Topographic coupling at the core mantle boundary

Rémy Monville, David Cébron, Dominique Jault
ISTerre, Université Grenoble Alpes, CNRS

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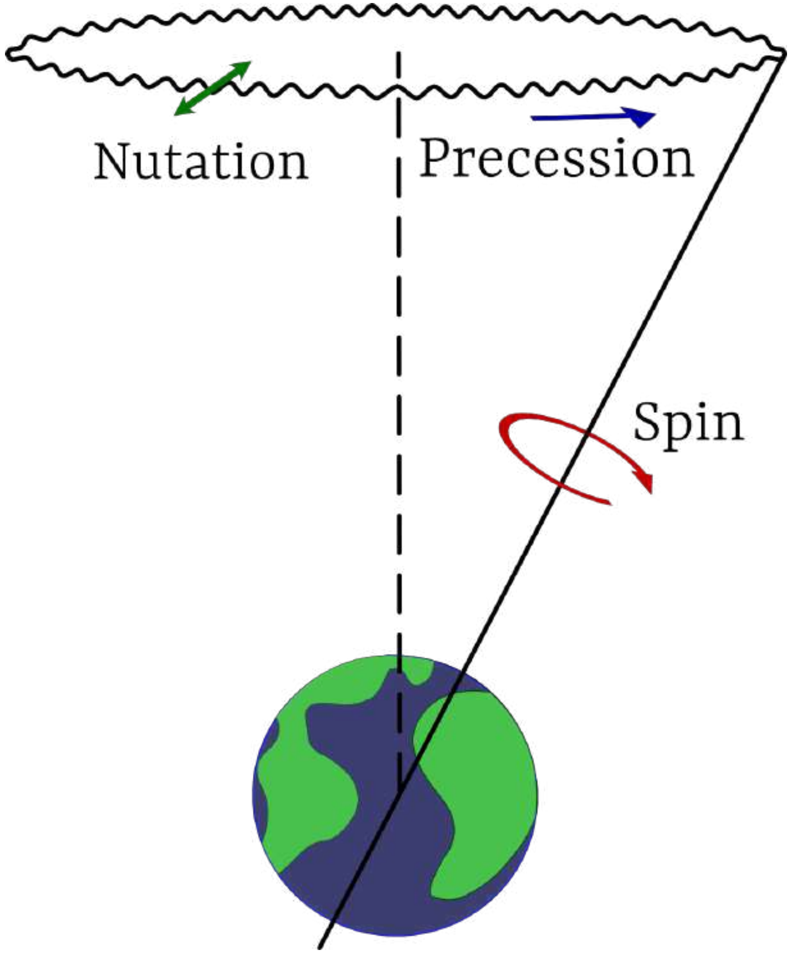
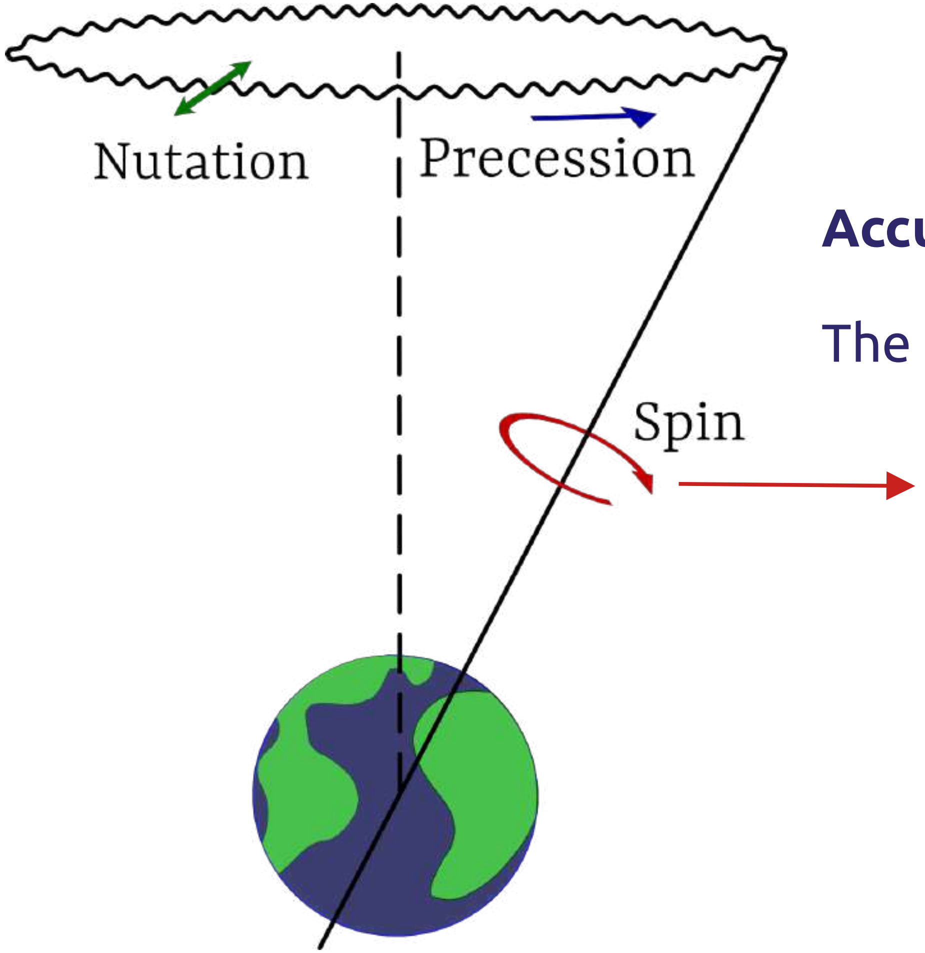
Measure and model the Earth's rotation



Accurate measurements

The **forward models** failed to reproduce the data.

