

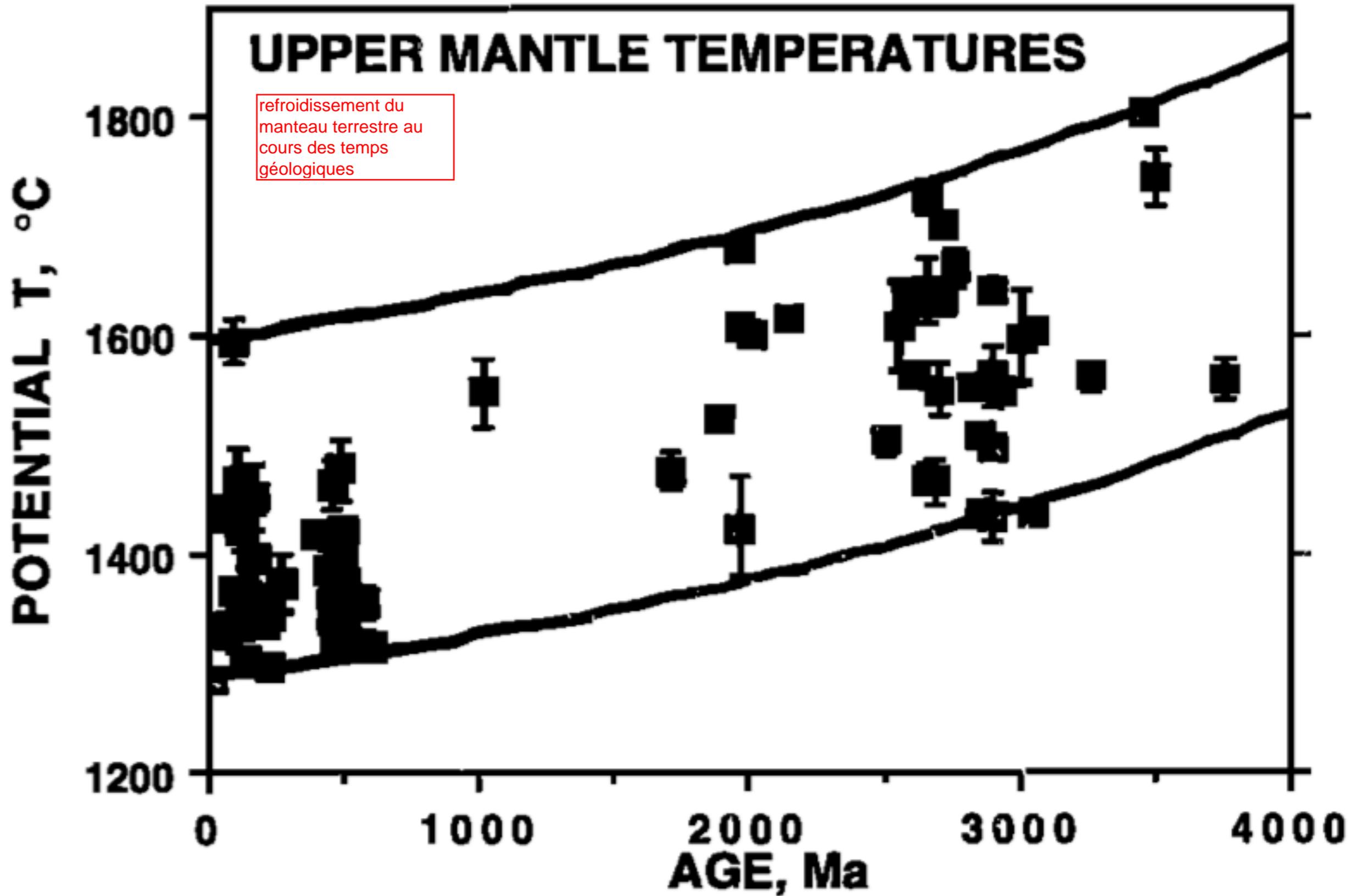
Les océans: la dernière frontière pour la sismologie terrestre



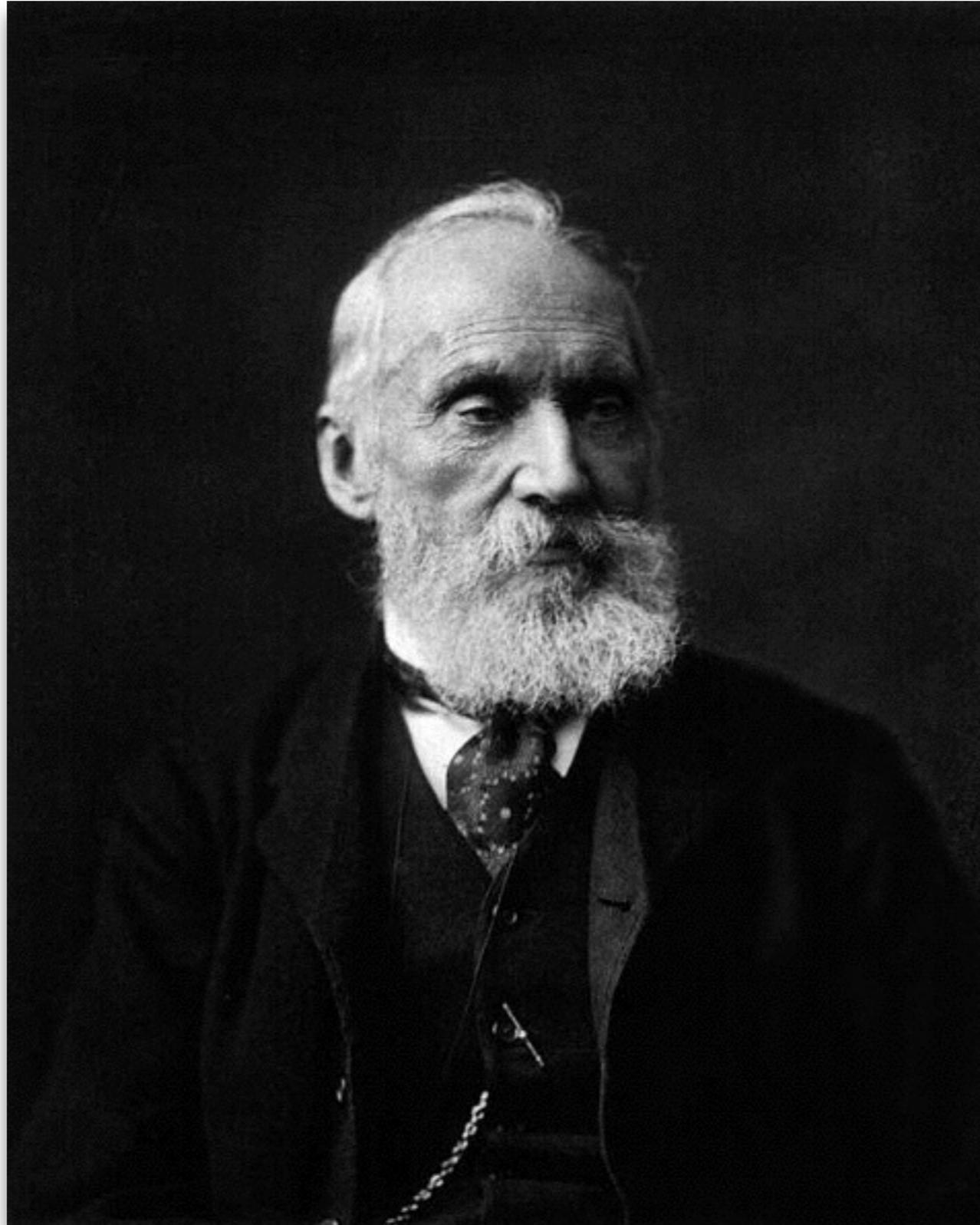
European Research Council
Established by
the European Commission

Guust Nolet
Université de la Côte d'Azur,
& Princeton University

EDUMED, 27 nov
2017



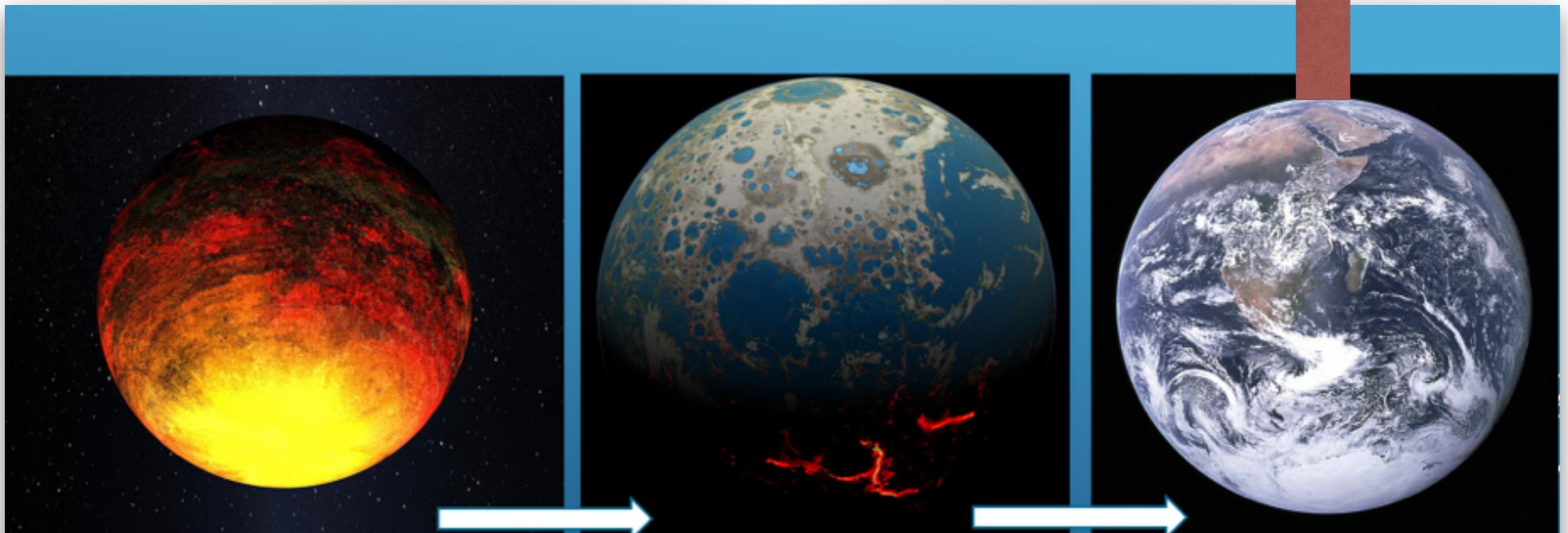
19e siècle: Lord Kelvin



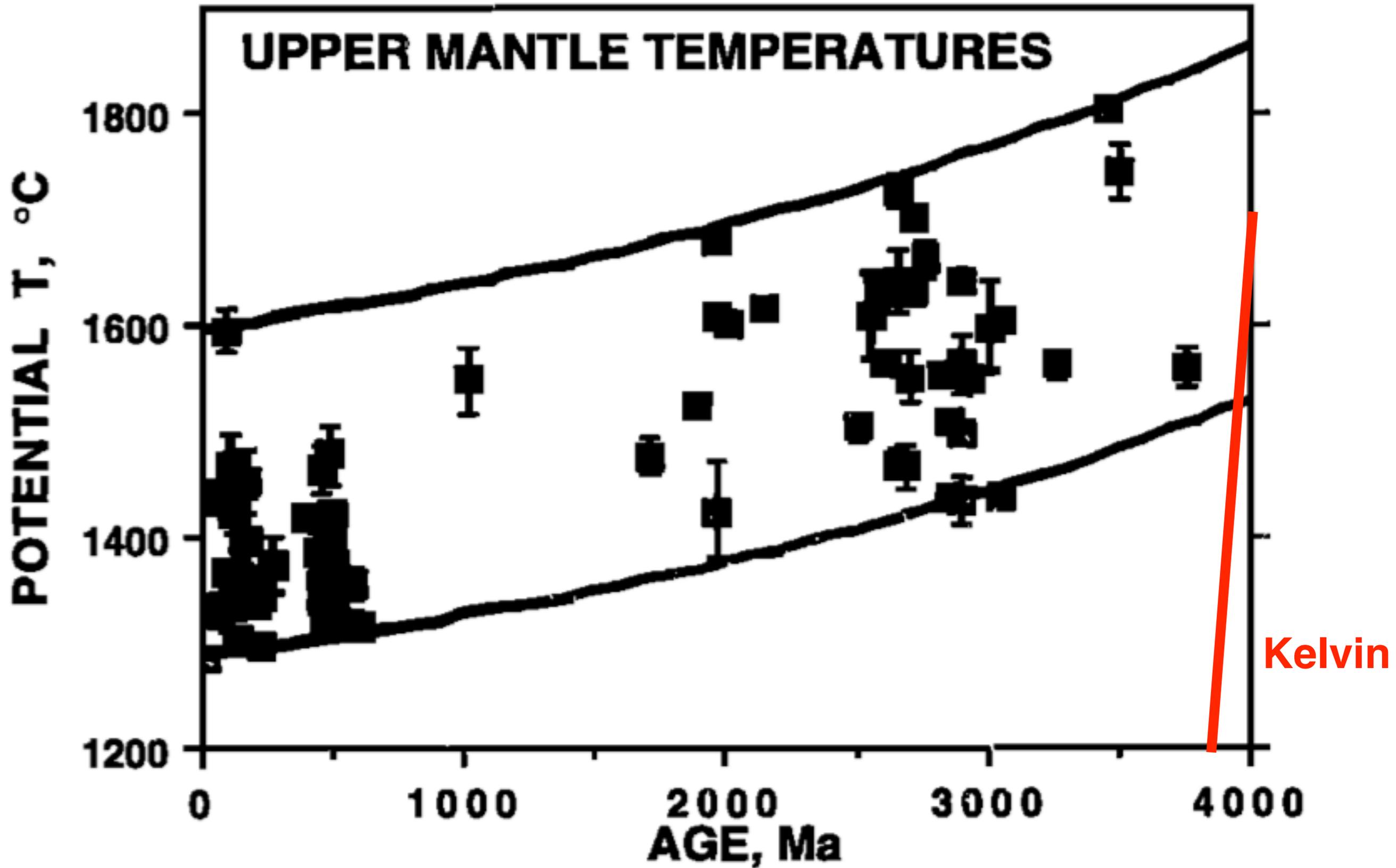
Lord Kelvin: refroidissement par *diffusion*

Pour Buffon : la terre actuelle serait le résultat du refroidissement d'une planète composée initialement de roches en fusion. Dans ses forges de Montbar, Buffon chauffe au rouge des sphères de rayons différents et composés de matériaux différents. Il mesure les temps de refroidissement et extrapole ses résultats à la Terre. Buffon ne dispose d'aucune théorie pour son extrapolation. Arrive alors le 'secours' de Lord Kelvin (1824-1907). En s'appuyant sur l'équation de la chaleur, il donne une fourchette de 20 à 40 millions d'années en 1897.

