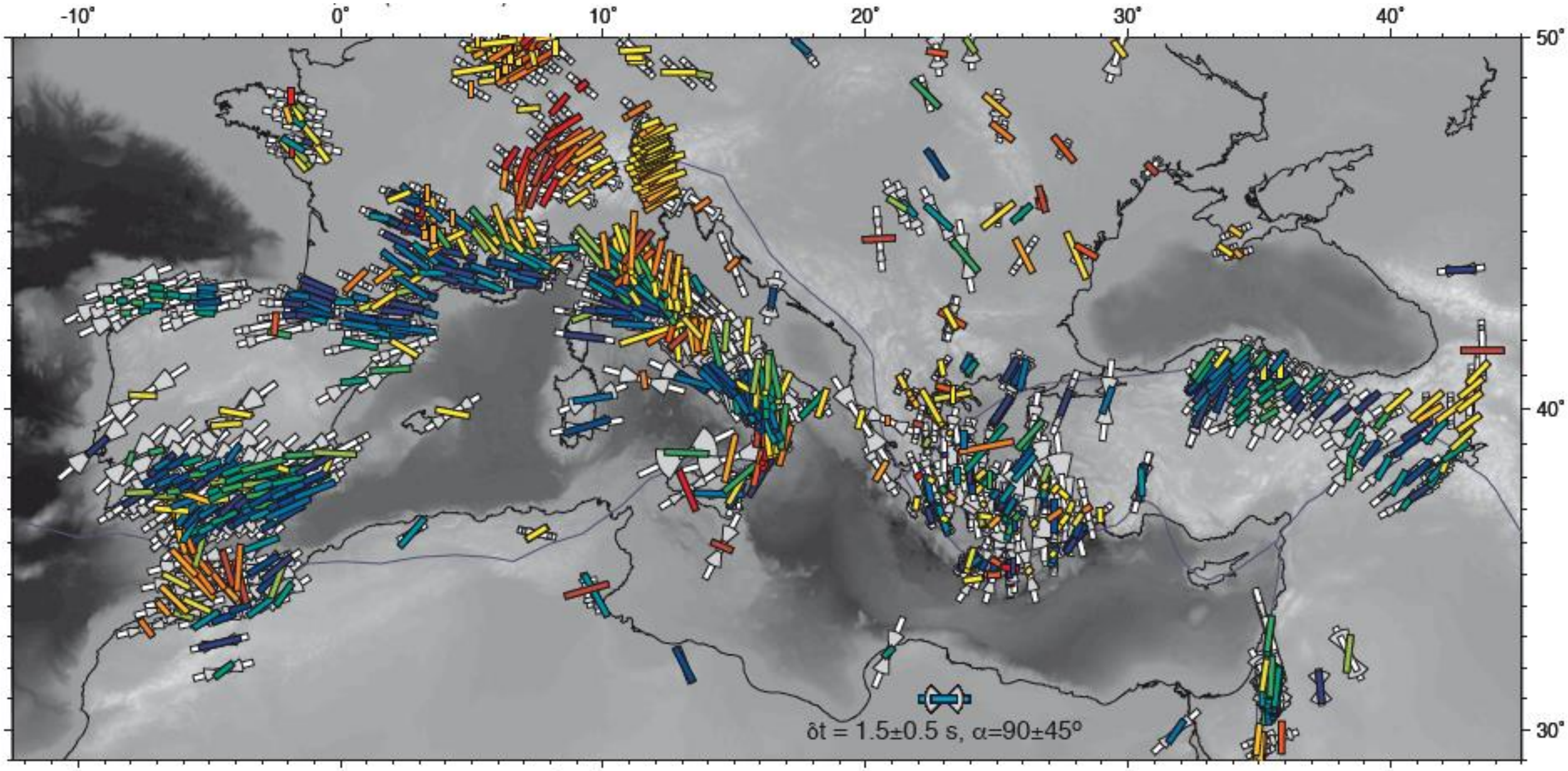
  - *compare with residual topography*

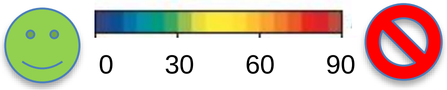
- **III: Mantle anisotropy:**

