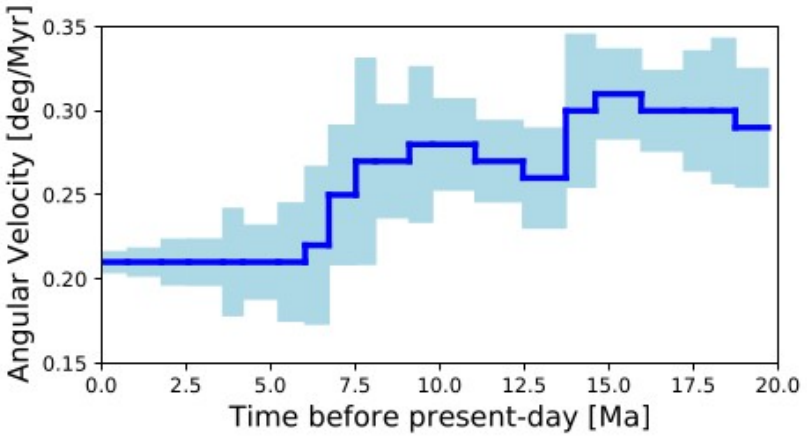
Plume push force: driving plate tectonics as constrained by horizontal and vertical plate motions

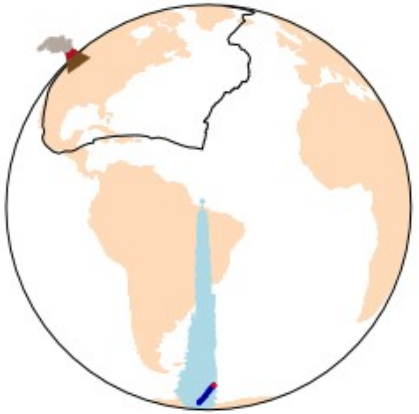
Ingo L. Stotz
Berta Vilacís,
Jorge N. Hayek,
Hans-Peter Bunge,
Anke M. Friedrich

Department of Earth and Environmental Sciences, Ludwig-Maximilians-Universität München, Germany

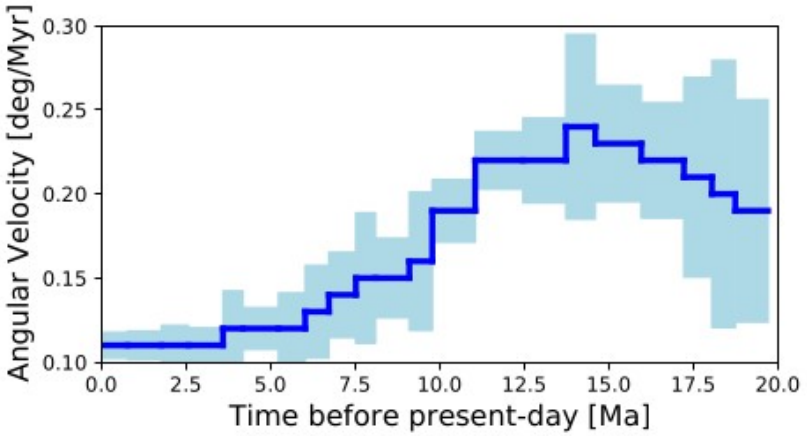
Neogene kinematics of the North American plate