~ 46 TW



< 100 my

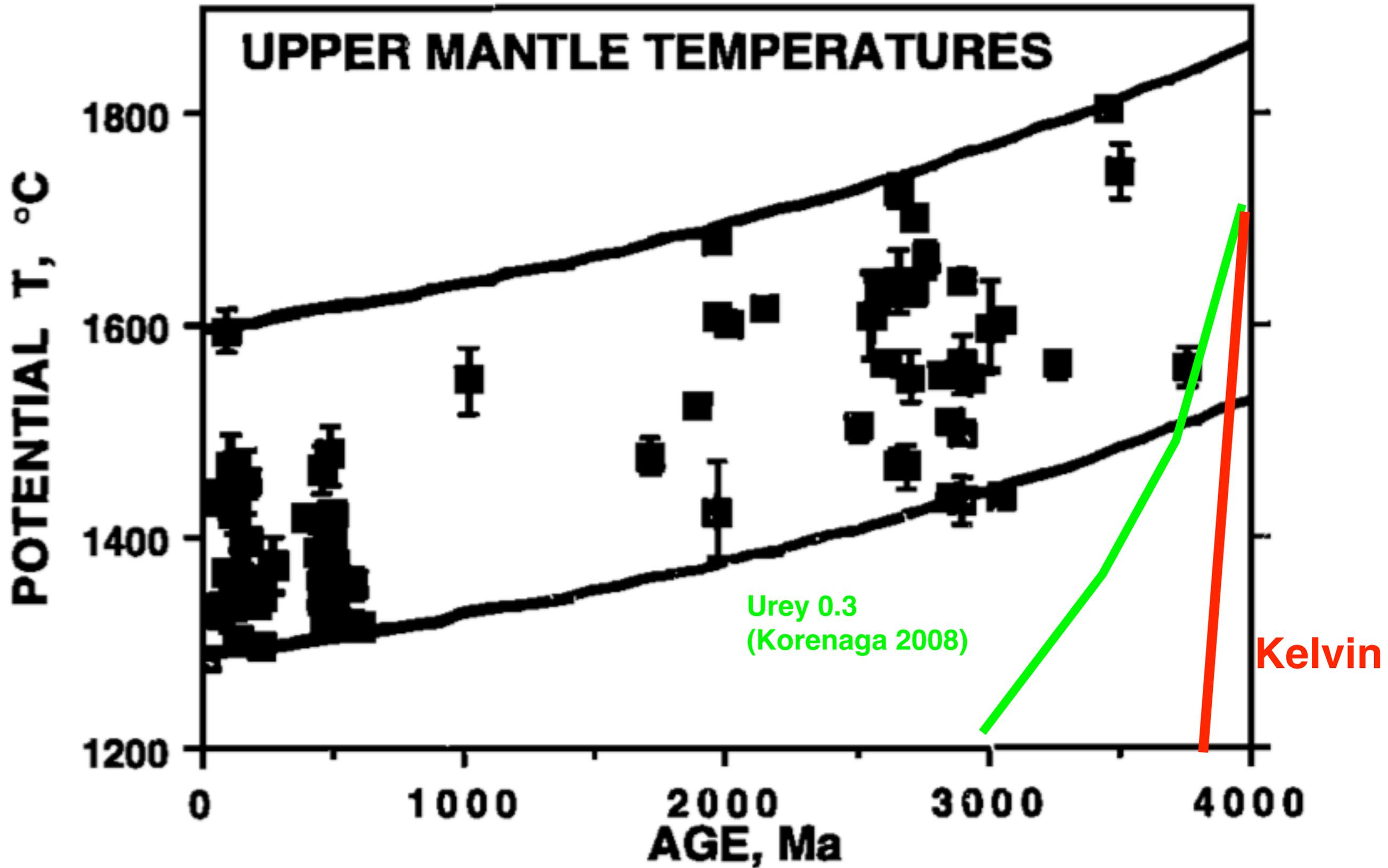


Radioactivité?

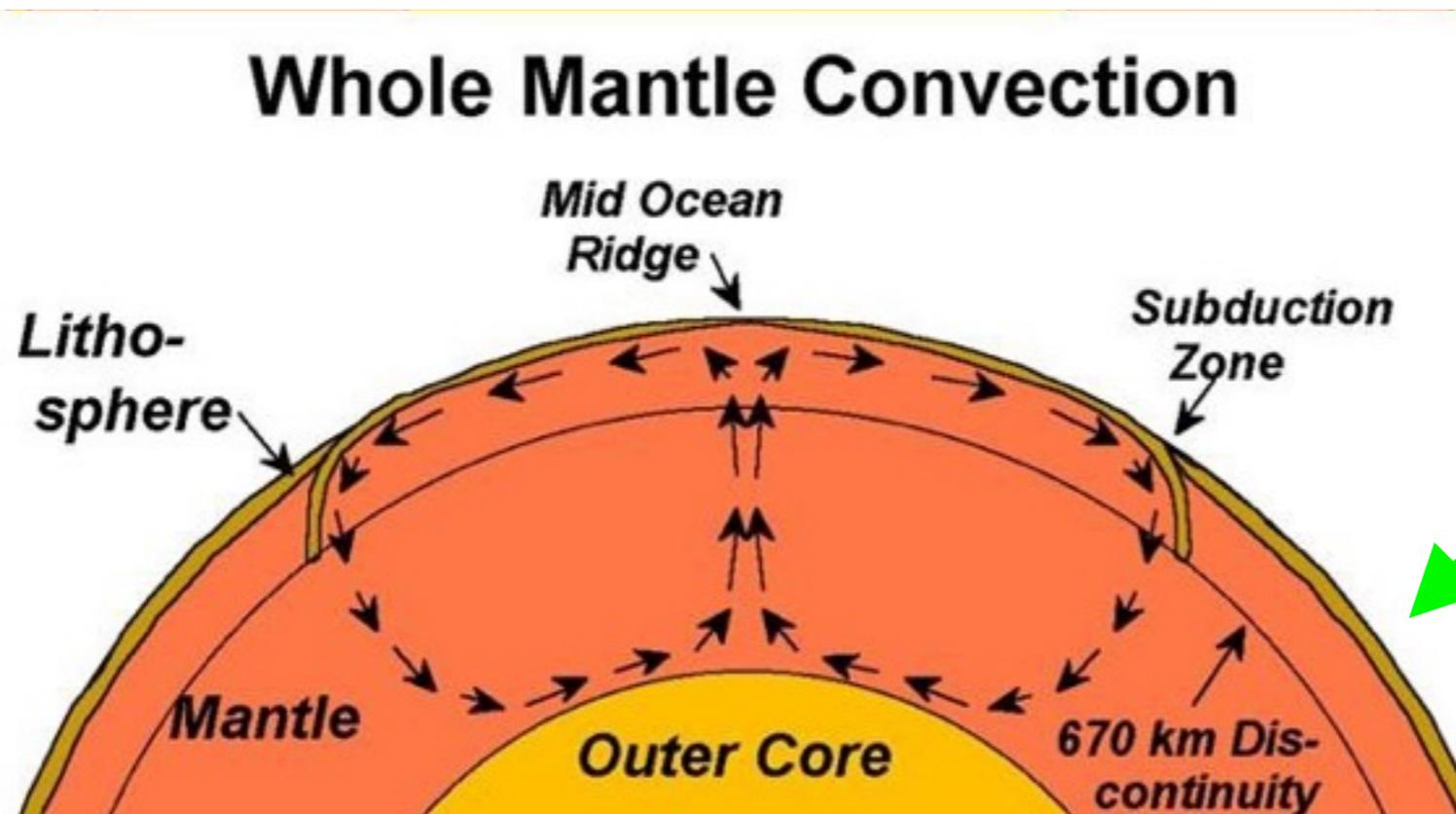
$$\text{Urey ratio} = \frac{\text{calories "radioactives"}}$$

toutes calories

Geochimie: 0.3-0.5



Quel type de convection?

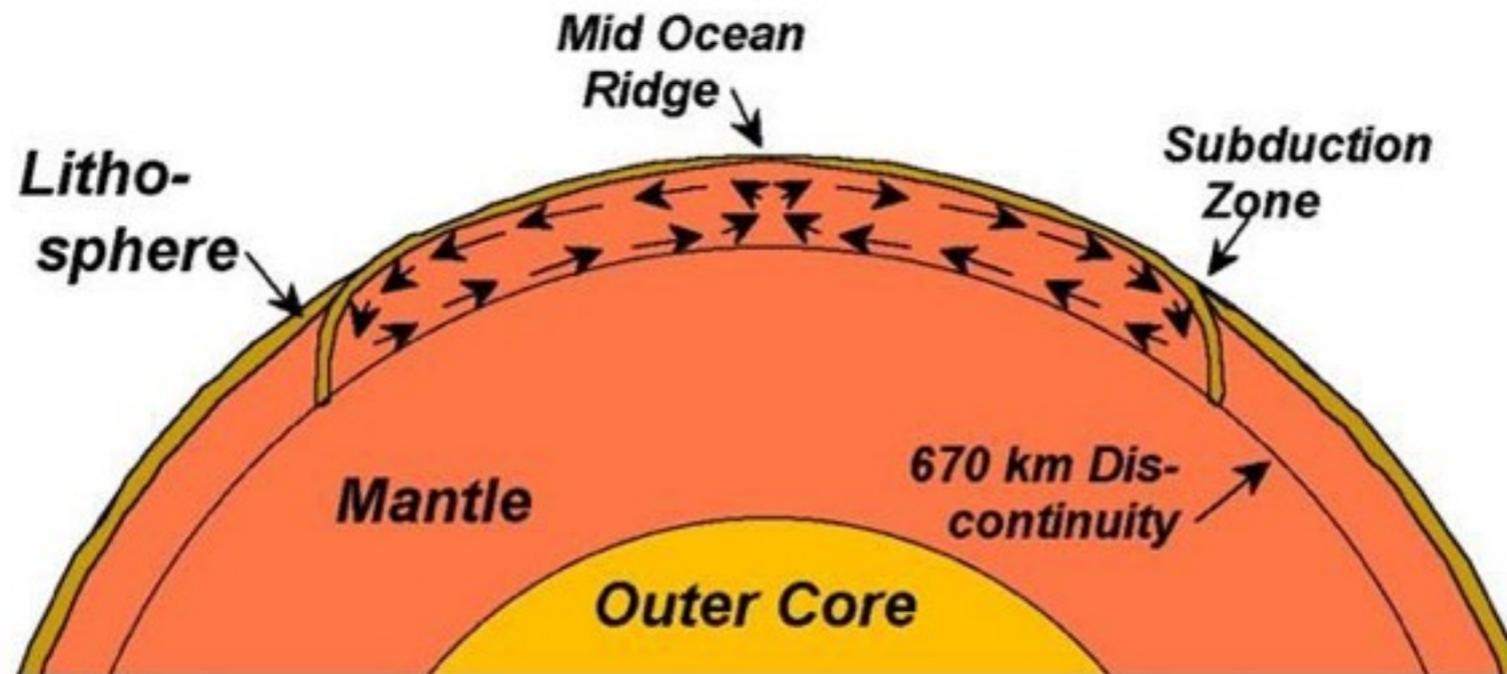


Korenaga's
hypothèse

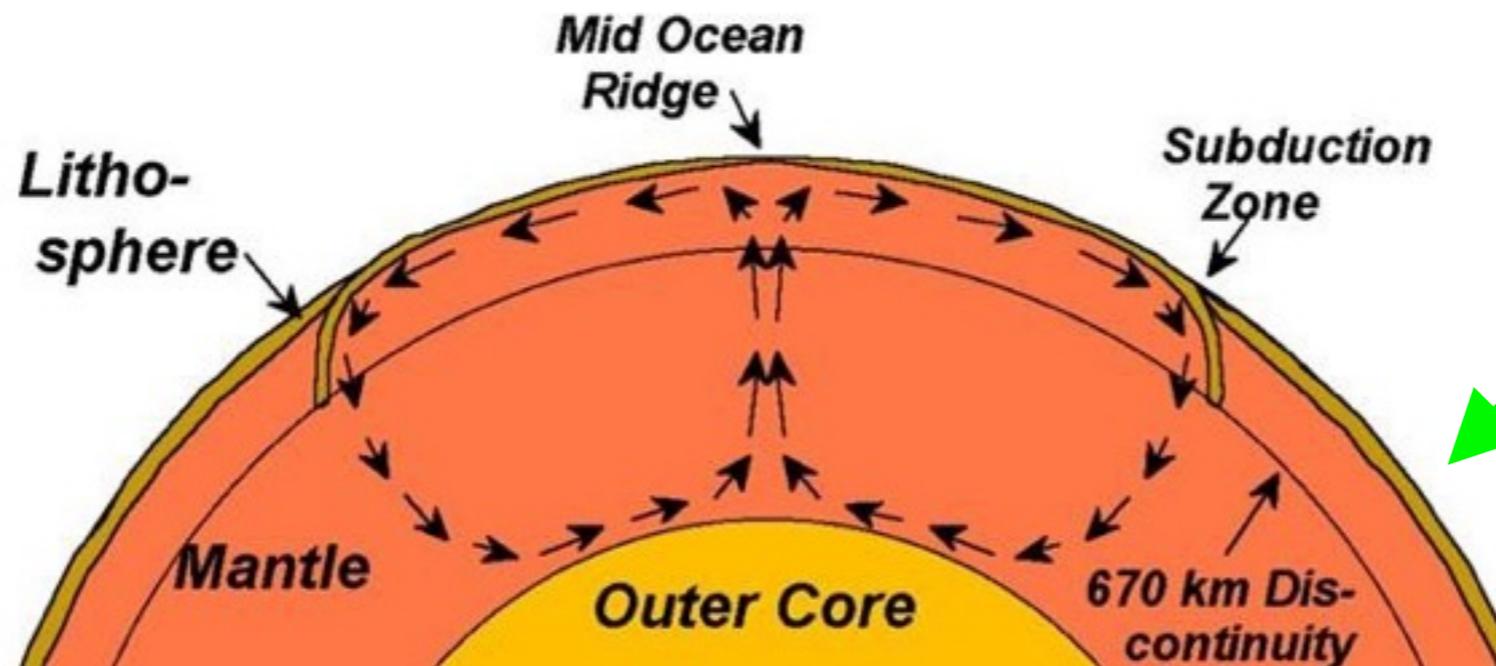
Quel type de convection?