  - *compare with SKS*



MANTLE ANISOTROPY

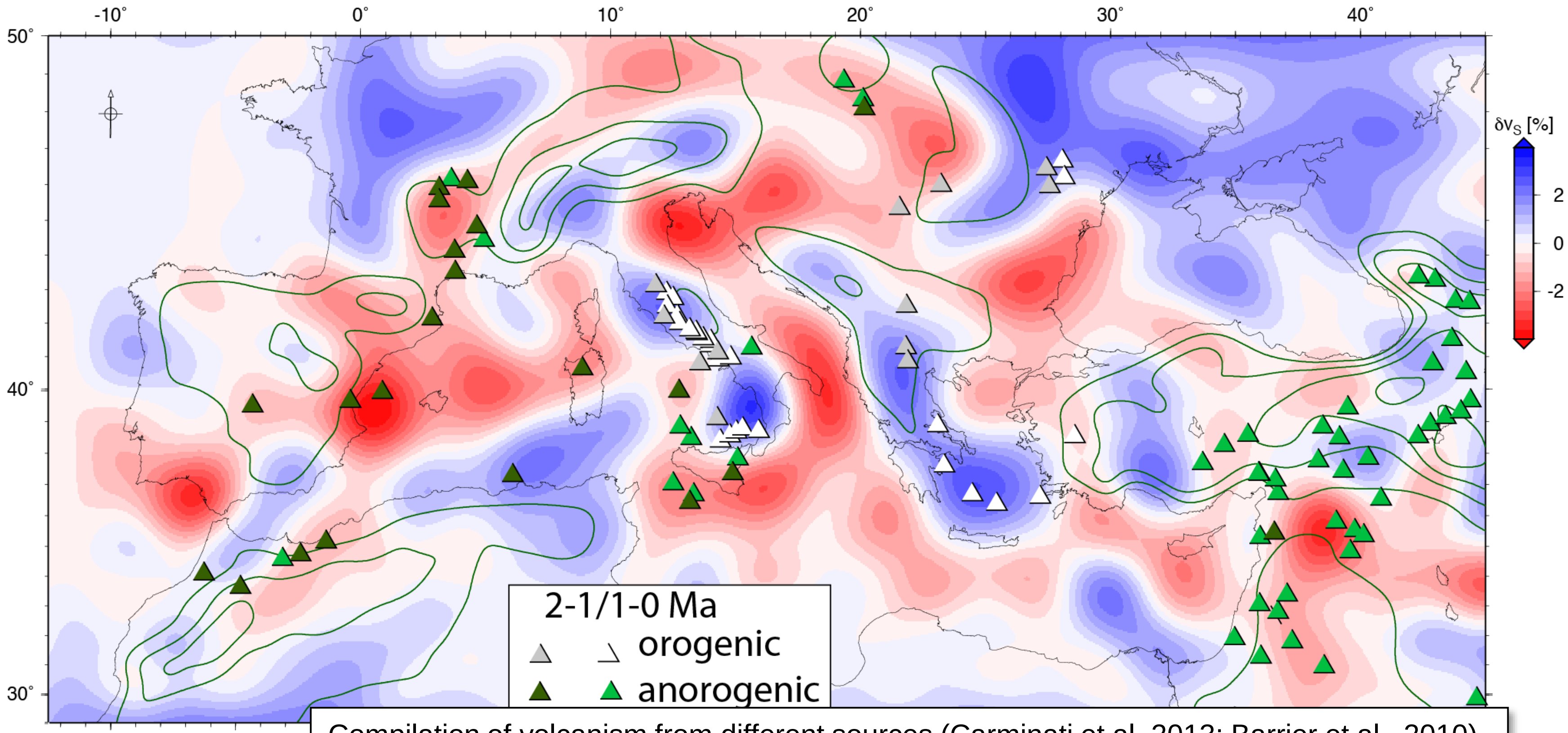




Back-arc basin: good fit with return flow related to the retreating slab