Measure and model the Earth's rotation

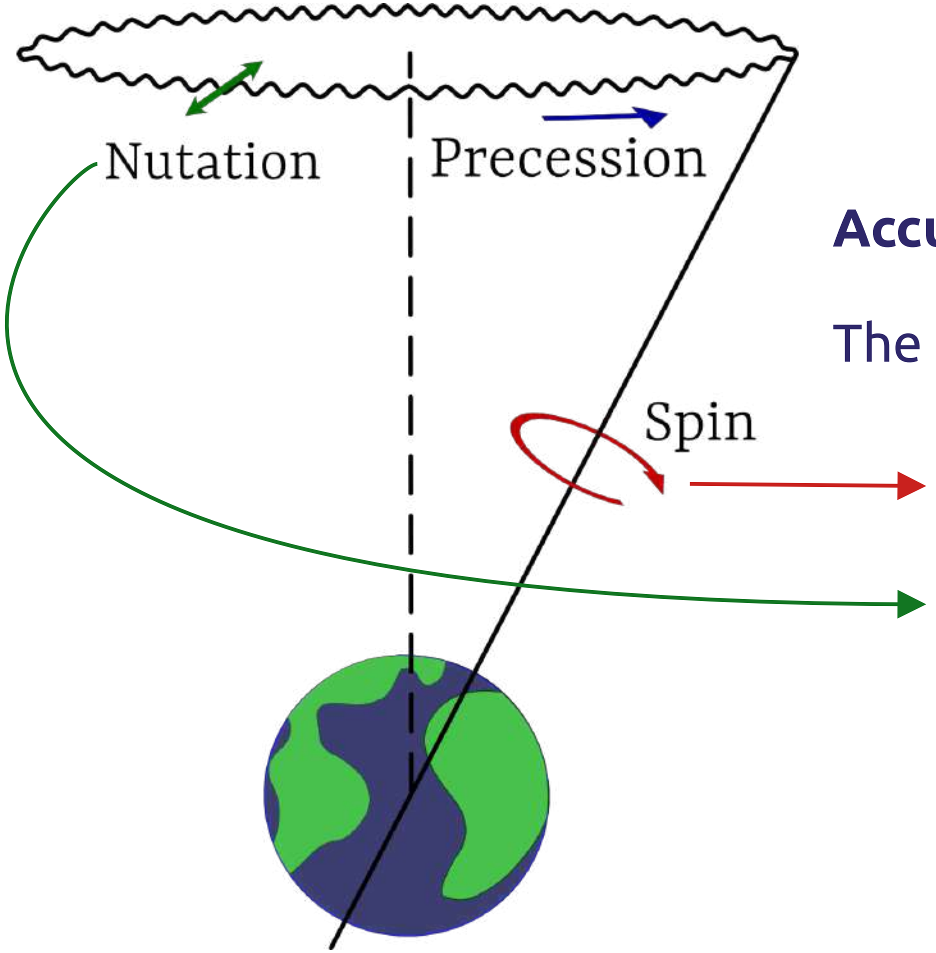


Accurate measurements

The **forward models** failed to reproduce the data.

- Decadal changes in **Length of the day**

Measure and model the Earth's rotation



Accurate measurements

The **forward models** failed to reproduce the data.

- Decadal changes in **Length of the day**
- Out of phase component in the retrograde **annual nutation**

Measure and model the Earth's rotation

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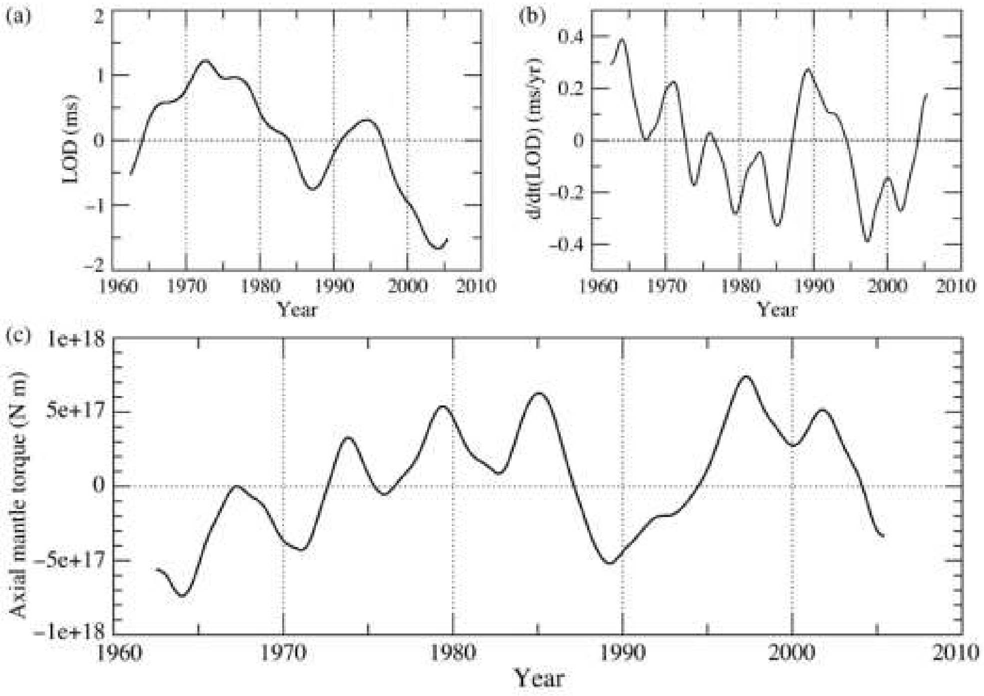
Inversion of rotation data provide constraints on the **coupling between the liquid core and the mantle.**

Coupling mechanism are still disputed and struggles to explain all the nutation and LOD measurements **simultaneously**



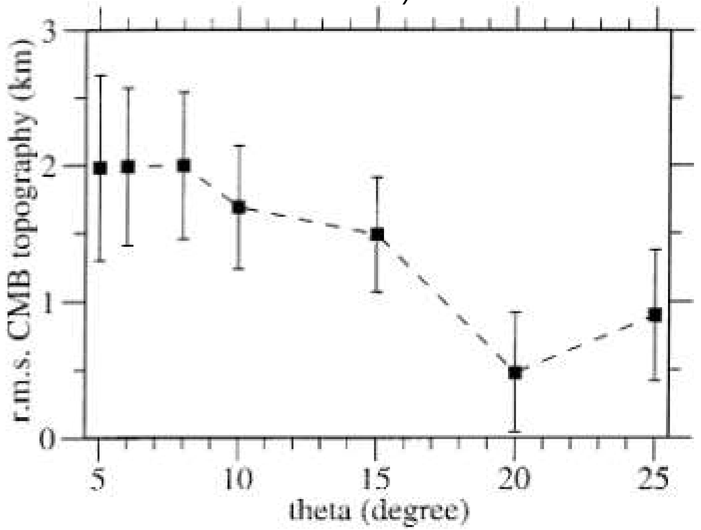
Holme and de Viron (2005).

Fluid-solid couplings

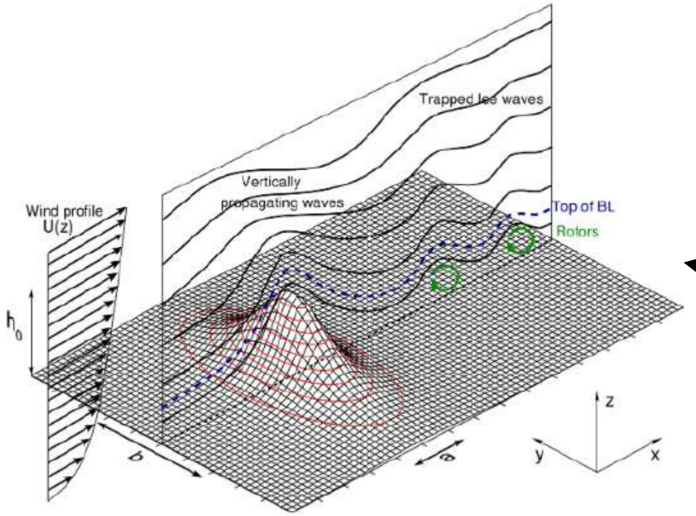
Pressure **Electromagnetic** Viscous Gravity

The topographic coupling, a generic features of geophysical flows

Garcia, R., & Souriau, A. (2000). *Physics of the Earth and Planetary Interiors*



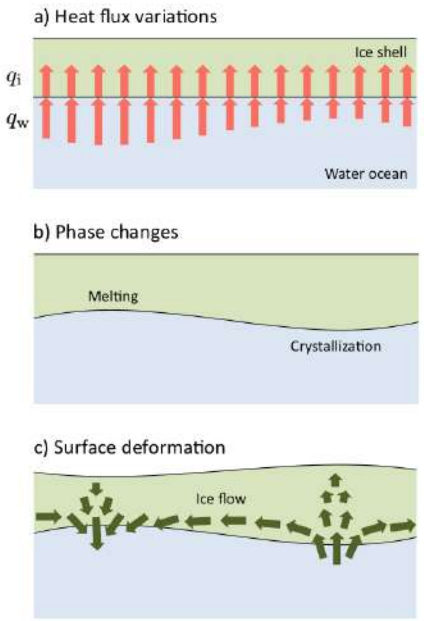
Core



Atmosphere

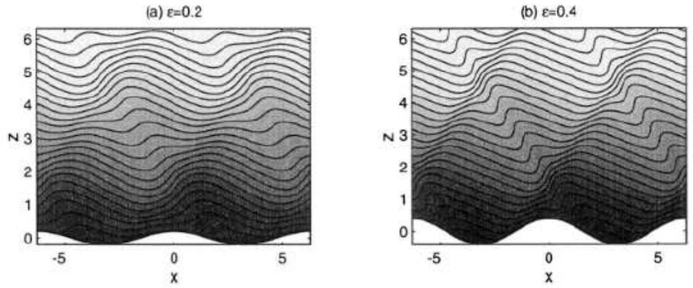
M. A. Teixeira, Frontiers in Physics 2014, 2, 43.