A) North America with respect to Eurasia fix





B) North America with respect to Atlantic hotspots



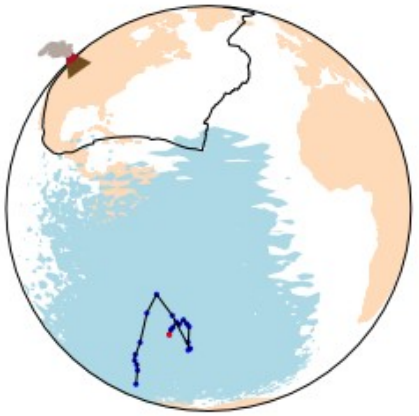


Plate motion changes have been explained by

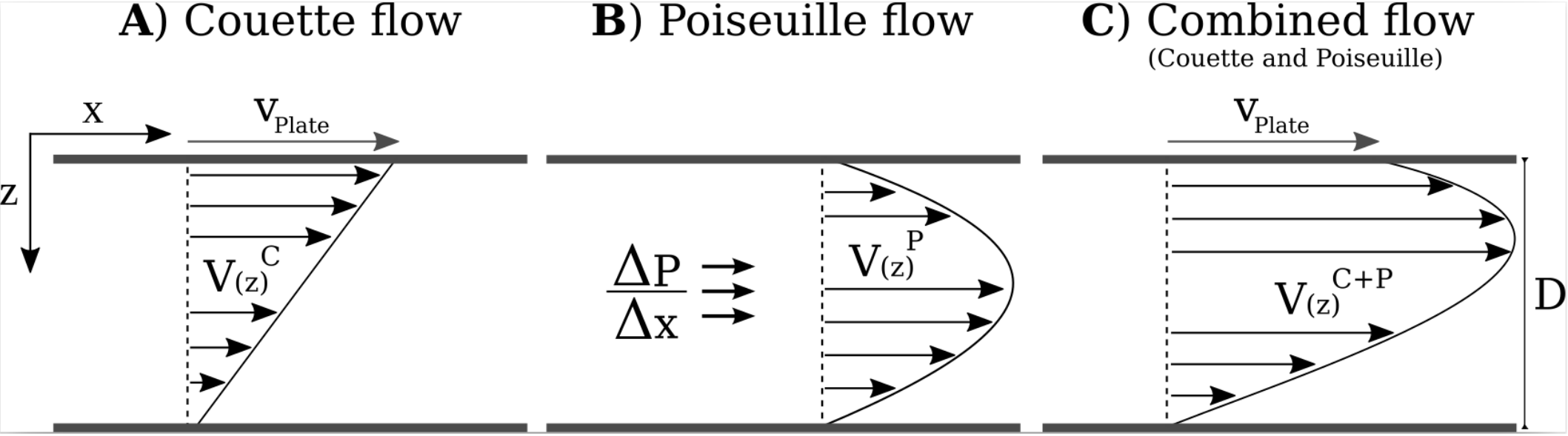
Plate boundary forces (e.g., slab pull)

Basal shear forces (e.g., mantle convection)

Plume push force invoked to explain these motions (Cande and Stegman, 2011, Iaffaldano et. al. 2018, Parnell-Turner et. al. 2014, van Hinsbergen et. al., 2020)