Faccenna et al., 2014

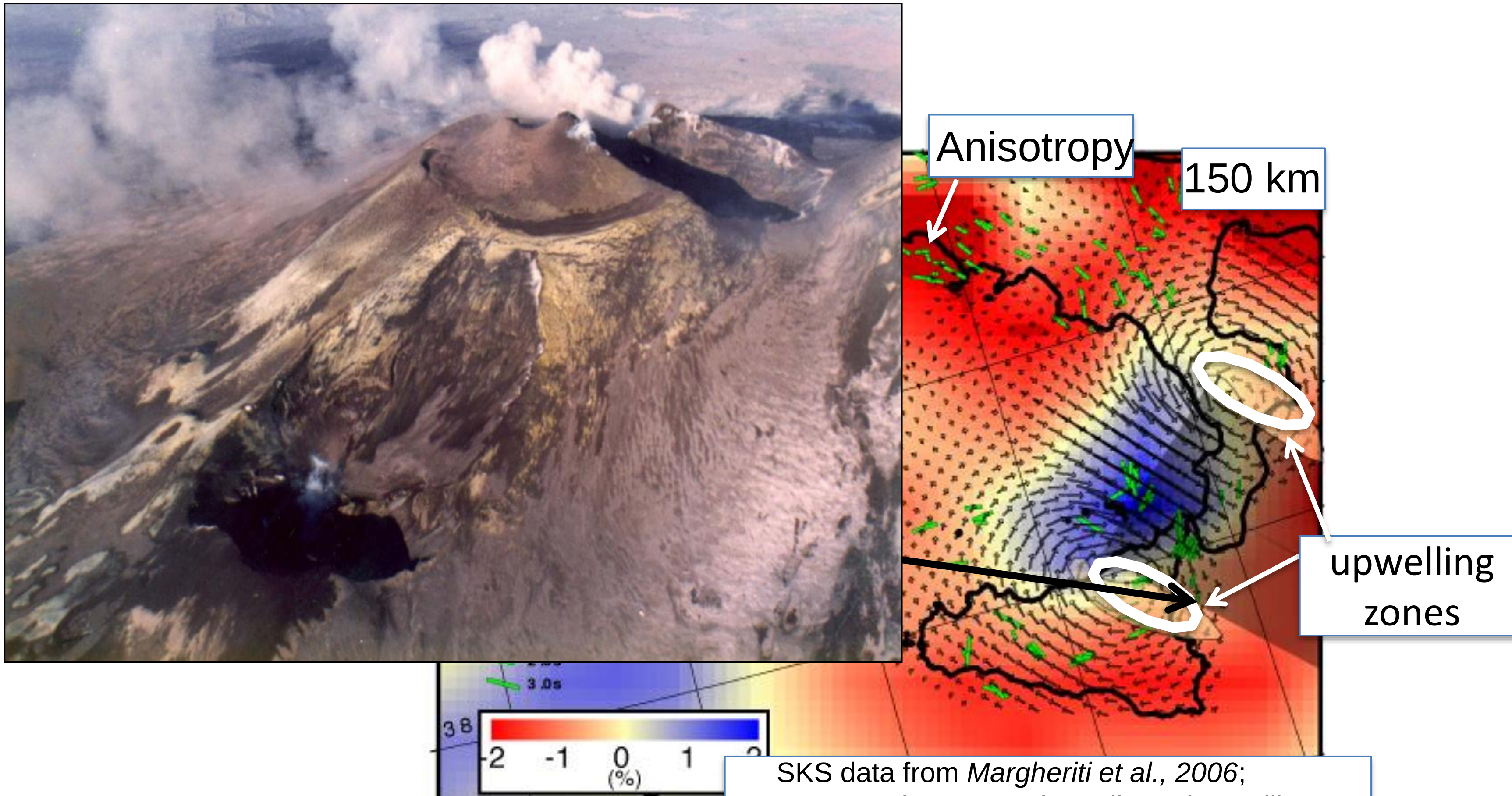
IV TEST: MEDITERRANEAN VOLCANISM



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