La convection du manteau terrestre est la clé de compréhension pour le refroidissement de la planète. Quel modèle peut être validé par les mesures sur Terre ? ...
une convection globale du manteau sur toute son épaisseur, ou des convections multiples notamment au dessus de la discontinuité des 670 km.

Upper Mantle Convection

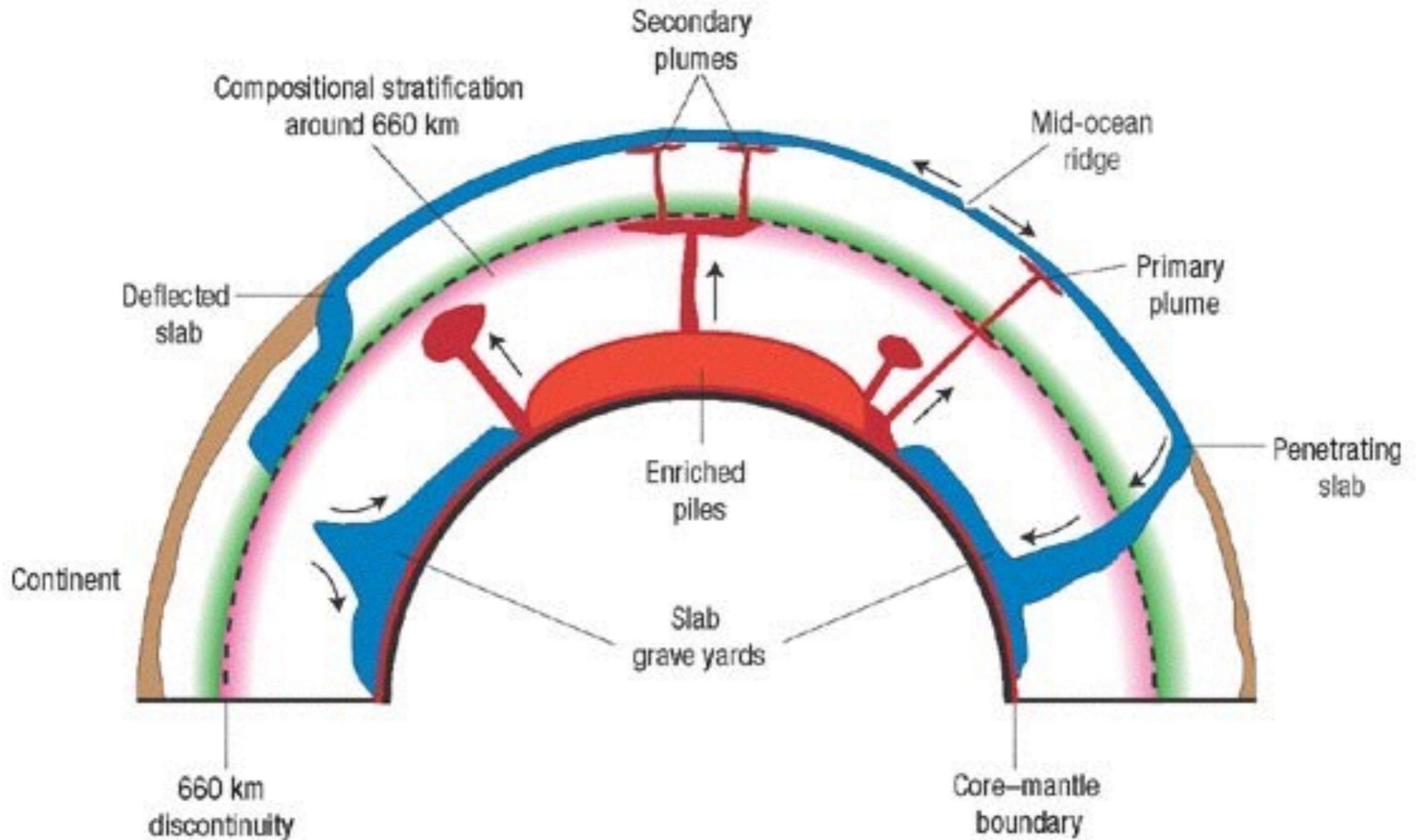


Whole Mantle Convection

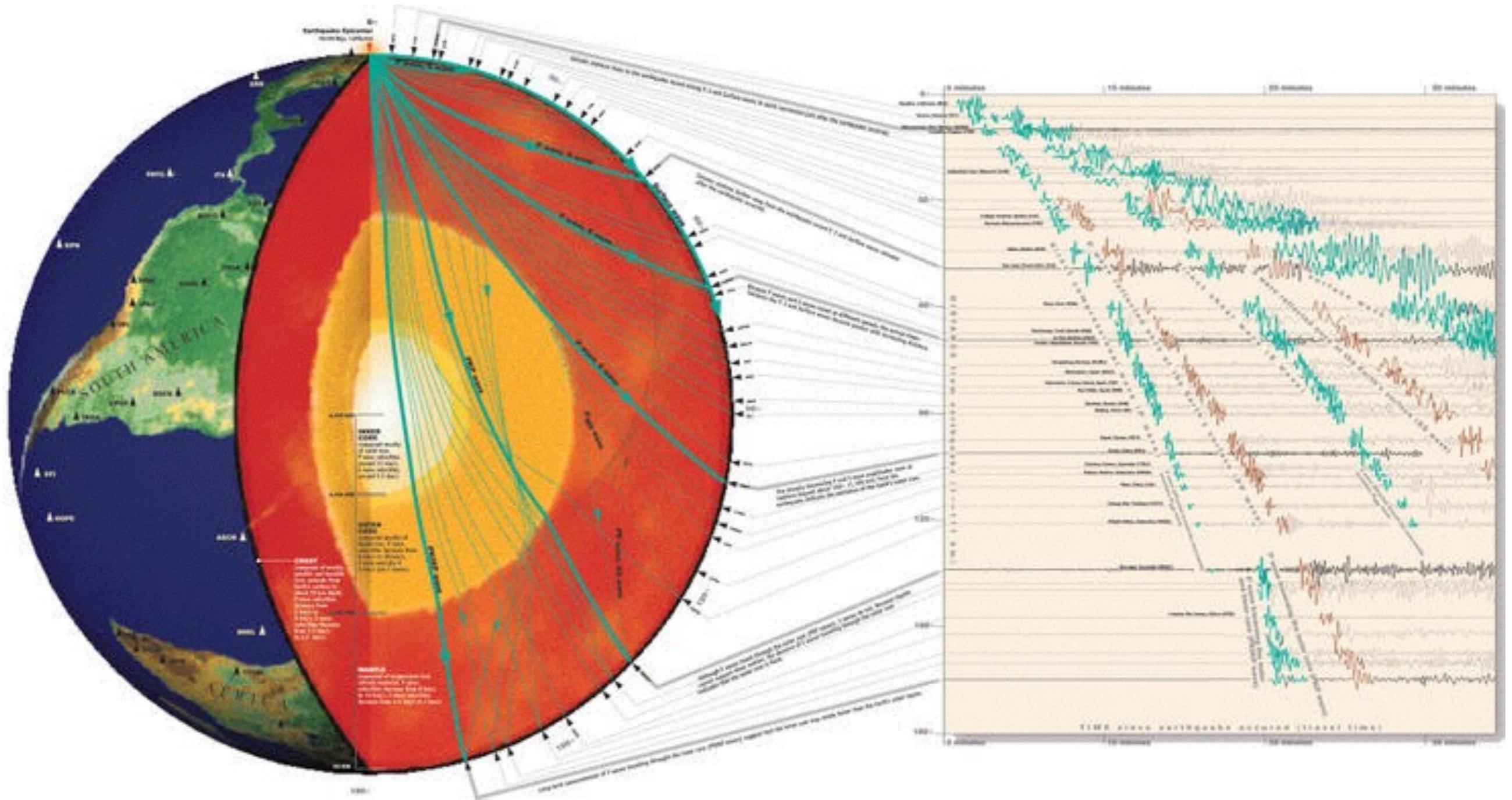


Korenaga's
hypothèse

transport de chaleur dans le manteau



Imagerie avec ondes sismiques

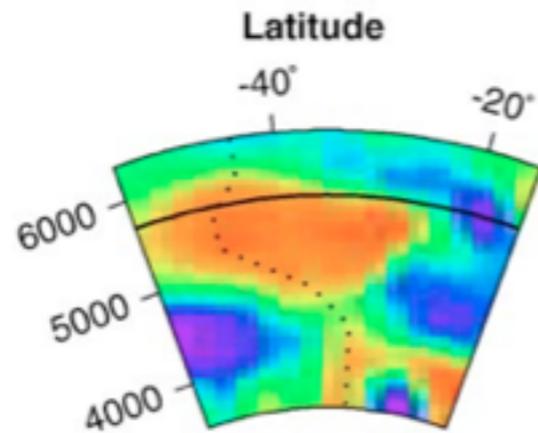
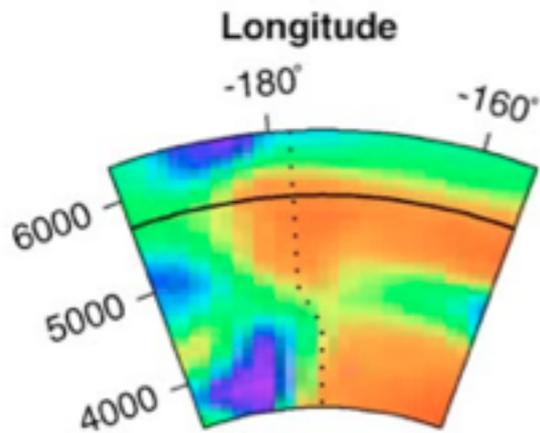


Arrivées tardives: 🖱️ haute température

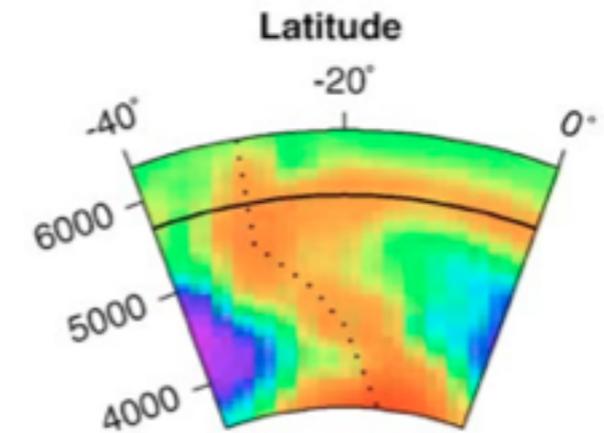
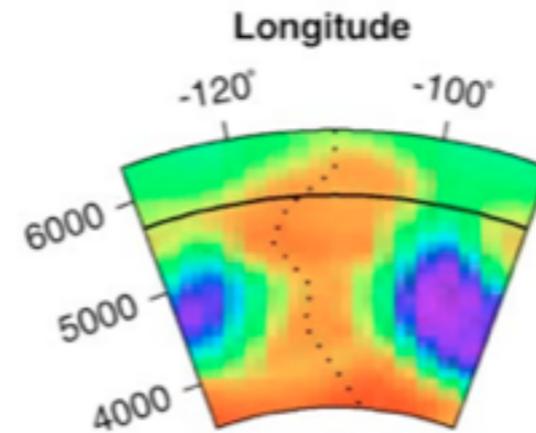
Arrivées anticipés: 🖱️ basse température

Resistance à 660 km profondeur?