Subsurface oceans



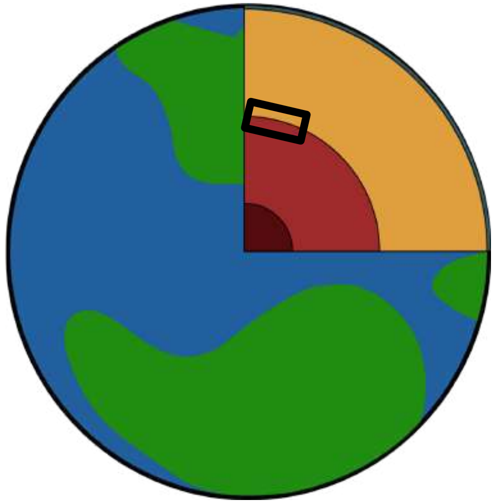
J. Kvorka, O. Čadek, G. Tobie, G. Choblet, Icarus 2018, 310, 149.

Oceans



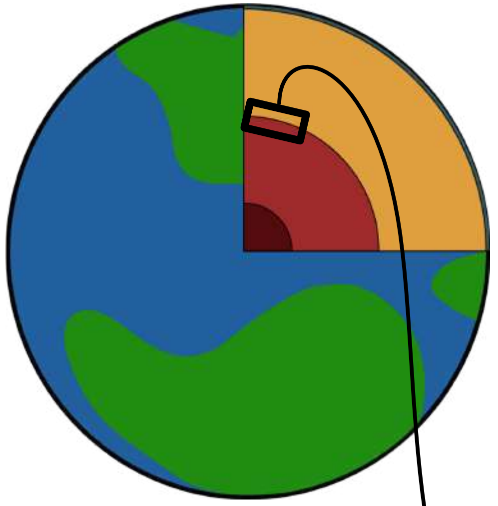
N. Balmforth, G. Ierley, W. Young, Journal of Physical Oceanography 2002, 32, 2900.

Method

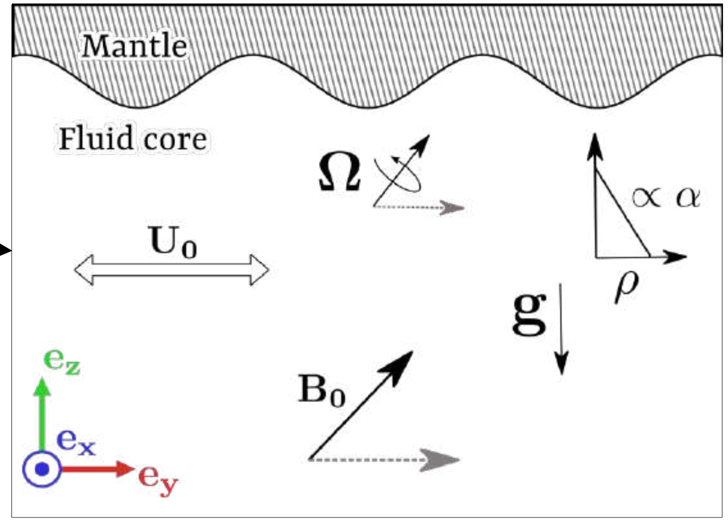


How to model the topographic coupling at the core mantle boundary ?

Method



Local model +
perturbation theory



Key ingredients:
- Buoyancy
- Rotation
- Magnetic field

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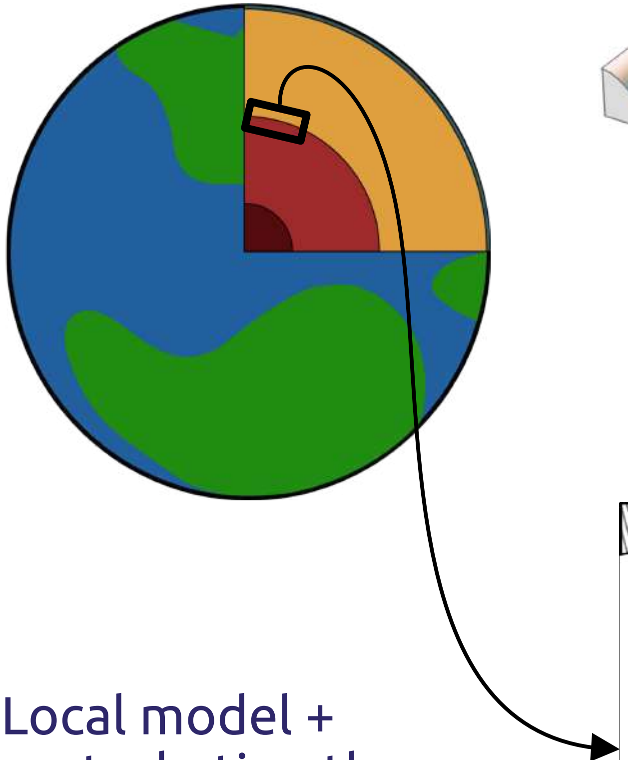
Method