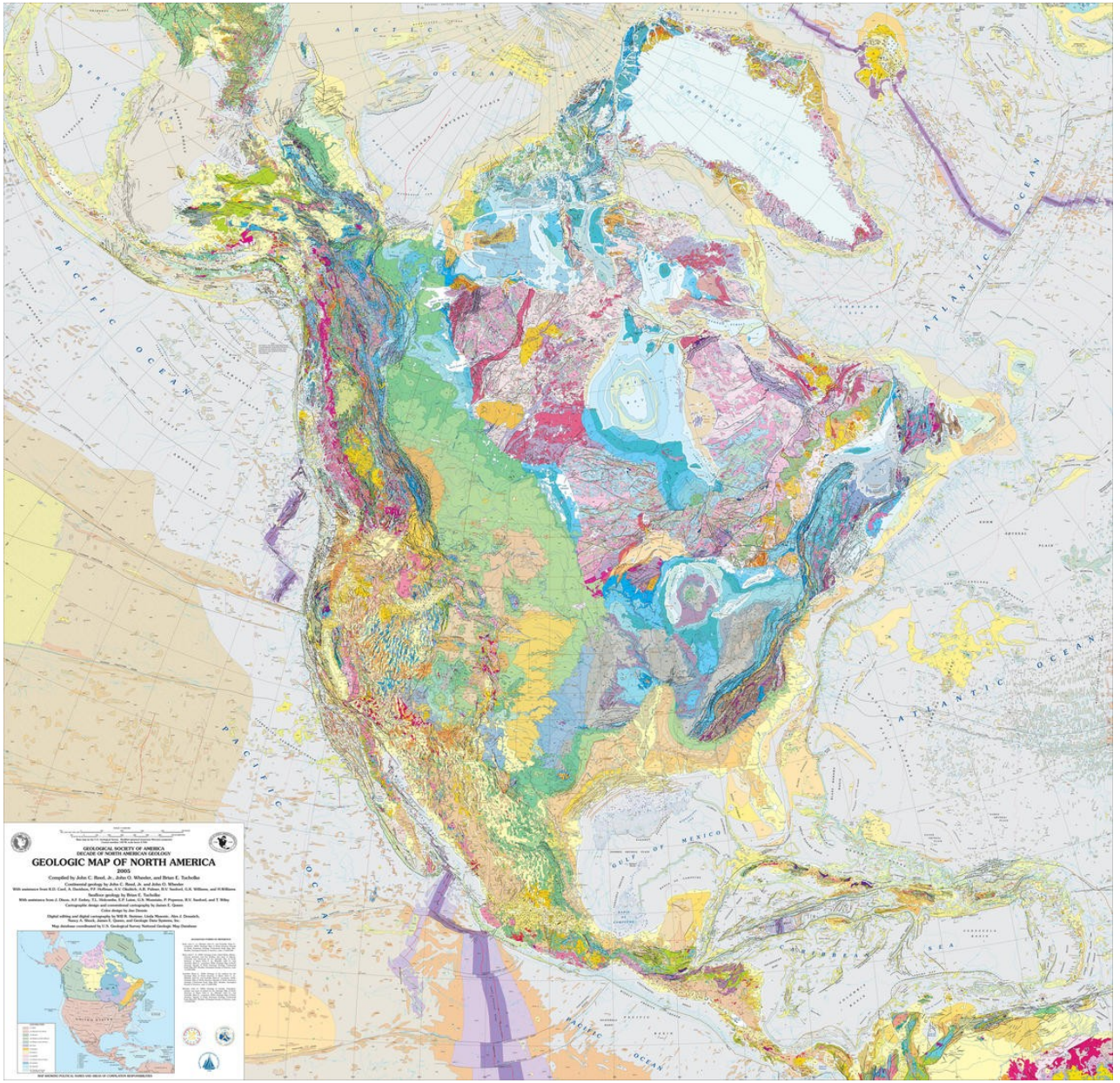
Based on recently publish data by DeMets et al. (2015, supporting Information Tables 1 and 3); Merkouriev and DeMets (2014a, 2014b) and Mueller et. al. 1993.

Earth's asthenosphere can contribute to drive plate motions through a Poiseuille-flow regime



Poiseuille flow in the asthenosphere links changes in **plate motions** to **dynamic topography** through a geodynamically plausible model.

Exploiting digital Geological maps to build a Base Hiatus Maps: case of North America



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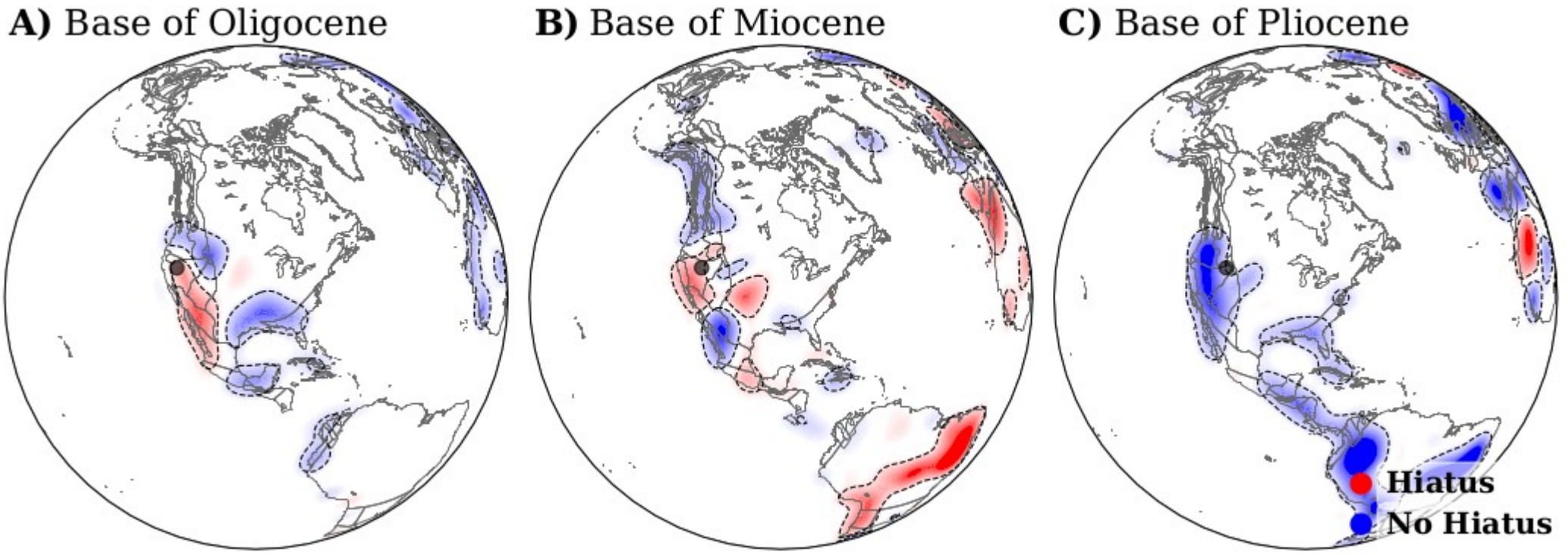
North American Base Hiatus Maps around the times of the Yellowstone plume arrival