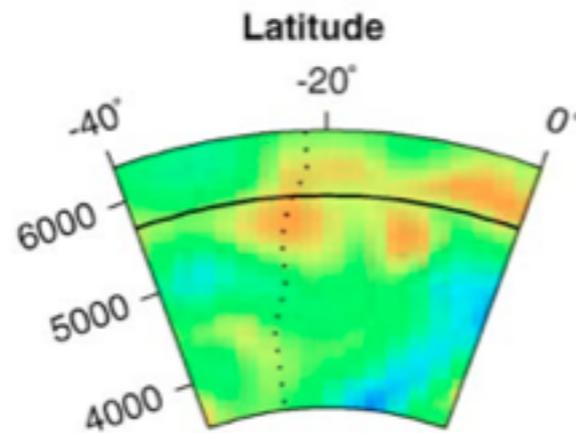
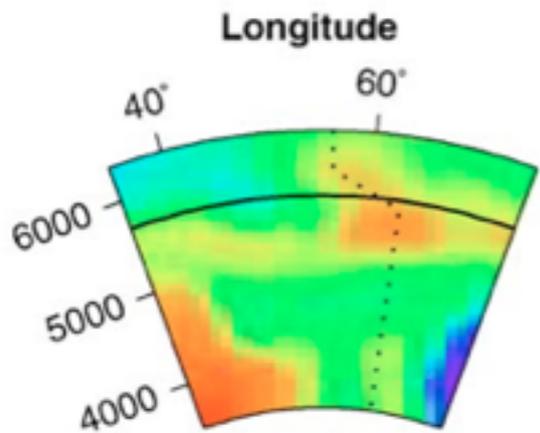
Chatham



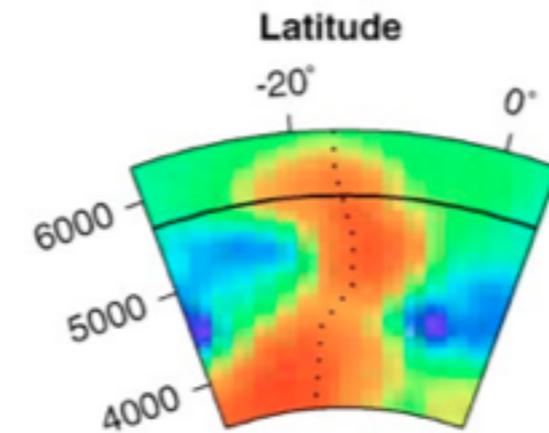
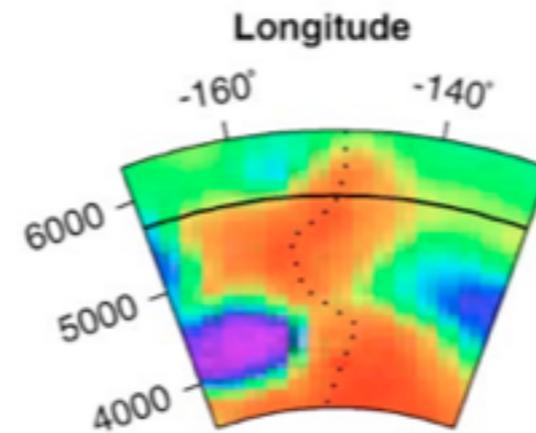
Easter



Reunion



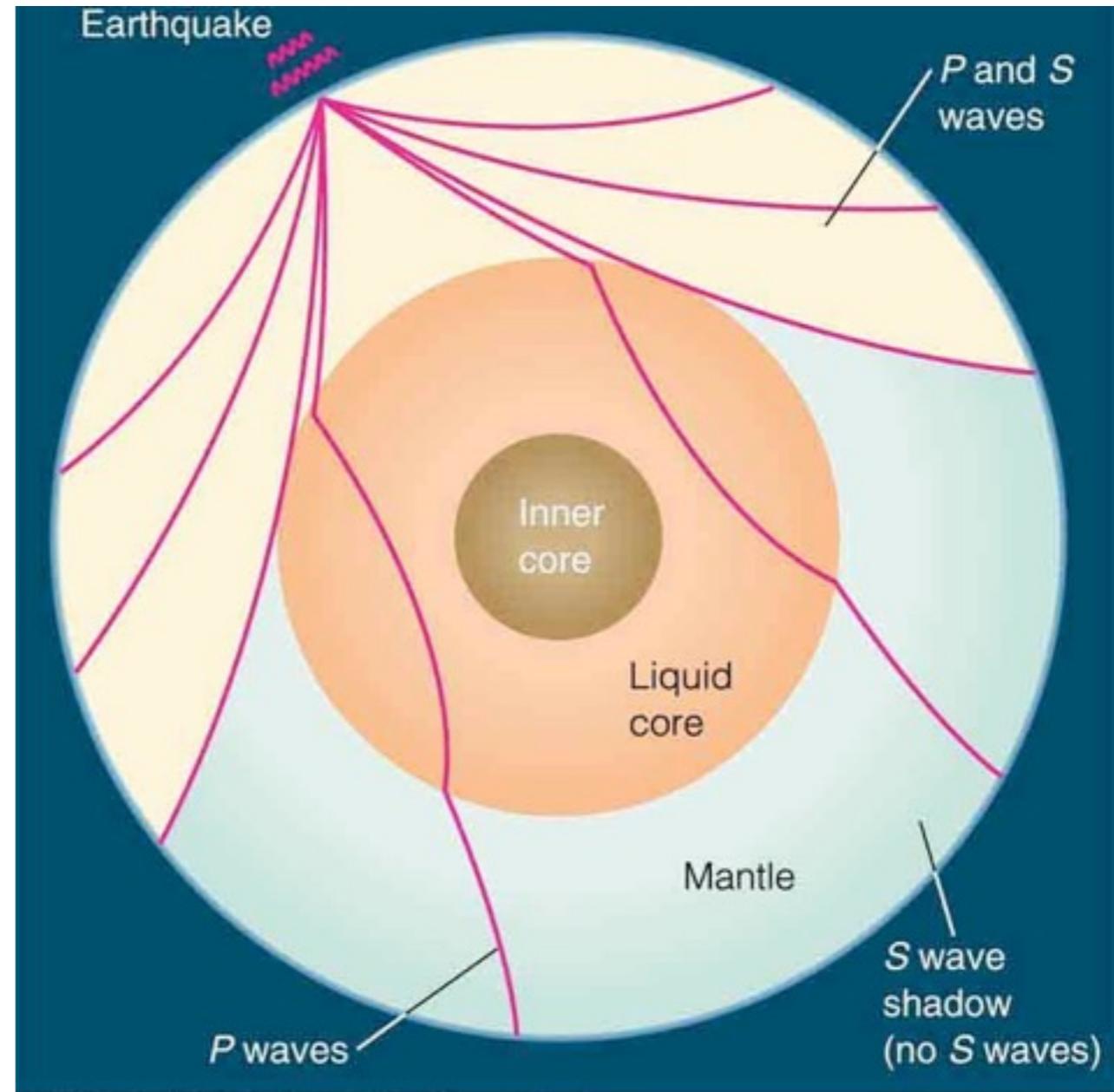
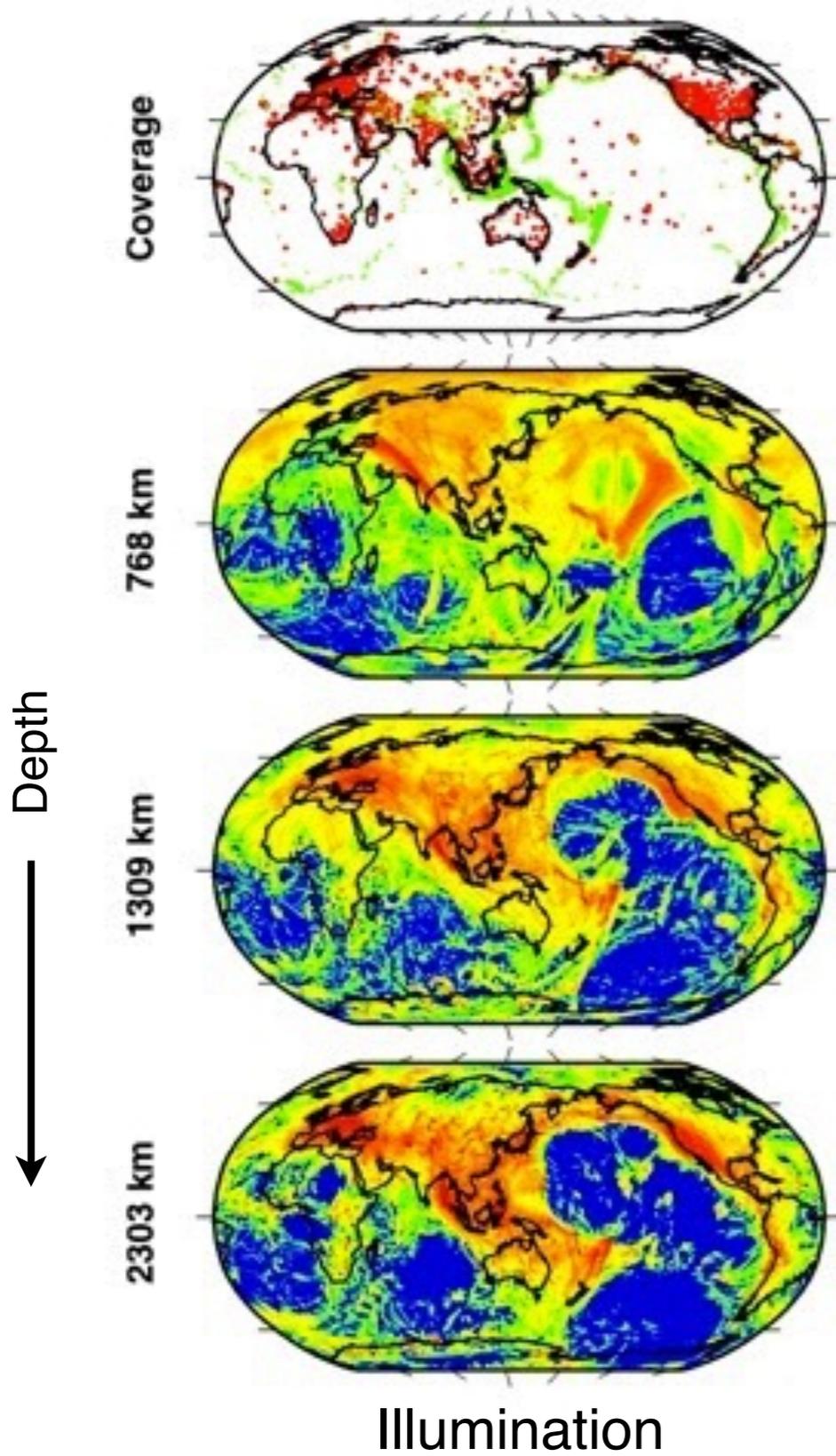
Tahiti



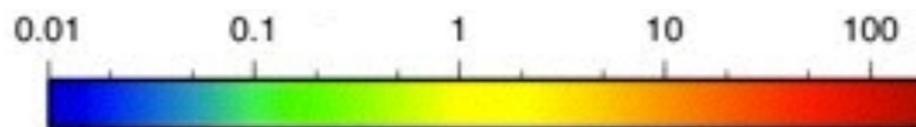
Nolet et al., EPSL 2006

Les données dont nous disposons par les réseaux sismologiques à terre manquent de résolution fine pour éprouver les modèles.

Manque de rayons sous les océans 👉 manque de résolution

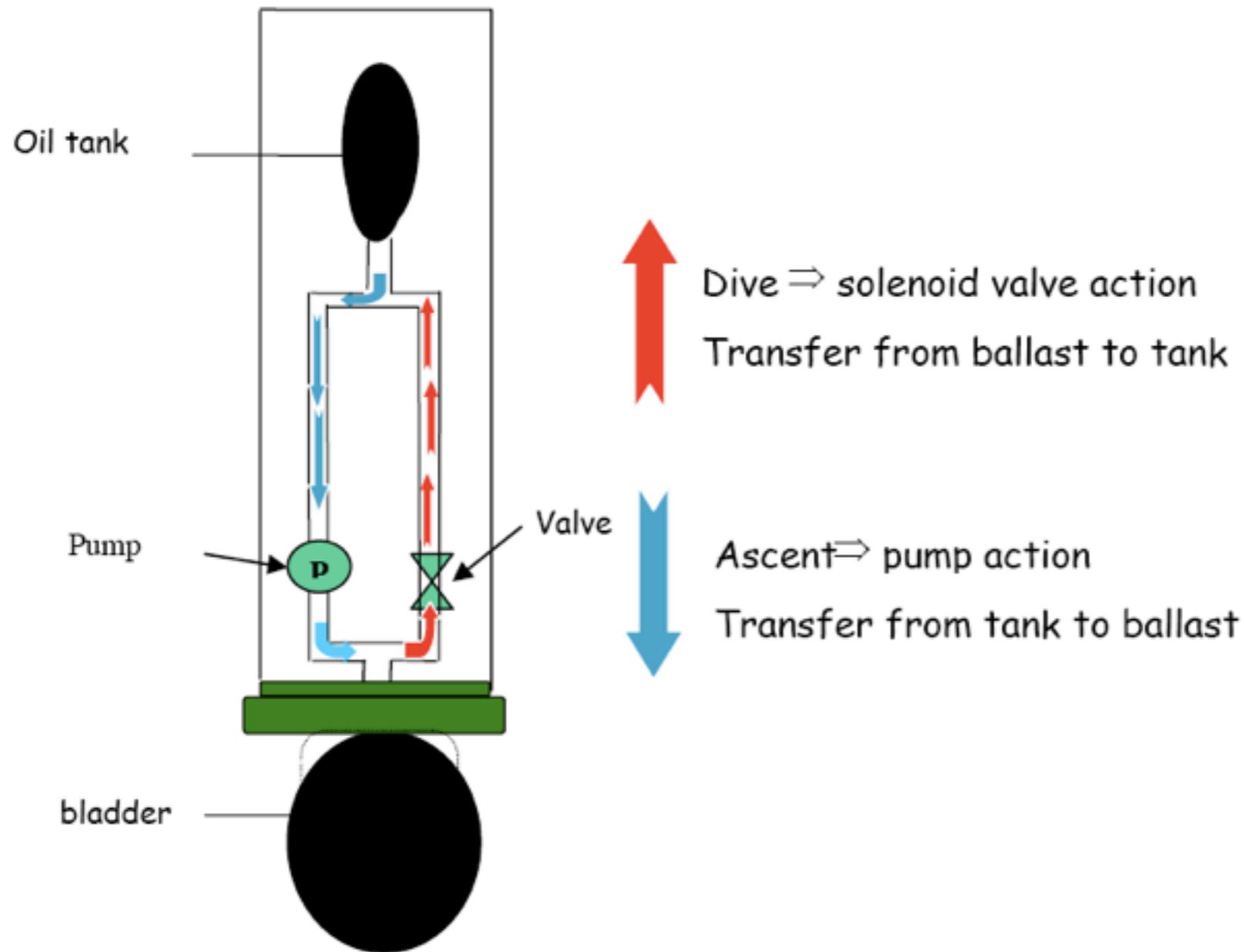


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2000: Flotteurs “Lagrangiens”