Periodic topographies



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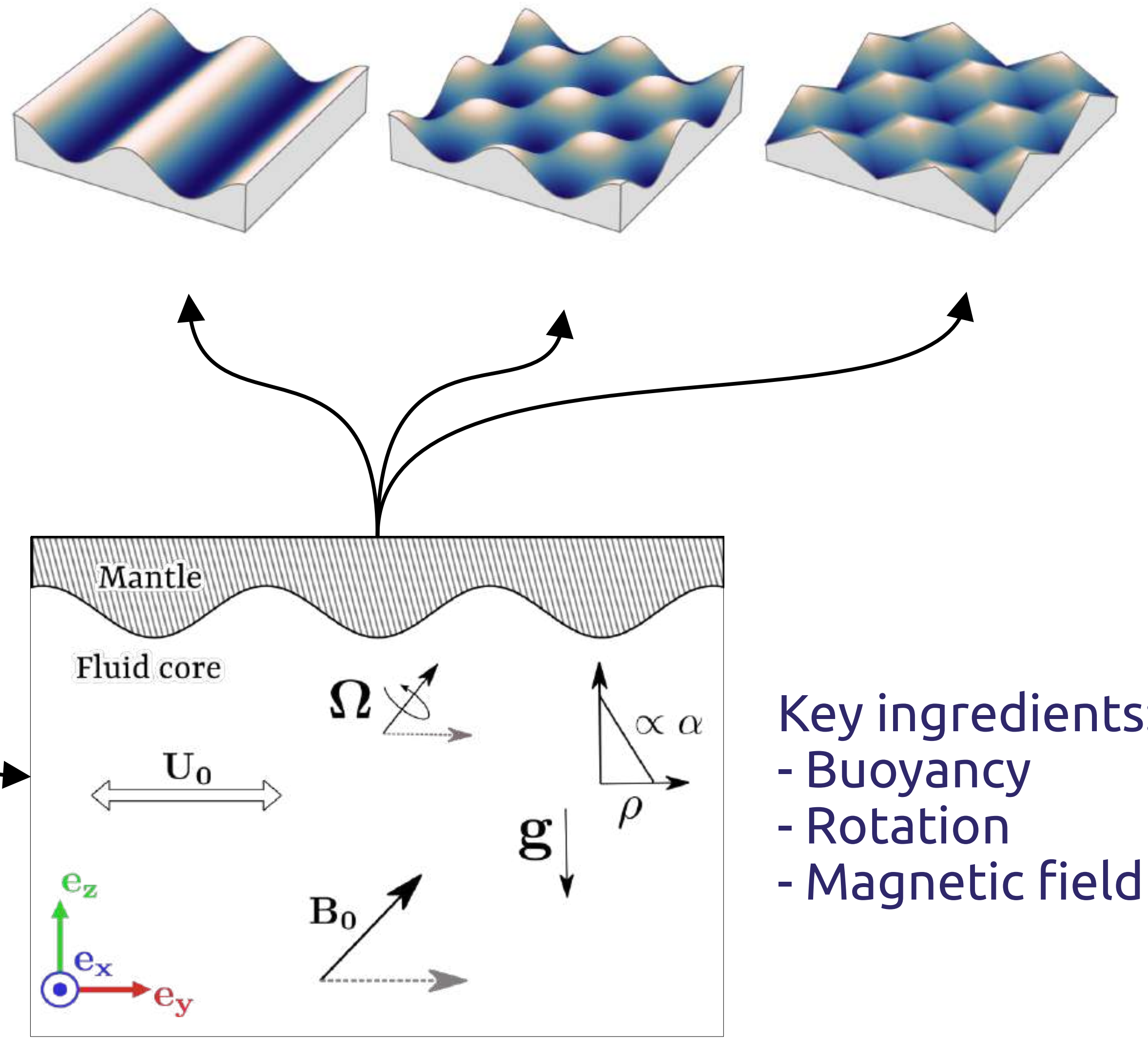

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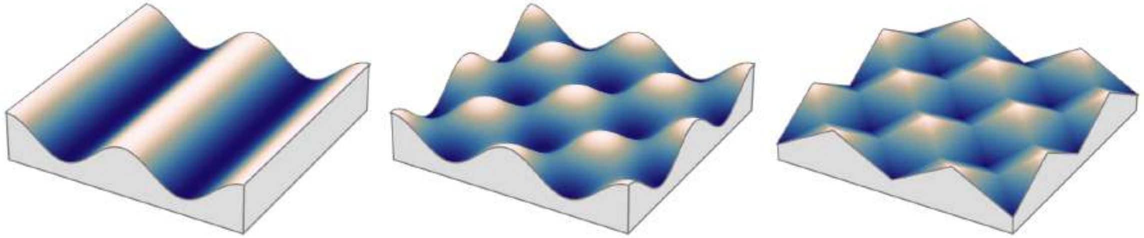

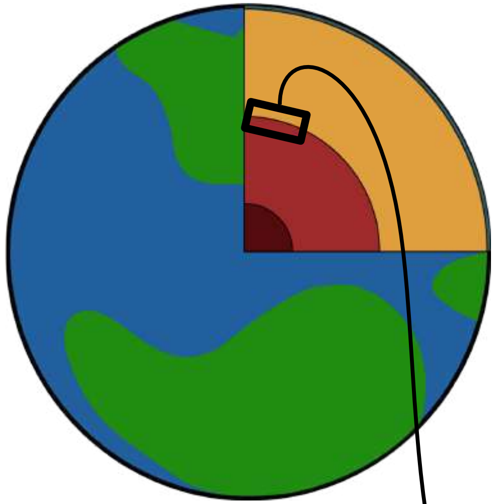

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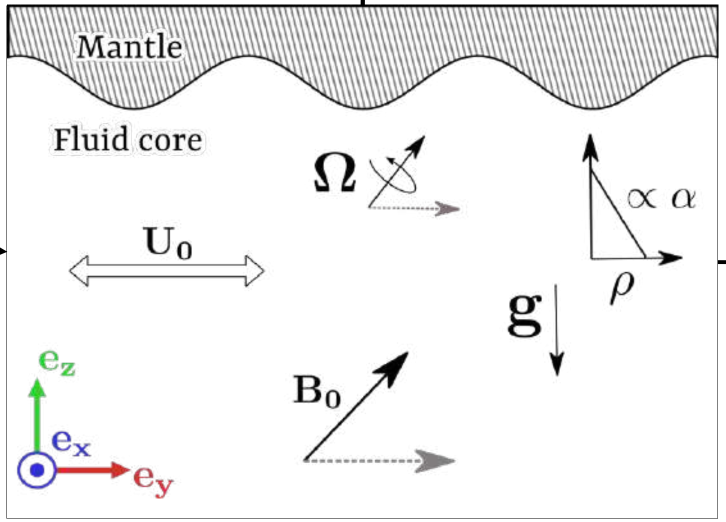
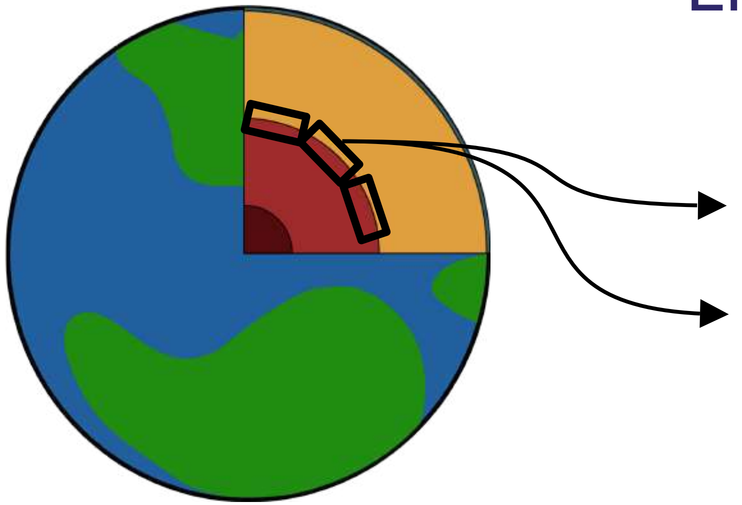


mpmath

Symbolic calculation
+ arbitrary precision

Method

Effects of the global geometry

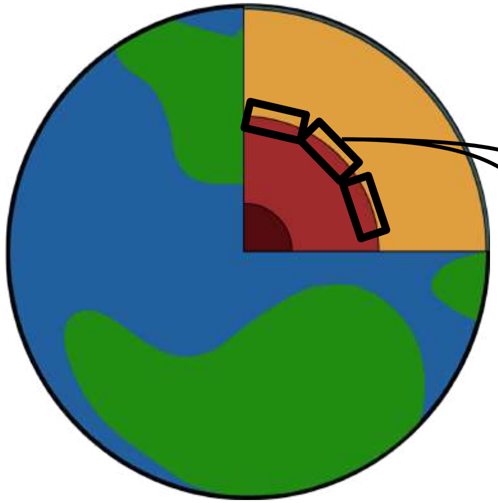


Multiple local boxes

0th order → uniform vectors

Method

Effects of the global geometry



- Multiple local boxes
- 0^{th} order → uniform vectors

$$\boldsymbol{B_0} = \left[0, \quad \boxed{\sin\theta/2}, \quad -\boxed{\cos\theta}\right],$$ → dipole

$$\boldsymbol{\Omega} = \left[0, \quad \boxed{\sin\theta} \quad , \quad \boxed{\cos\theta} \quad \right],$$