In the western half BHS changes at interregional scales while North America approaches the Yellowstone hotspot

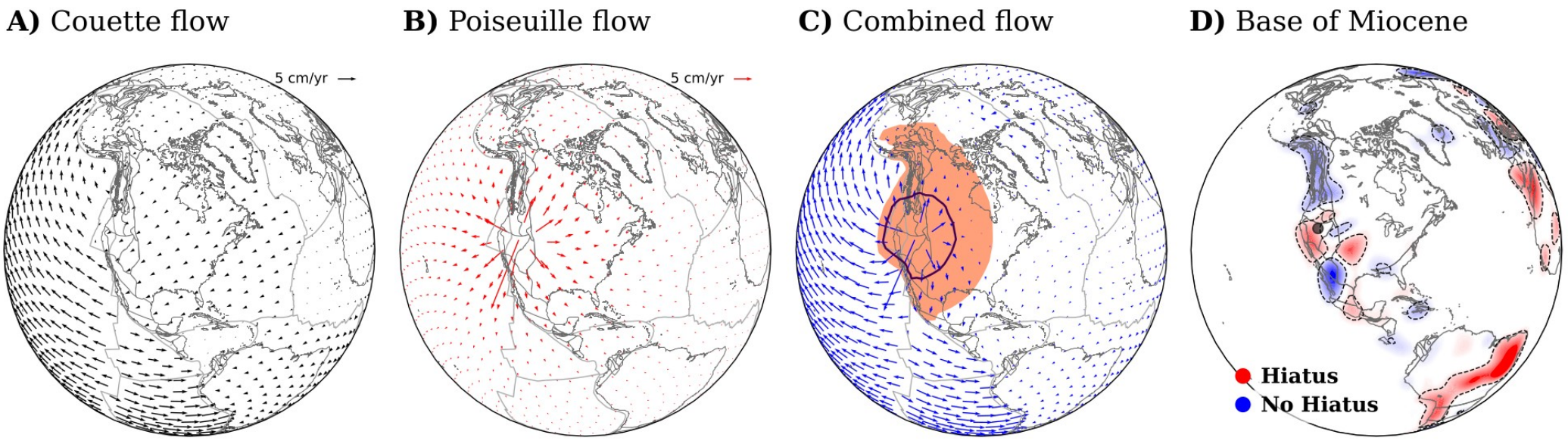


A prominent change occurs from the Base of Oligocene to Base of Miocene when the hiatus signals extend deep into the continental interior, indicative of growing topography

based on Hayek et. al., 2021

Effects of the Yellowstone plume on North America

Our analytical flow calculations provide a theoretical estimate of upper mantle flow beneath the North American plate induced by a combination of Couette and Poiseuille flow