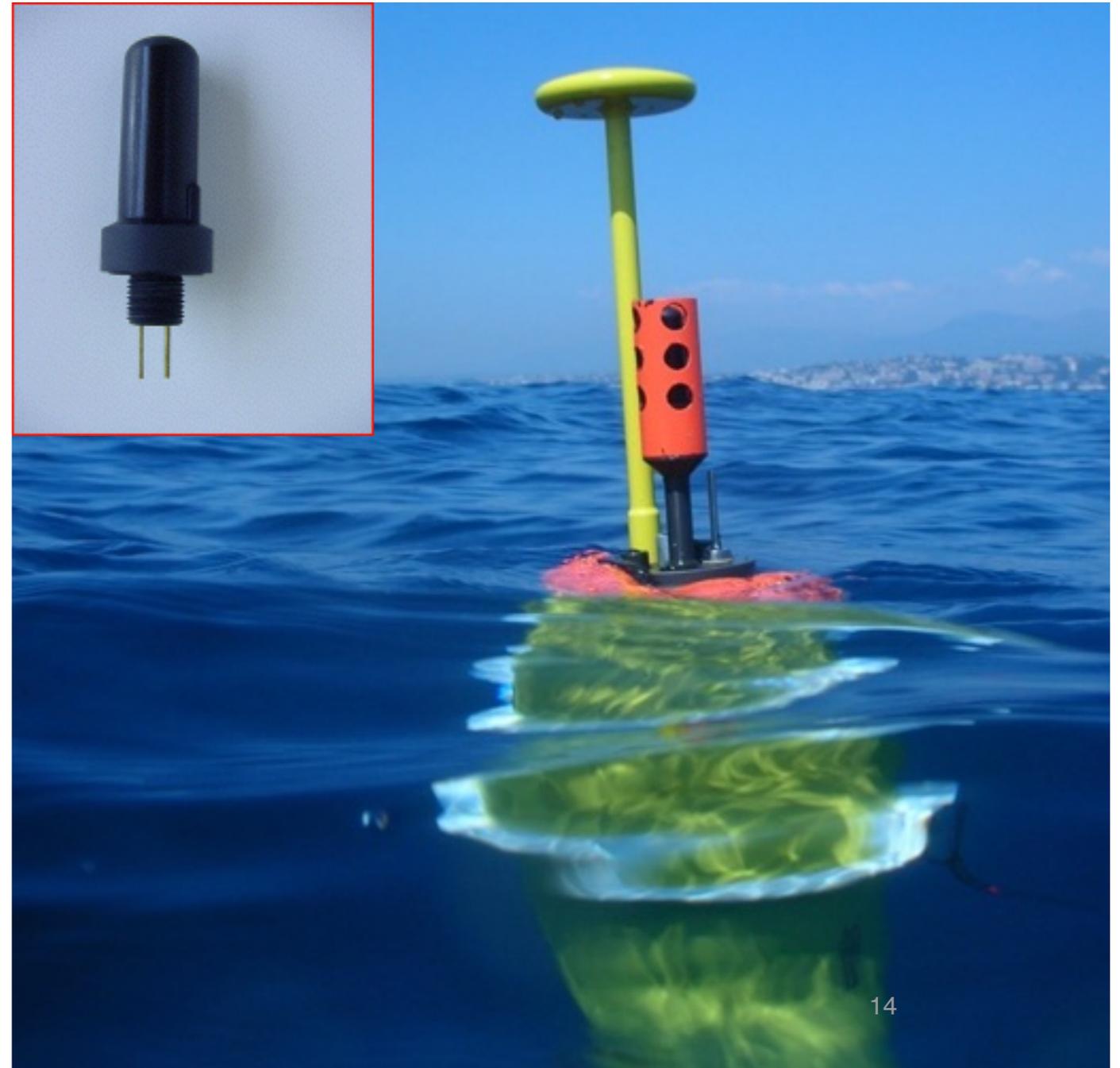
L'apport des flotteurs MERMAID, un modèle de la famille des flotteurs lagrangiens



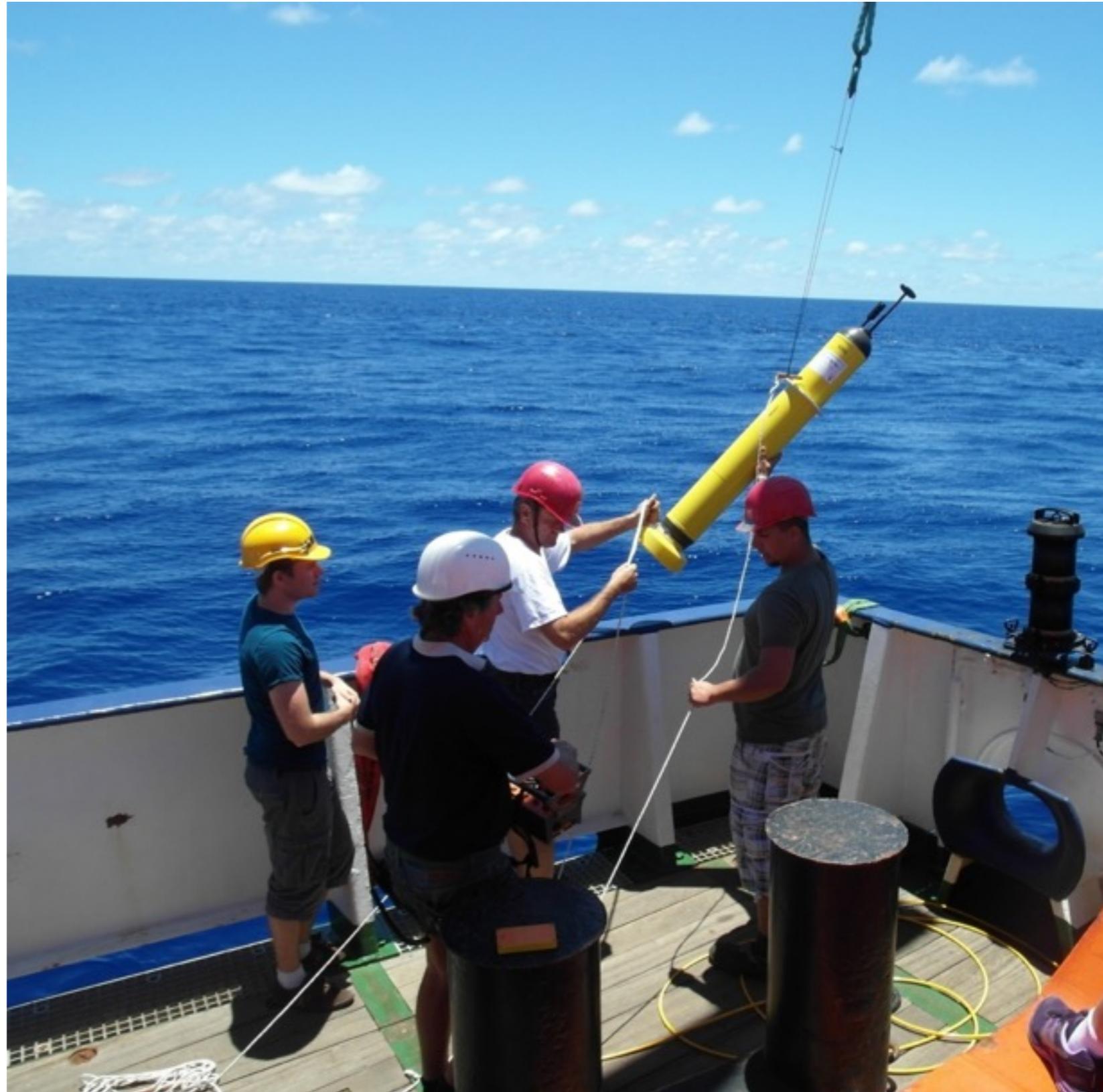
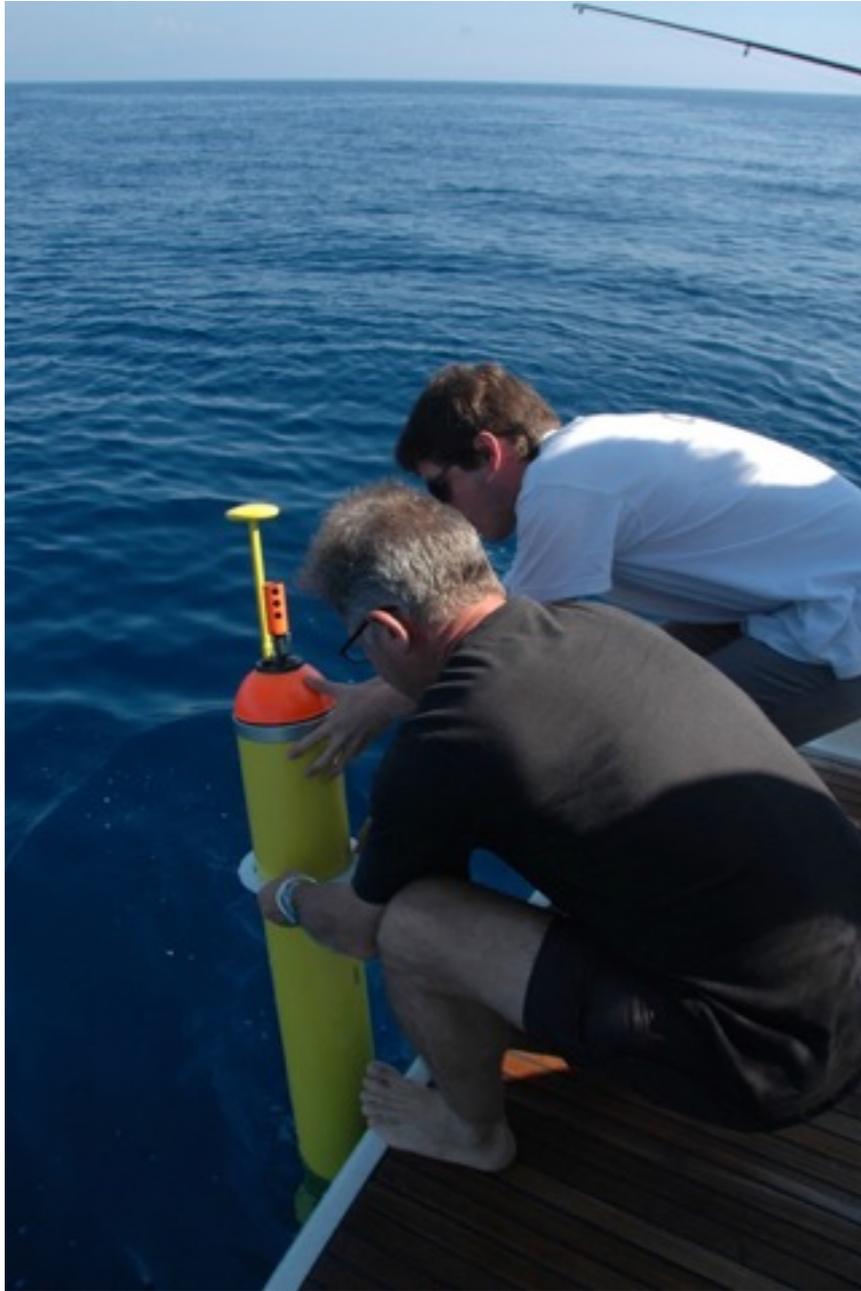
Principle of PROVOR and ARVOR floats buoyancy



Mermaid processeur/ enregistreur et hydrophone



Larguer un Mermaid



Un flotteur MERMAID est muni d'un hydrophone qui enregistre les ondes acoustiques de l'océan. Les flotteurs sillonnent les mers vers 1500 m de profondeur. Les ondes acoustiques peuvent provenir de plusieurs sources différentes ... vibrations telluriques

...mais aussi de mouvements de bateaux, d'animaux marins, des tempêtes ...