Method

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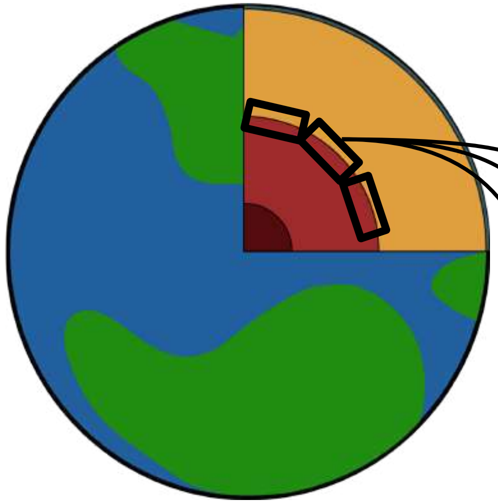
Effects of the global geometry



→ Multiple local boxes

→ 0^{th} order → uniform vectors (orange box)

→ 1^{st} order → Beta-plane approximation (green box)

$$\boldsymbol{B_0} = \left[0, \quad \sin\theta/2, \quad -\cos\theta\right],$$

→ dipole

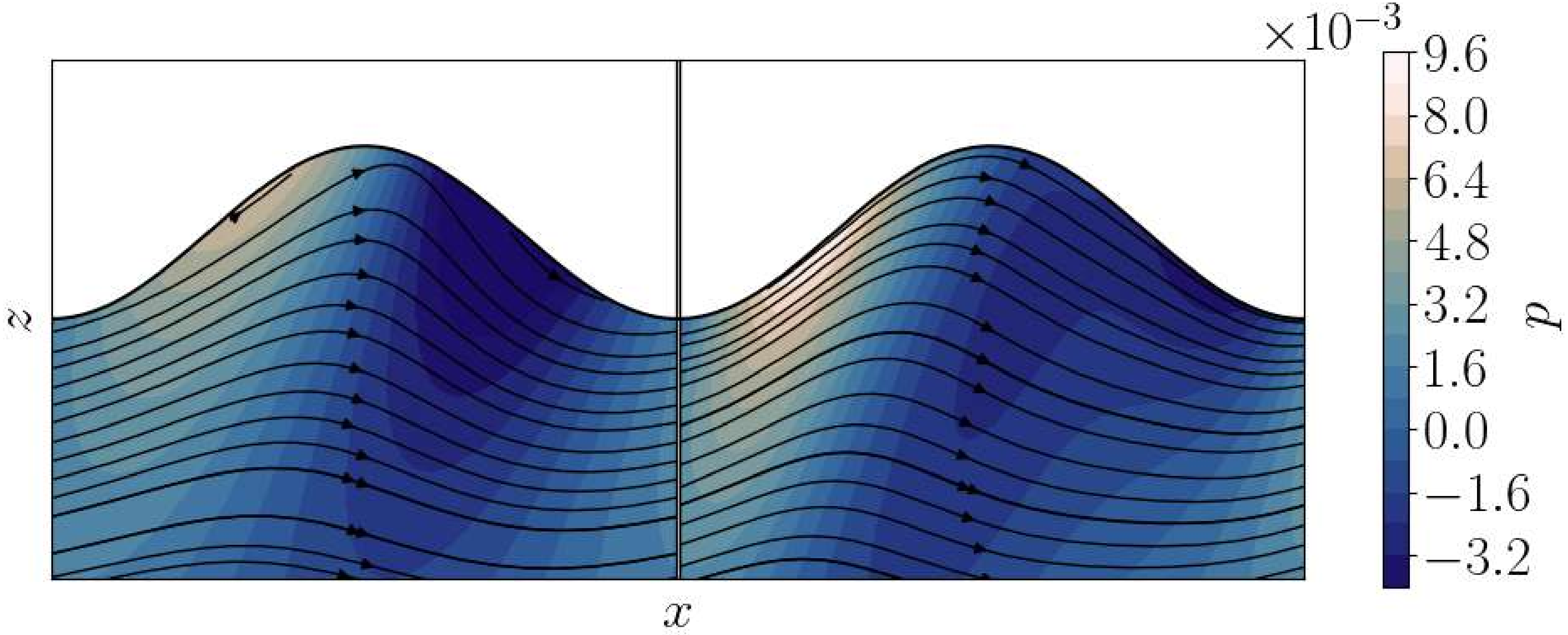
$$\boldsymbol{\Omega} = \left[0, \quad \sin\theta - 2\chi y\cos\theta, \quad \cos\theta + 2\chi z\cos\theta + \chi y\sin\theta\right],$$

Method

Perturbation method at higher order

$$\boldsymbol{u} = \boldsymbol{u}_0 + \sum_{m,n=0} \epsilon_t^m \epsilon_v^n \boldsymbol{u}_{m,n}, \quad \boldsymbol{b} = Al^{-1}\boldsymbol{b}_0 + \sum_{m,n=0} \epsilon_t^m \epsilon_v^n \boldsymbol{b}_{m,n}, \quad a = \sum_{m,n=0} \epsilon_t^m \epsilon_v^n a_{m,n},$$

topography (ϵ_t^m) non-linearities (ϵ_v^n)