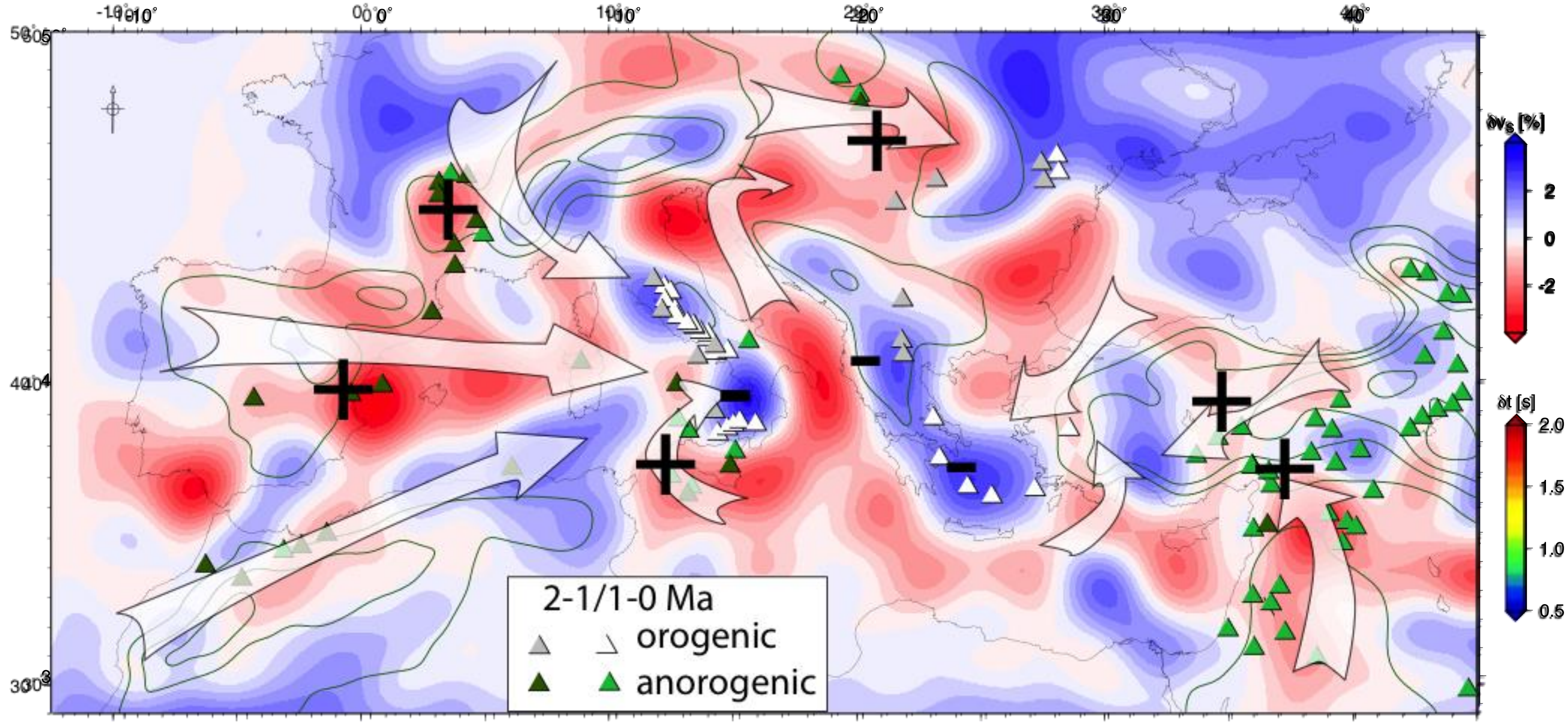
THE ETNA VOLCANISM



SKS data from *Margheriti et al., 2006*;
Tomography PM01 *Piromallo and Morelli, 2003*