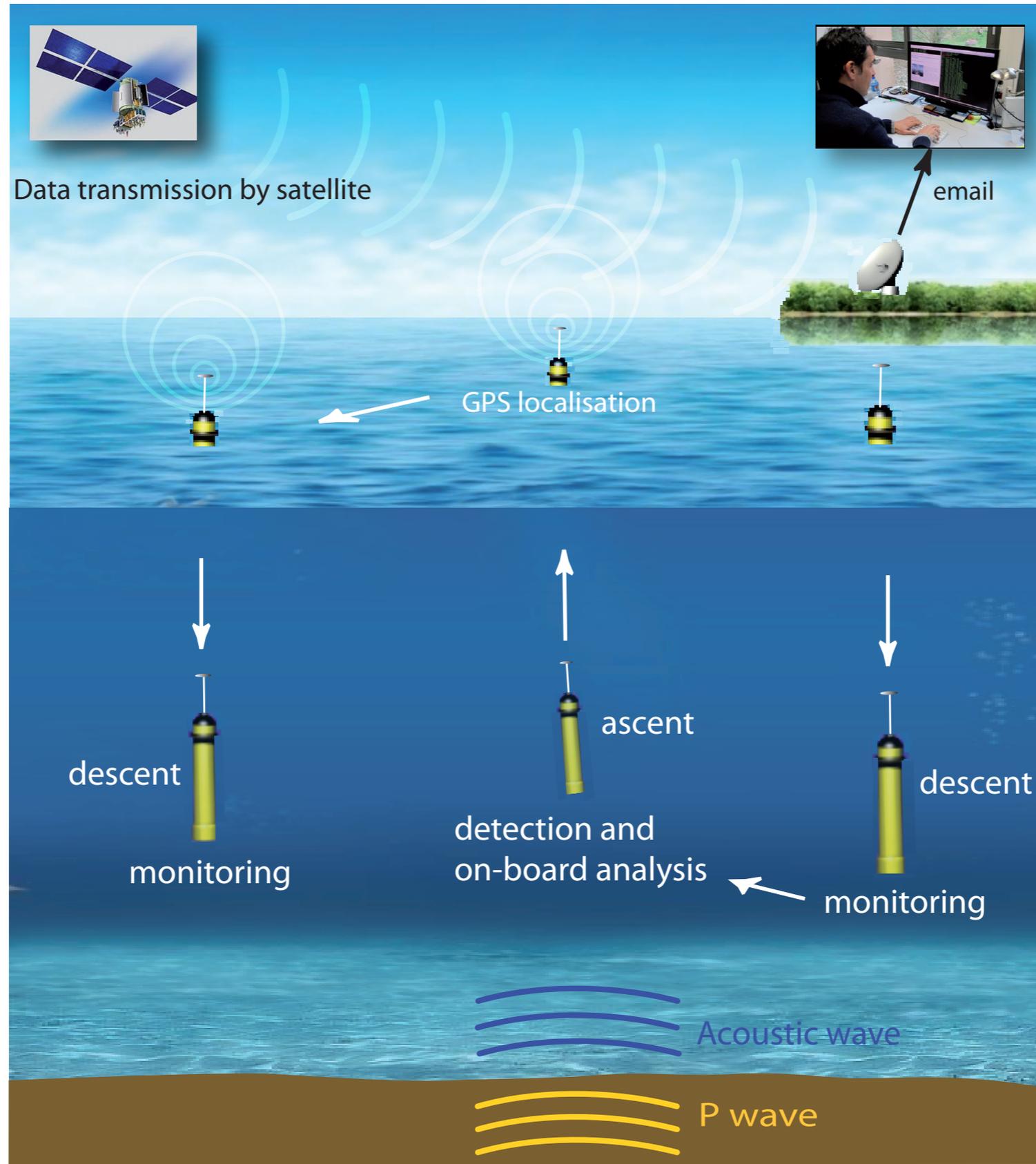
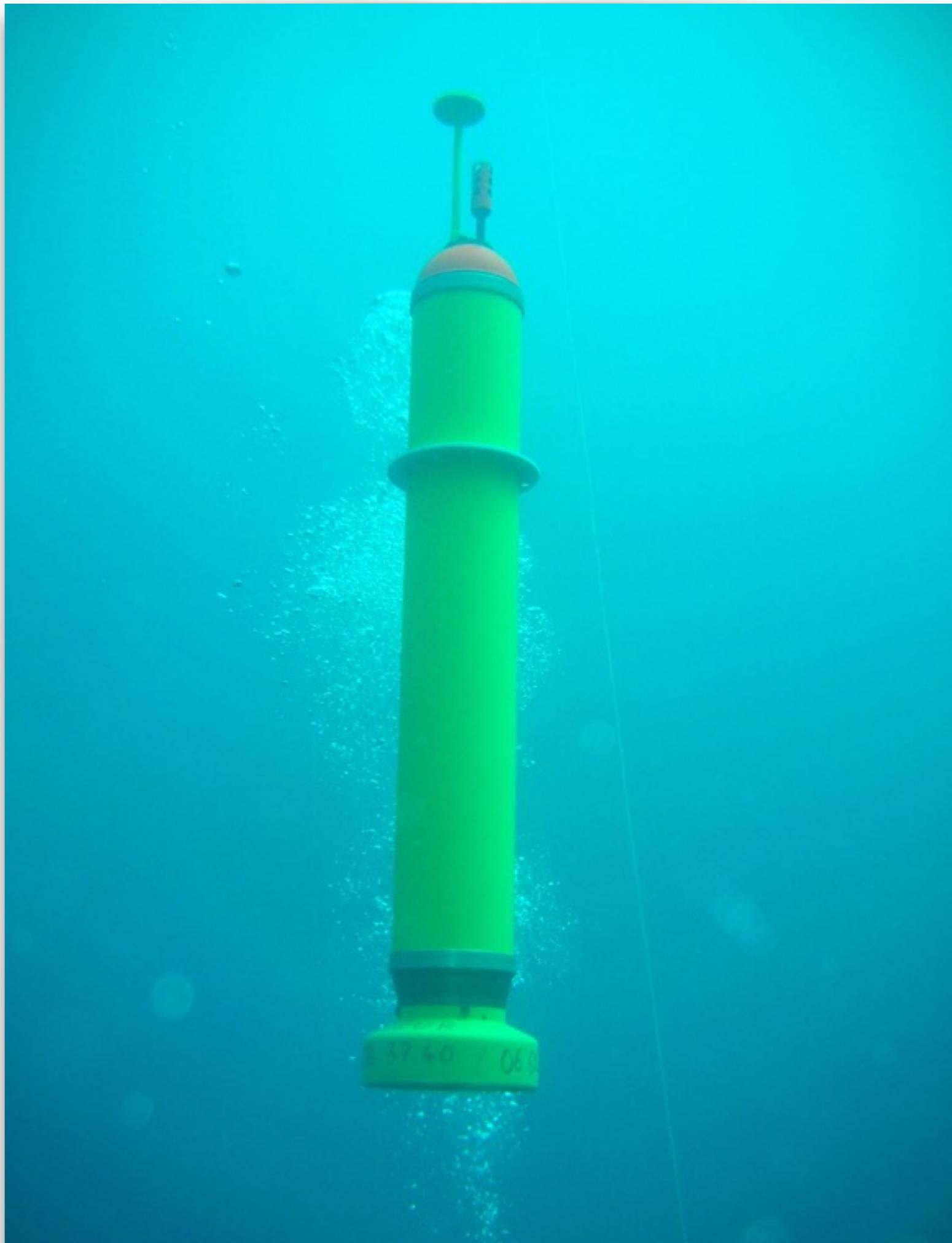
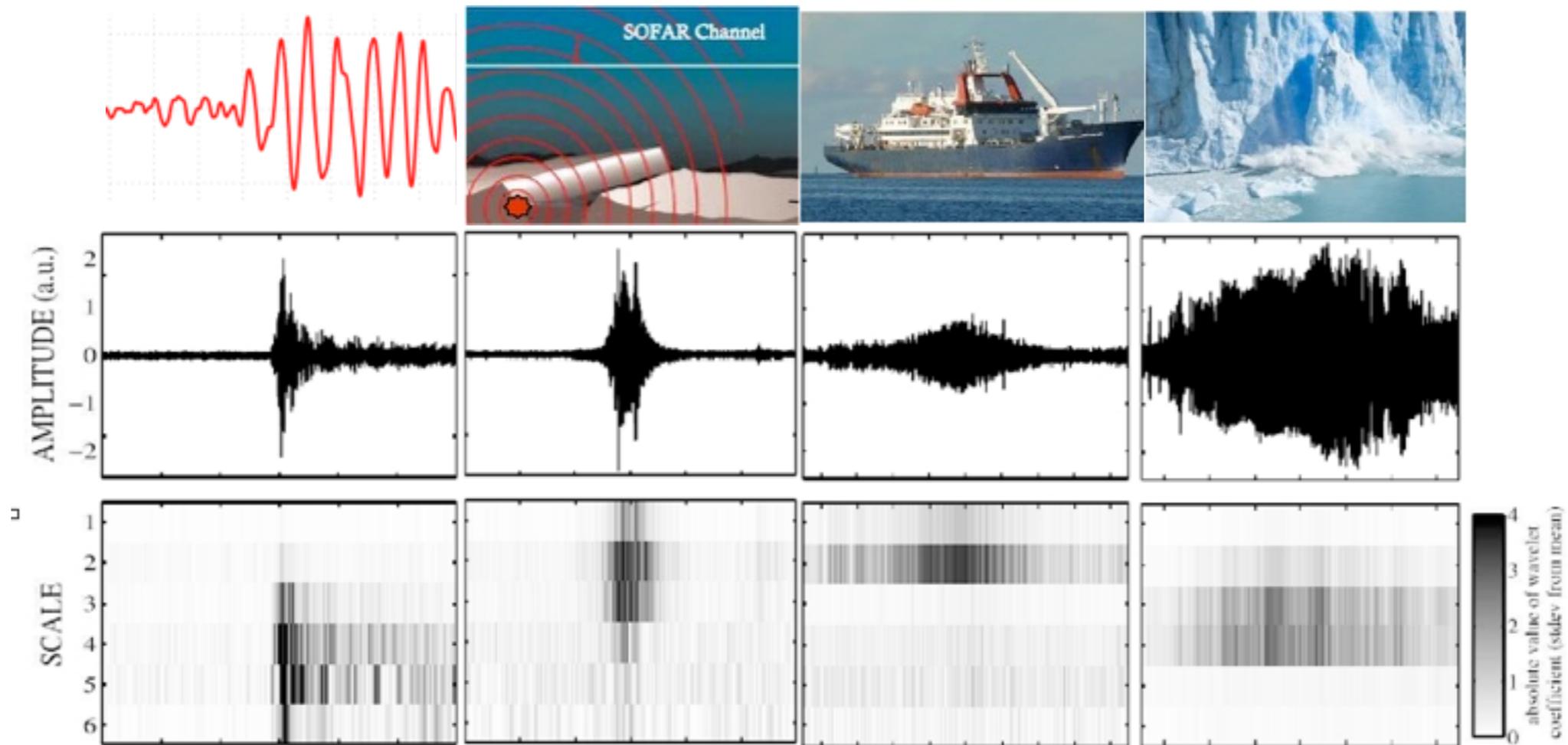