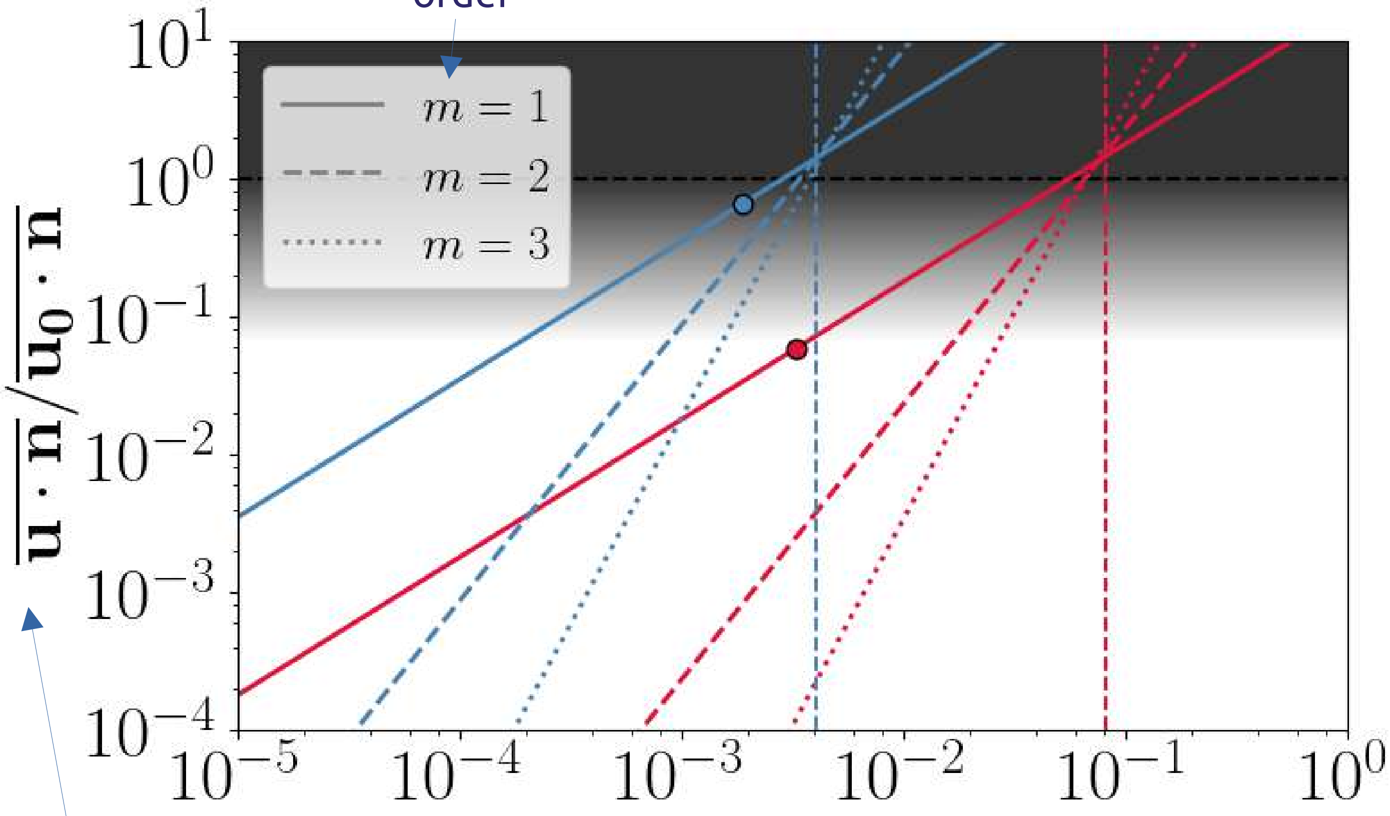


→ Increase accuracy 1st order 4th order

Method

Perturbation method at higher order

order



Topography height ϵ_t

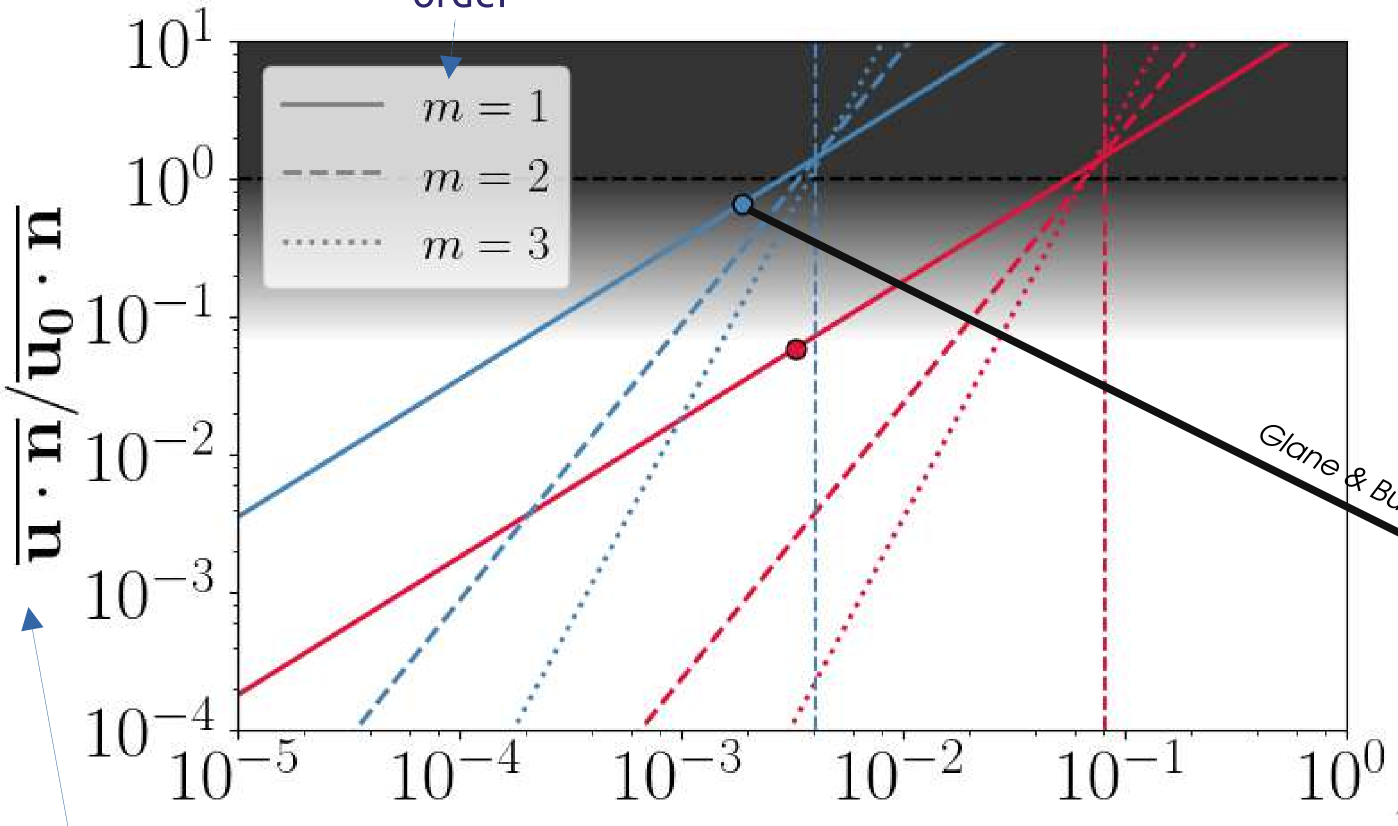
← Bounds the convergence of the model

Error on the non-penetration boundary condition

Method

Perturbation method at higher order

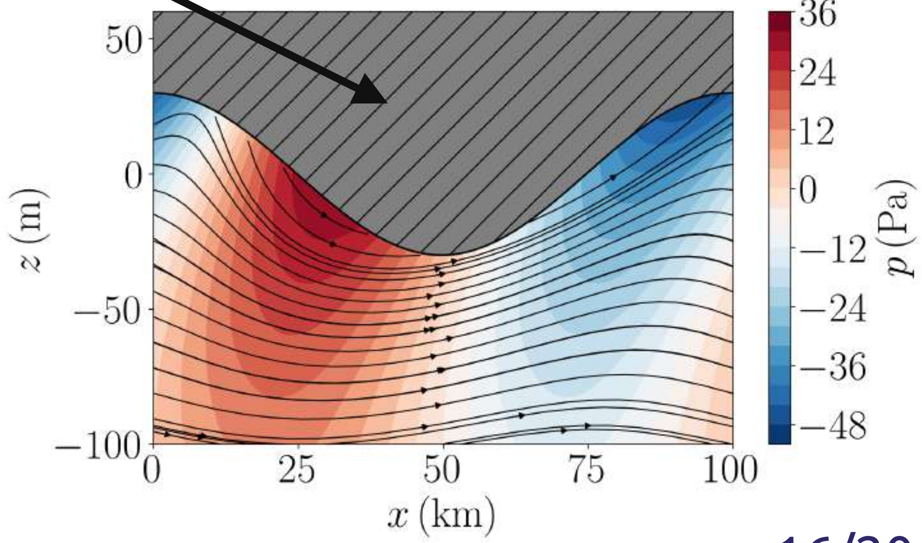
order



Topography height ϵ_t

← Bounds the convergence of the model

Glane & Buffett (2018)