Faccenna et al., 2005; 2011

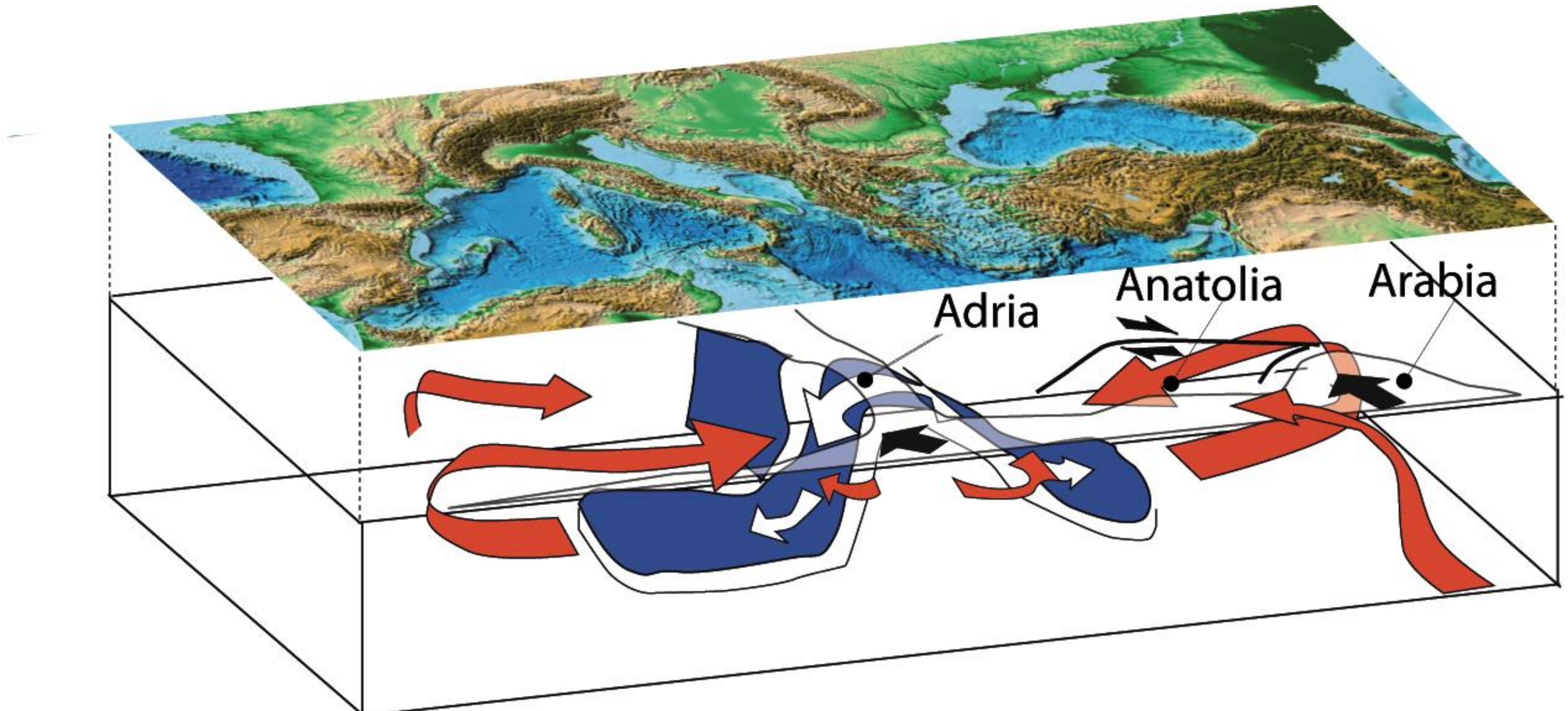
MANTLE FLOW PATTERN



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

REMARKS

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



THANKS


LE CELEBRE POUR LES VAISSAUX AUTRE FOIS SI DANGEREUX DETROIT DE FARO DI MESSINA