illustration
Inna Slezak



Toutes sortes de signaux dans les océans



&

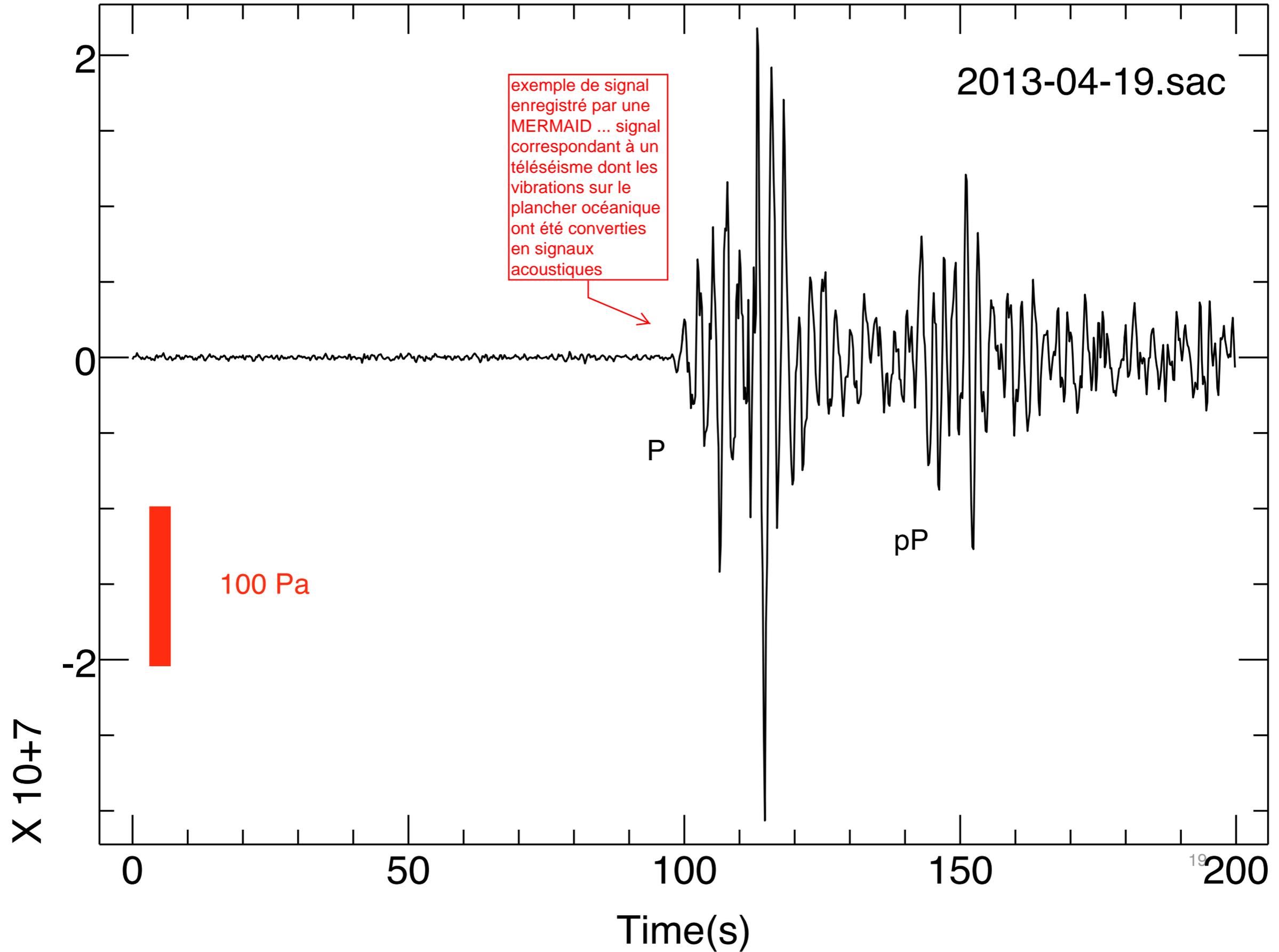


Mw 7.3 Delta 86.1 KURIL ISLANDS

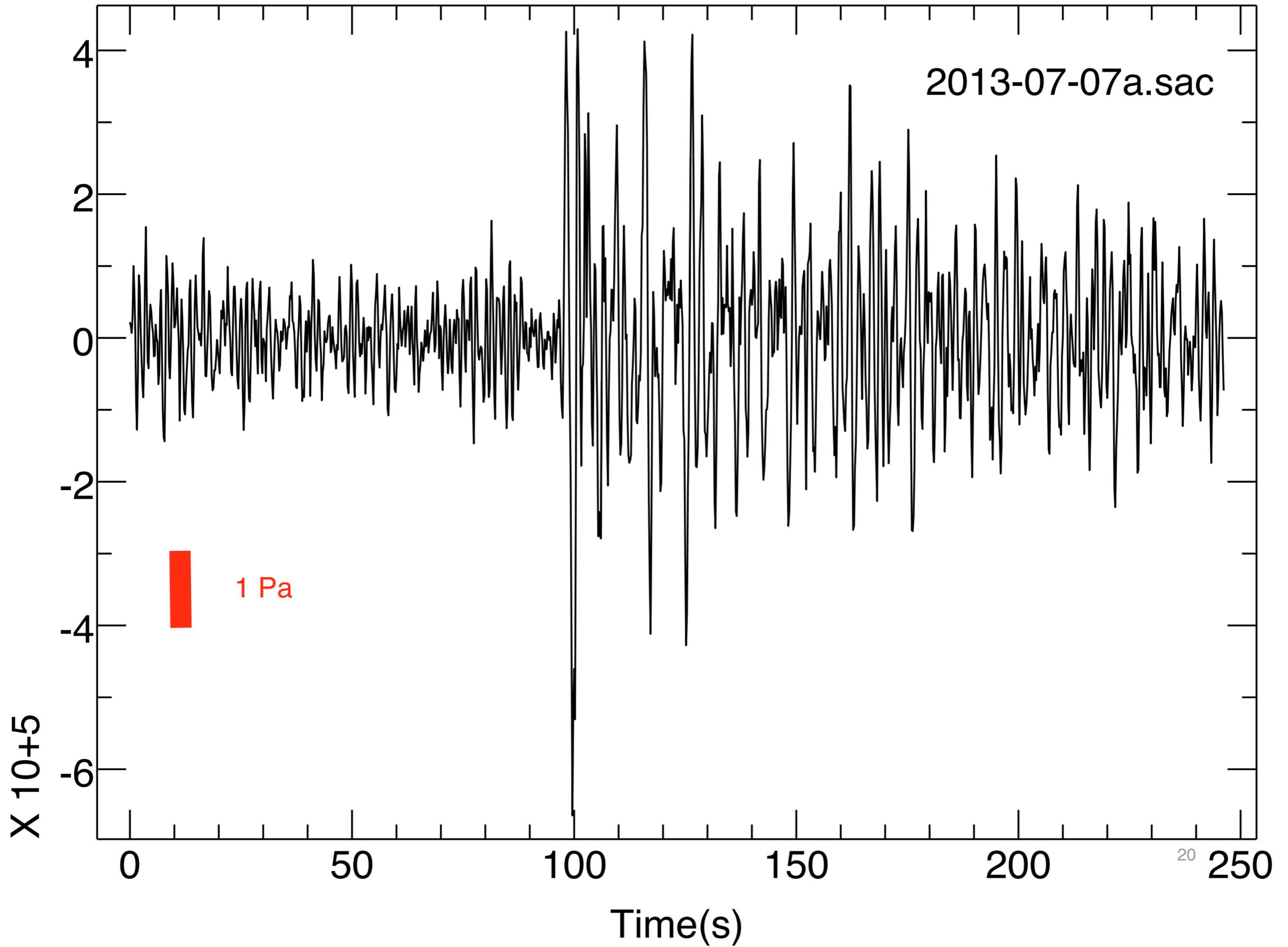
Depth 110

2013-04-19.sac

exemple de signal enregistré par une MERMAID ... signal correspondant à un télé-séisme dont les vibrations sur le plancher océanique ont été converties en signaux acoustiques