Error on the non-penetration boundary condition

Does pressure stress vary differently within the various planetary fluid layers

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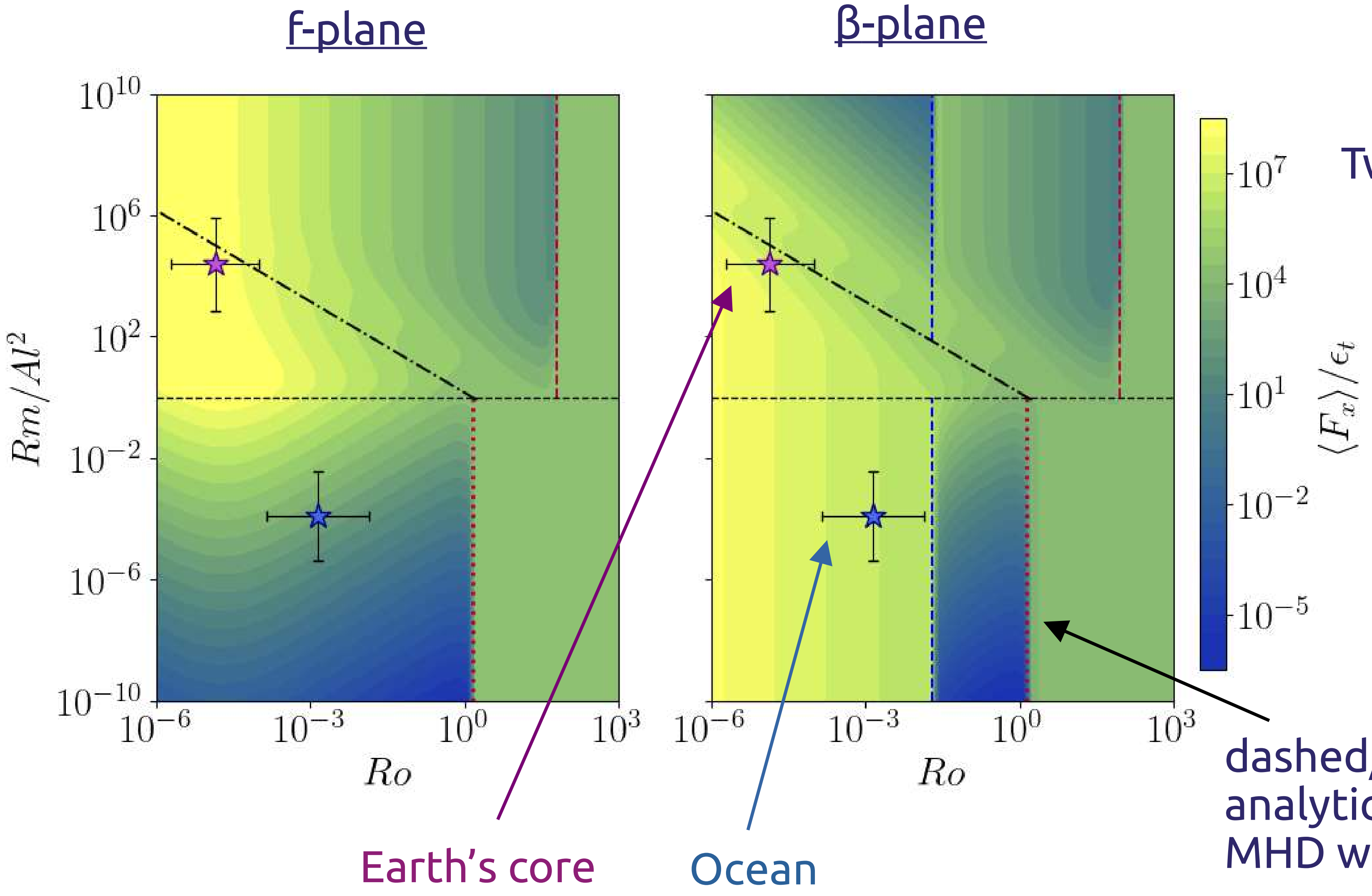
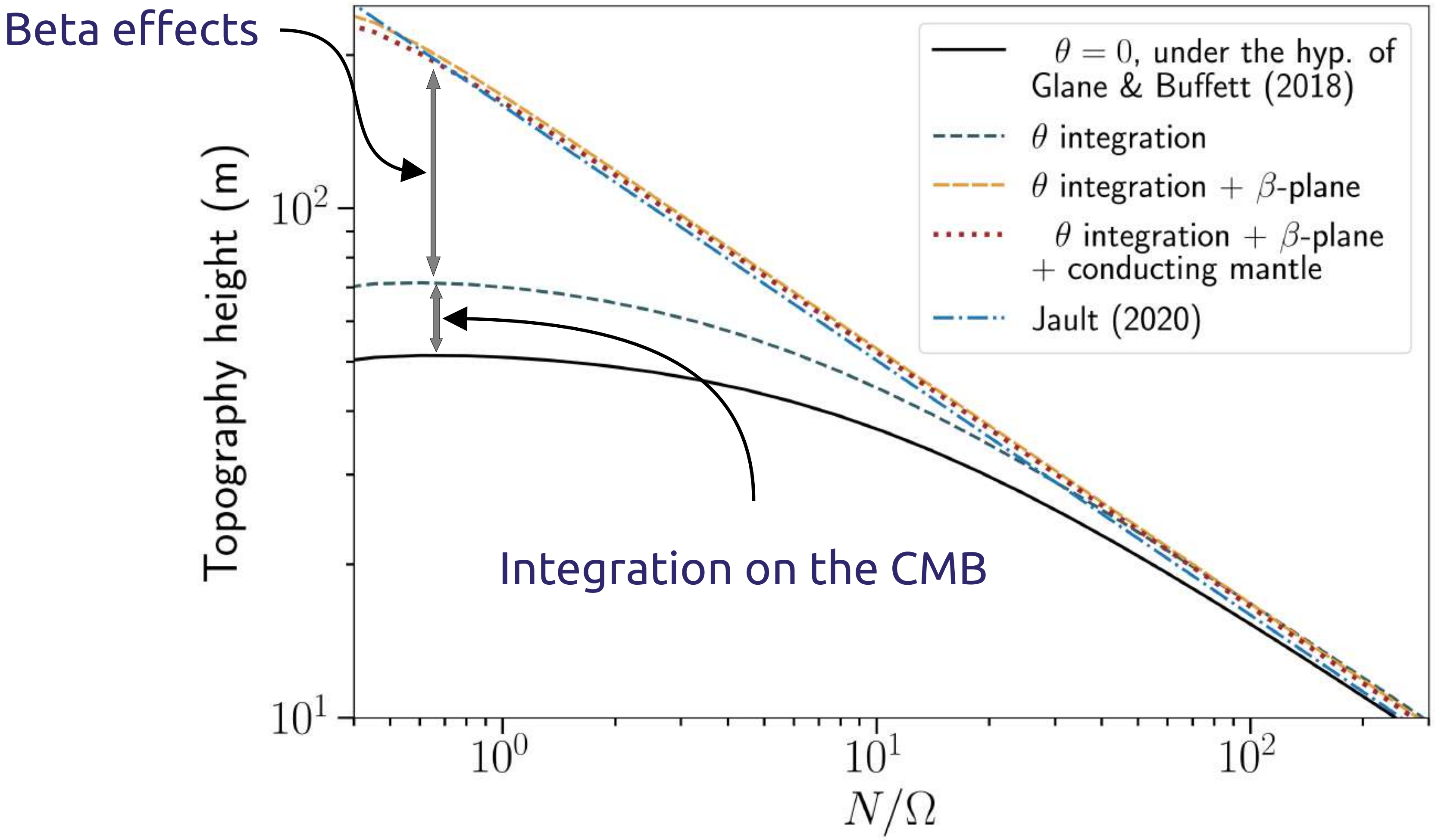