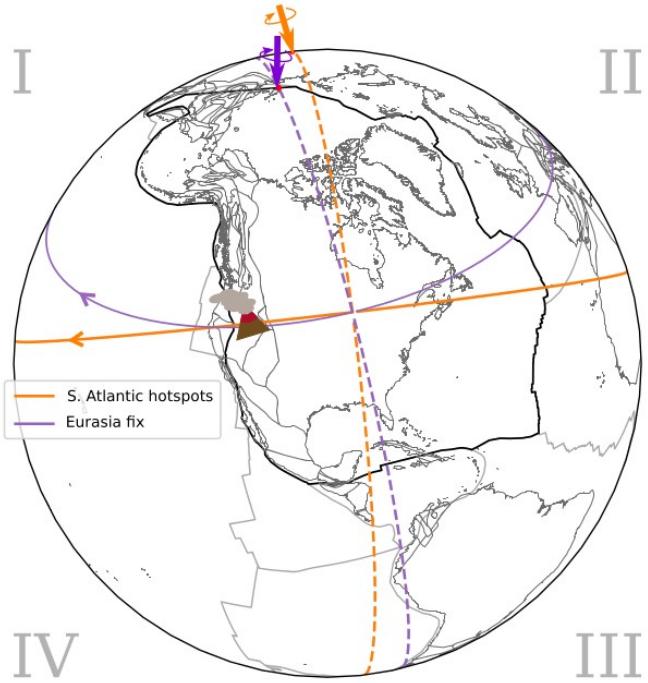


The plume flow dominated area, estimated based on the ratio between Couette and Poiseuille flow, agrees well in size with the area affected by hiatus as defined by the hiatus/no-hiatus contours. Importantly, both involve a comparable length-scale provided by their diameter (2500 km)

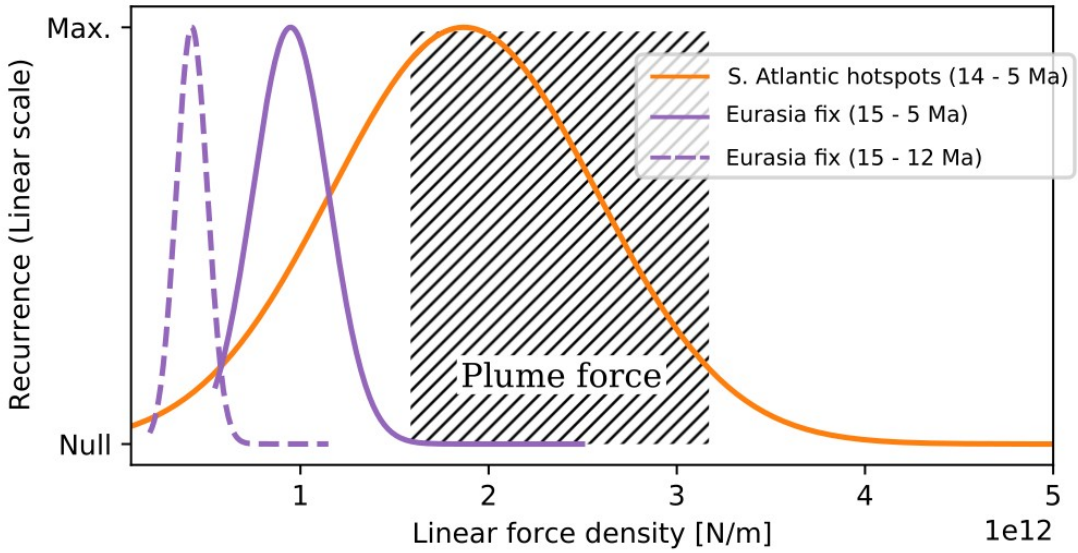
Effects of the Yellowstone plume on North America

Plume push force provides a dynamically viable mechanism to explain North America's plate motions

A) Euler vector pole



B) Analysis of tectonics forces



Conclusions

- Reconstructions of past plate kinematics and their temporal changes are an ideal constraint to analytical calculations and numerical models.
- Analytical calculations show that the pressure-drive Poiseuille flow is an important component of the force balance.
- Our results indicate that the plume push force provides a dynamically viable mechanism to affect North America's plate motions.
- Poiseuille flow within the asthenosphere links changes in dynamically maintained topography (vertical) and plate motion changes (horizontal) through a geodynamically plausible model.