Two key effects:

- **Rotation:** stress highly impacted by β effects
- **Magnetic field**

dashed/dotted lines = our analytical predictions (from MHD wave eq.) of the regimes

How to match the length of day data?



With these variations and **our new features** we expect to **reconcile length of day and nutation data**.

Conclusion

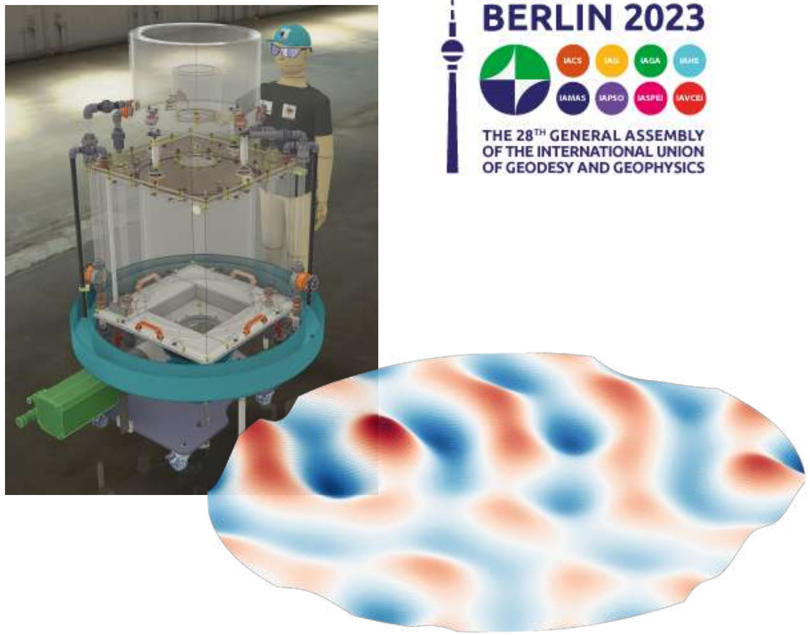
- We developed a **robust model** able to solve many types of problem **efficiently**.

- **High order** perturbation : better **accuracy** & provides the **limits** of this method

- New insight on the topography **coupling** and **topographic waves** in the Earth core context

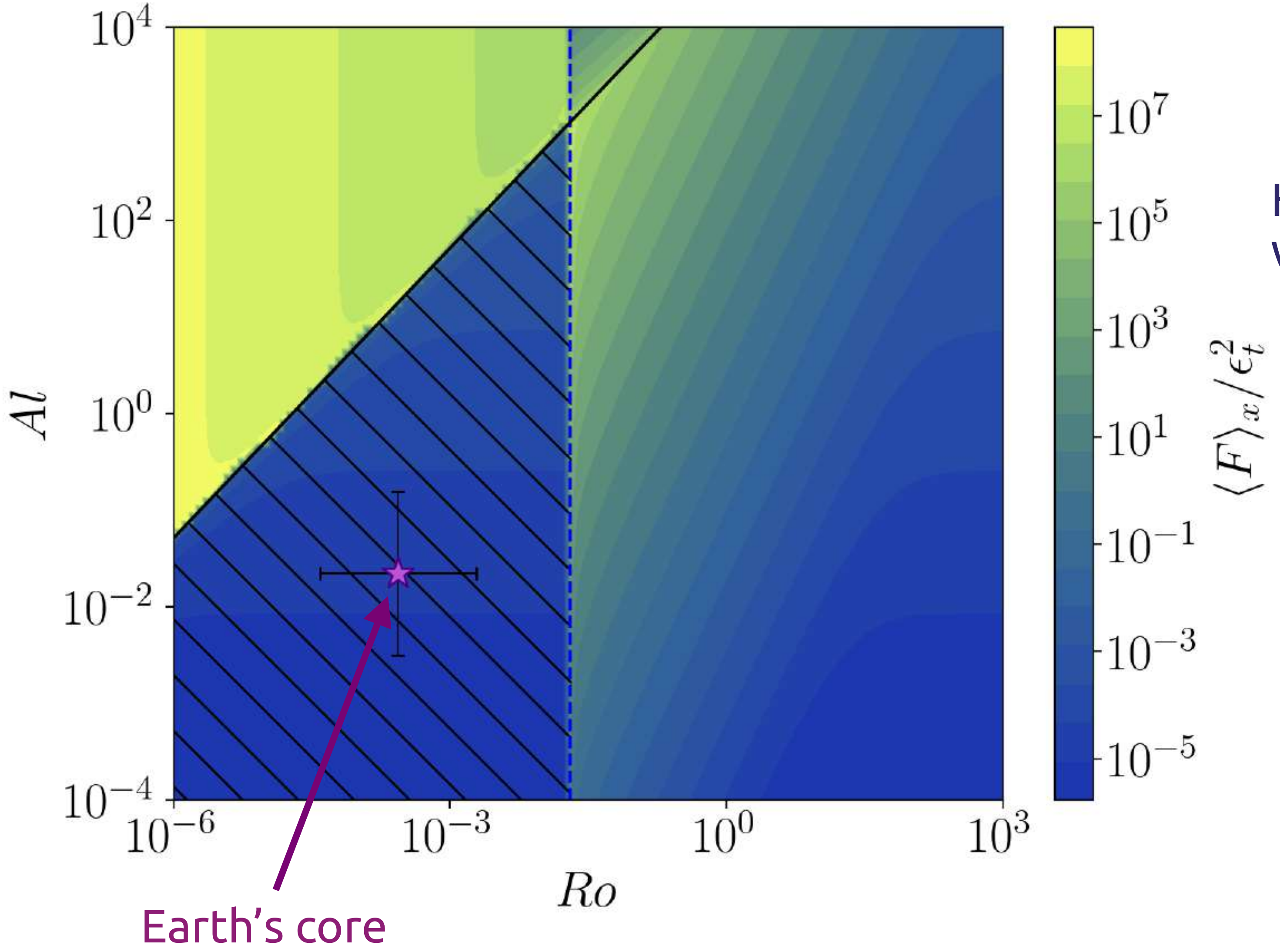
- Automated method: easy to **optimise on geophysical data**.

- In the future, we plan to link up with **rotating table experiments**.



Low-diffusion wave drag or Ohmic dissipation?

Stress at low magnetic diffusivity (high conductivity, Rm »1)



Hatches : the only regime where stress → 0 when Rm → ∞

→ Earth's Core stress highly depends on Ohmic dissipation