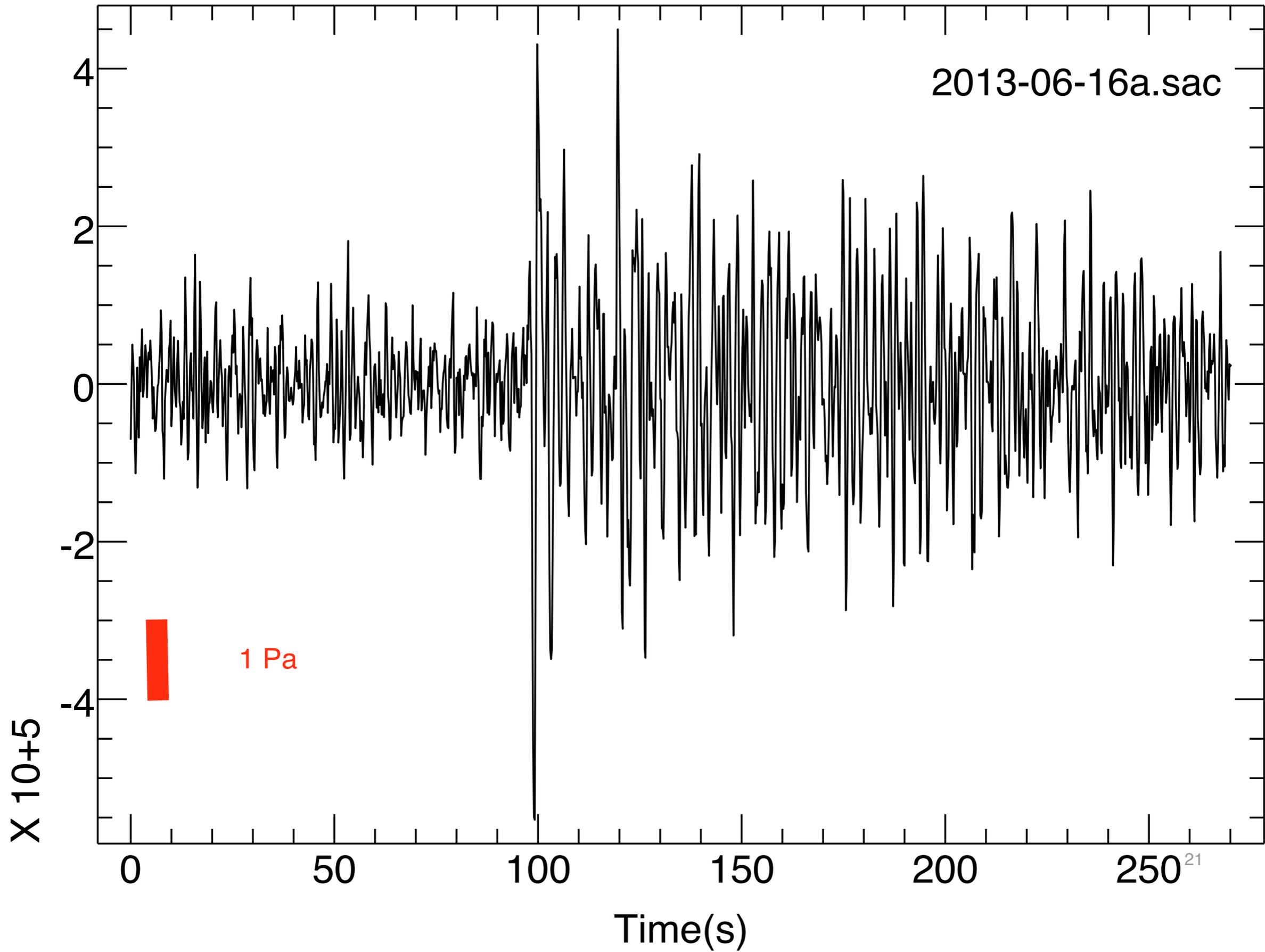


Mw 6.6 Delta 134.2 NEW BRITAIN REGION



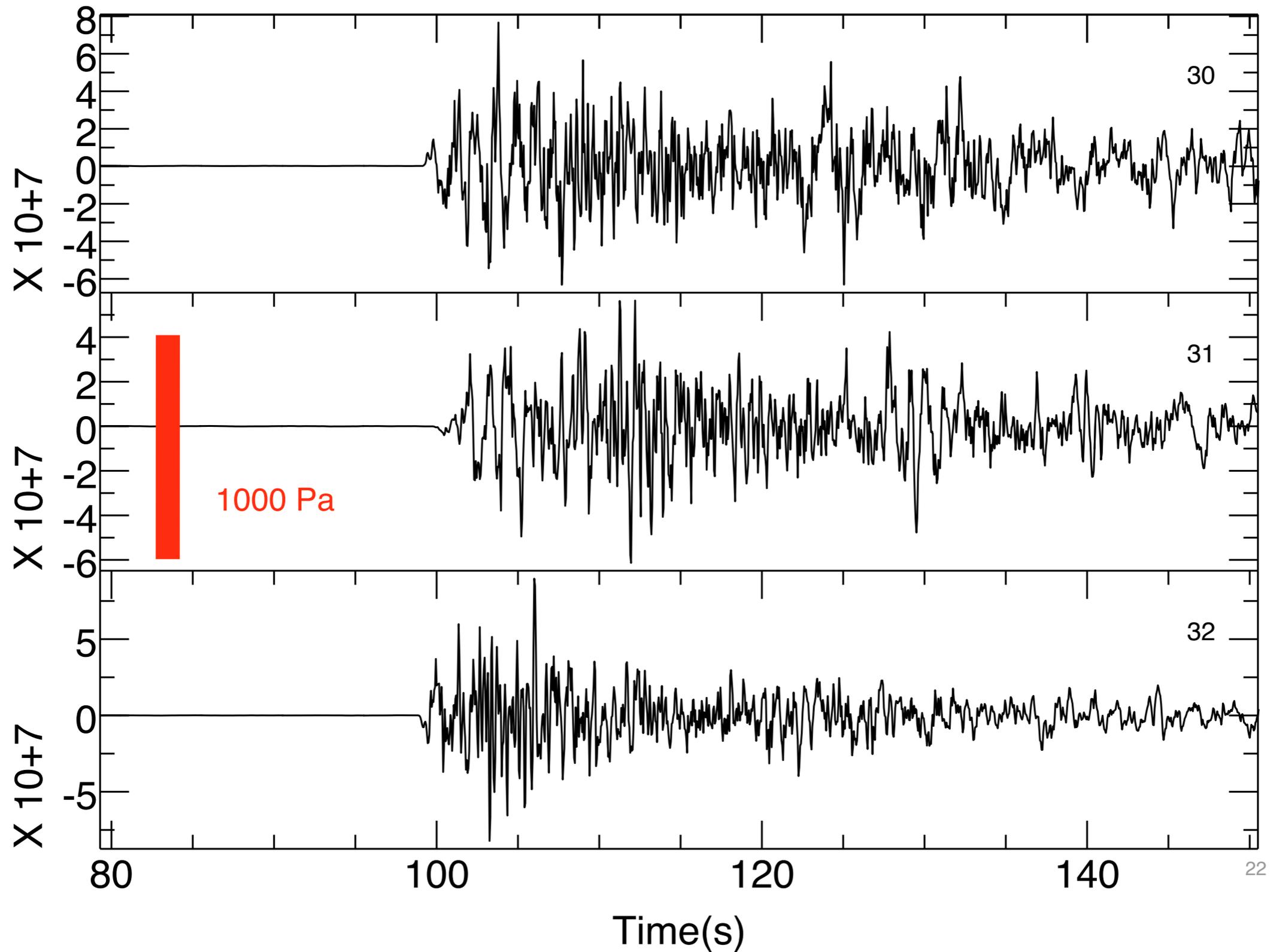
Mw 5.9 Delta 87.8 GUERRRERO, MEXICO

2013-06-16a.sac

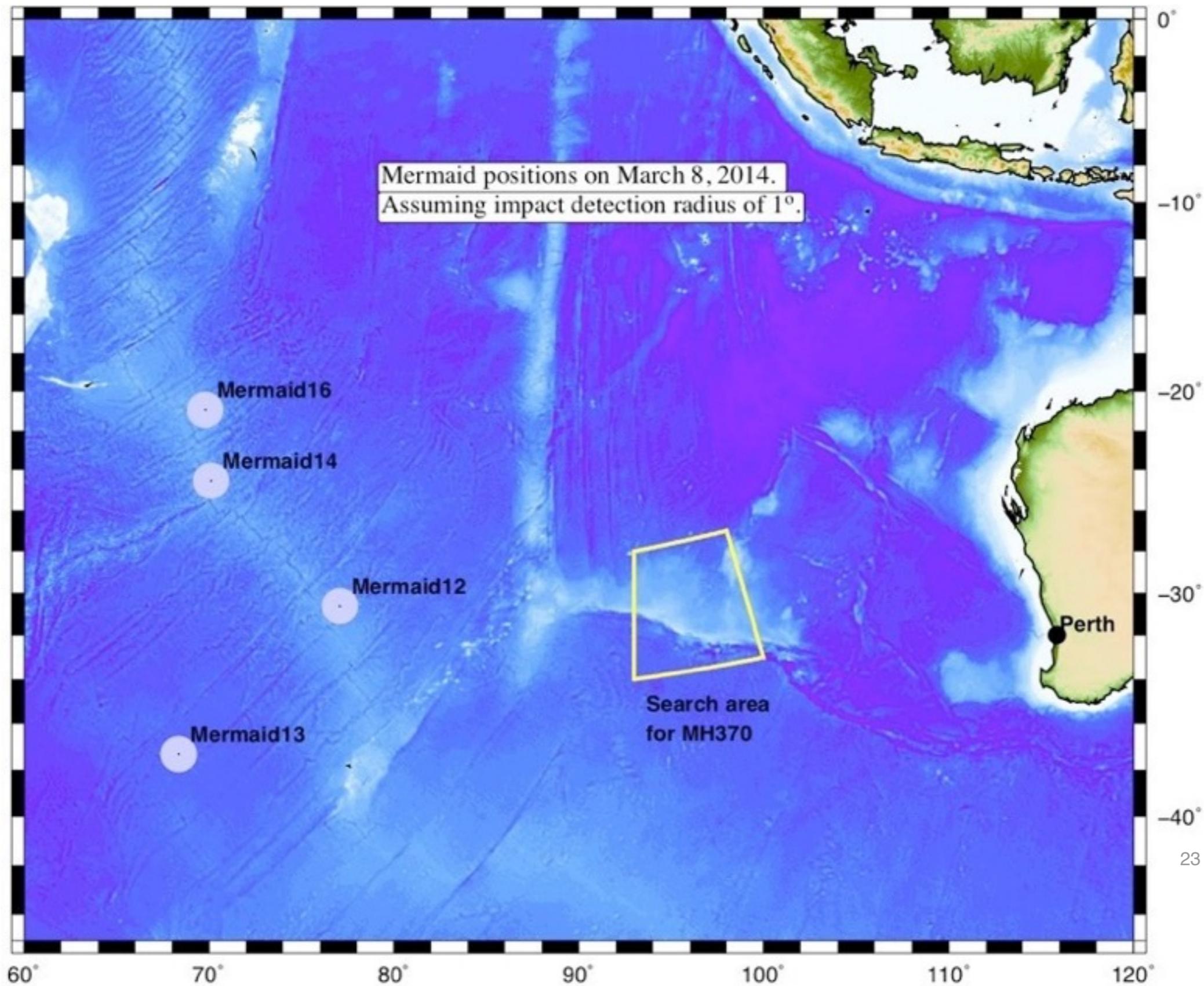


Barcelonette, April 7 2014, M 4.9

Barcelonette Apr 7, 2014, M4.9

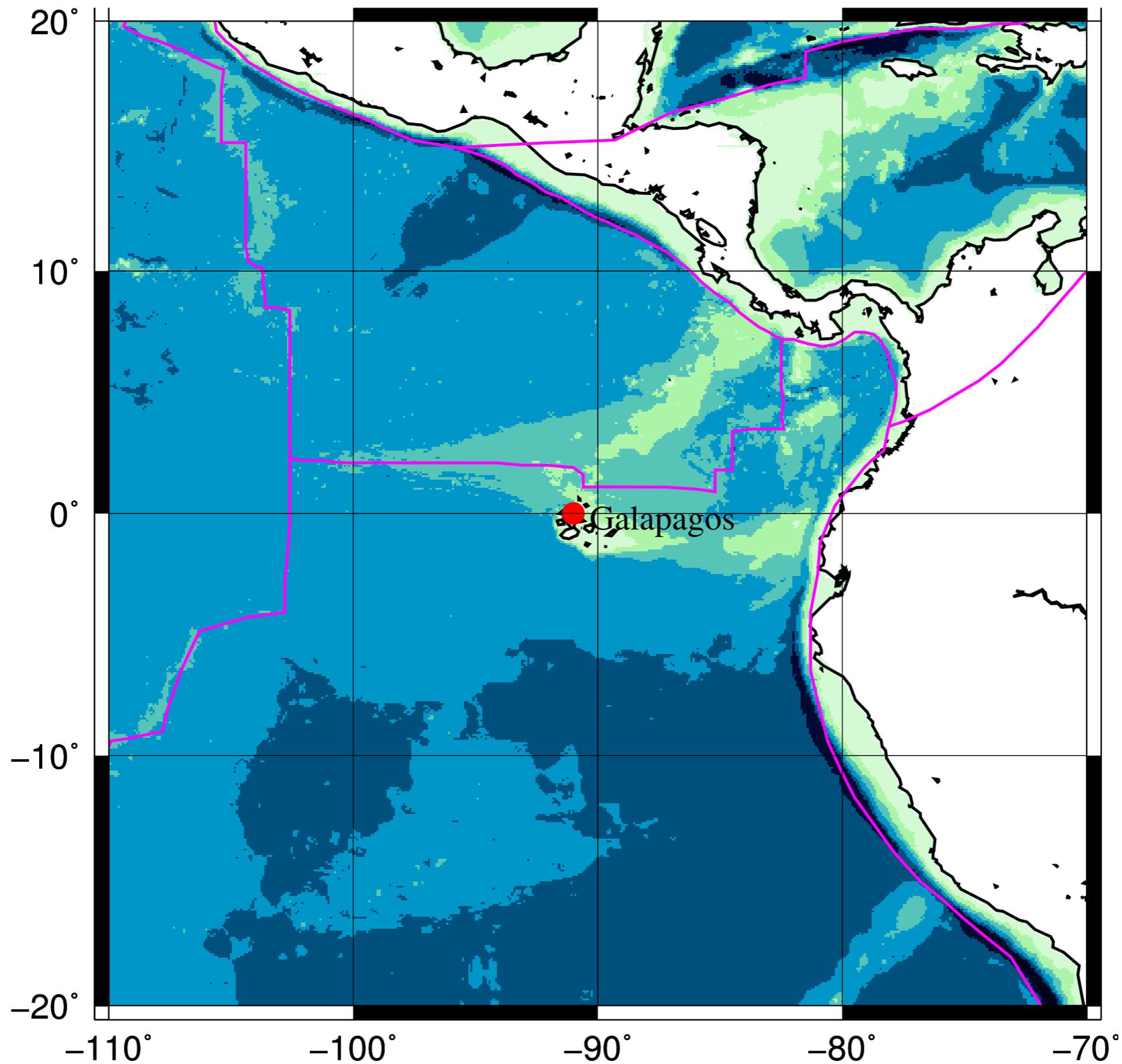


Intermezzo: vol MH370 et les Mermaids



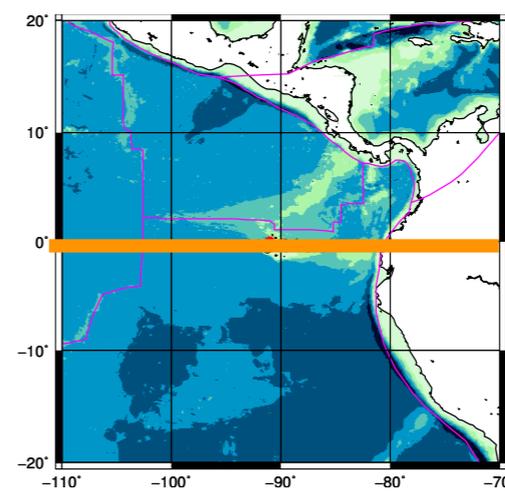
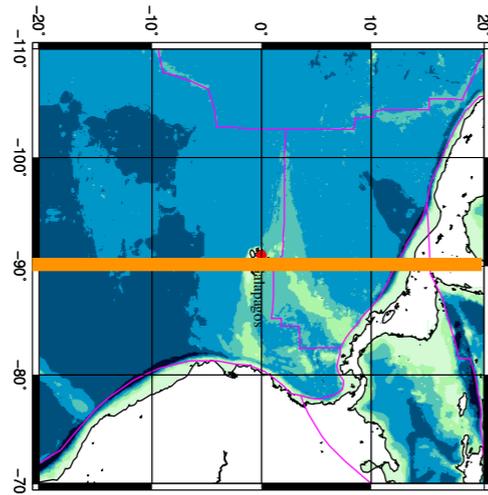
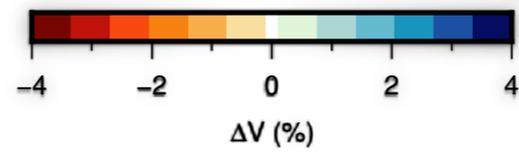
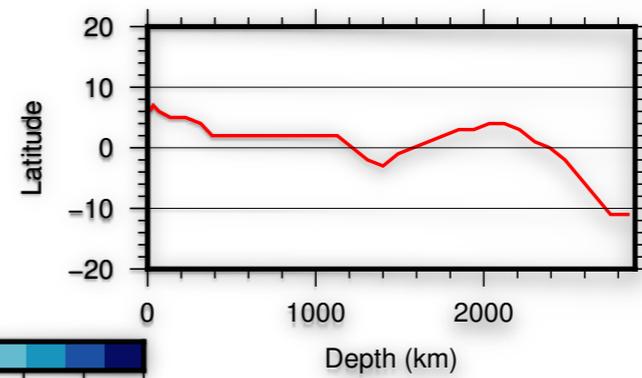
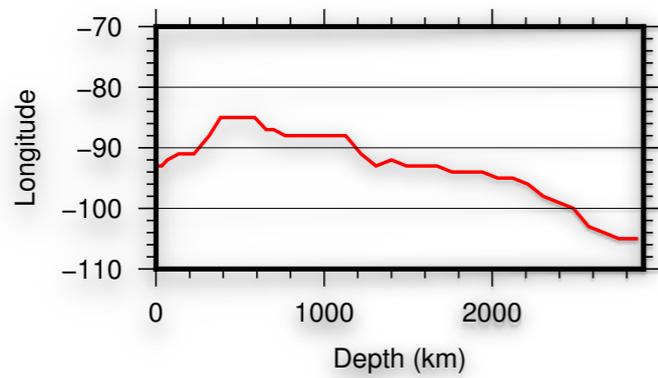
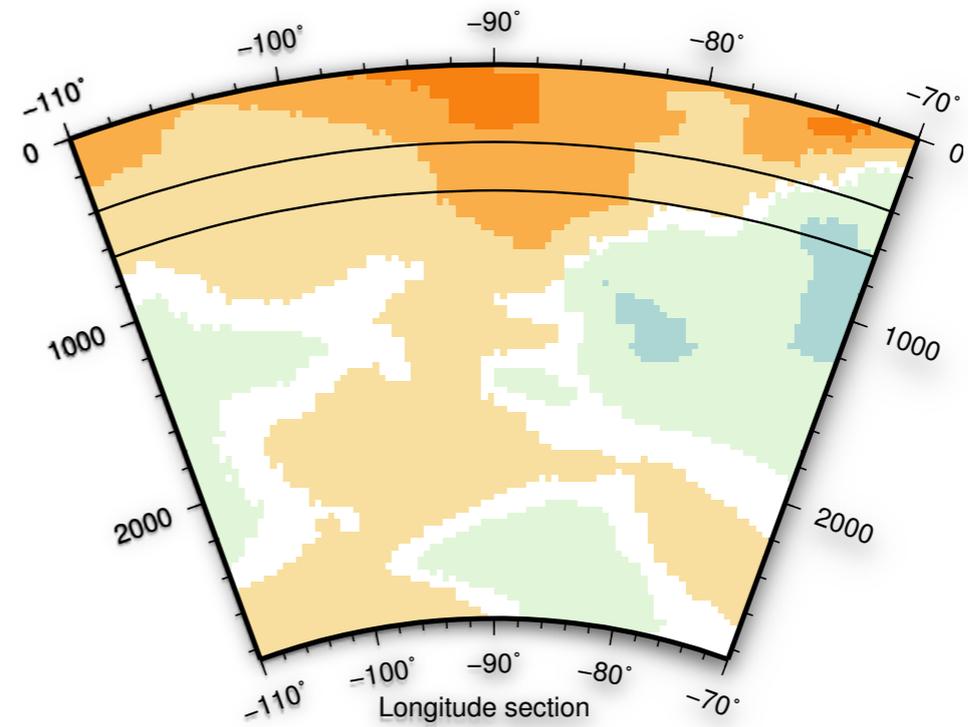
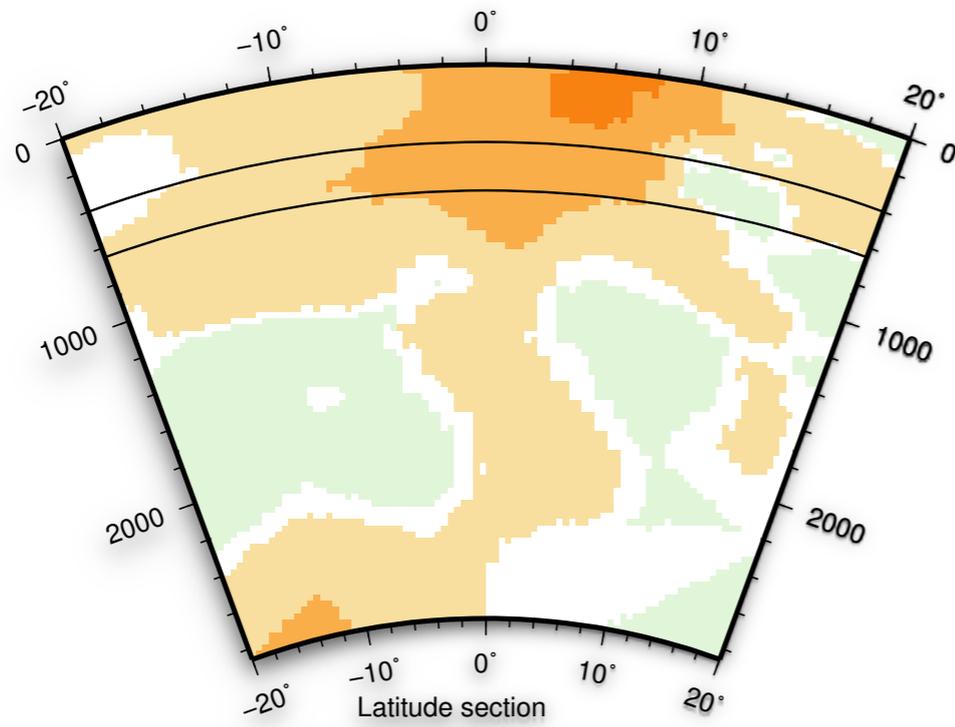
Lors de l'accident du vol MH370 dans le Pacifique, de nombreux pays ont déployés beaucoup de moyens pour la recherche de l'épave. Les MERMAID étaient malheureusement trop loin pour pouvoir enregistrer l'impact de l'avion lors de sa chute.

Galapagos: une panache?



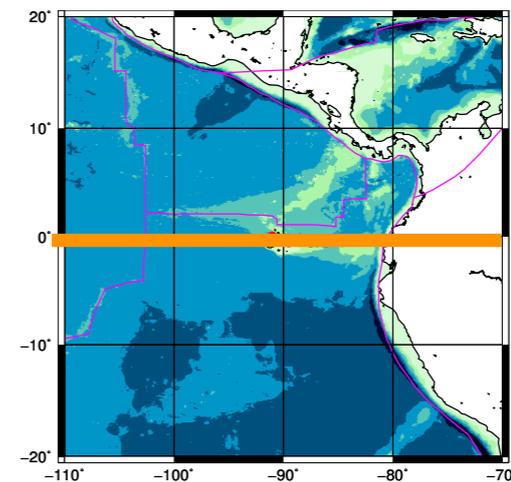
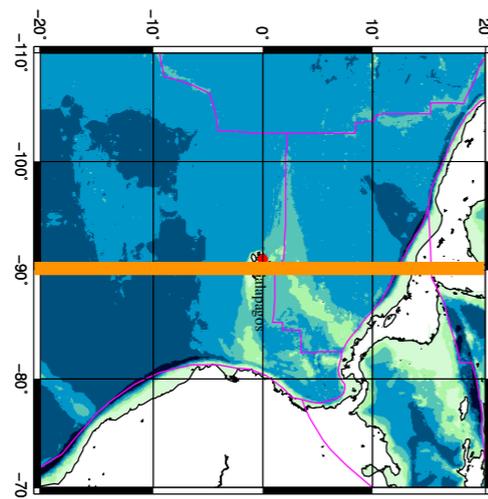
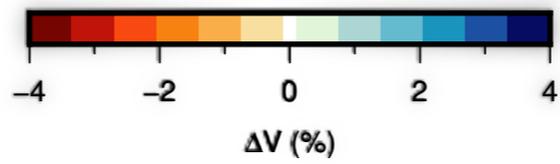
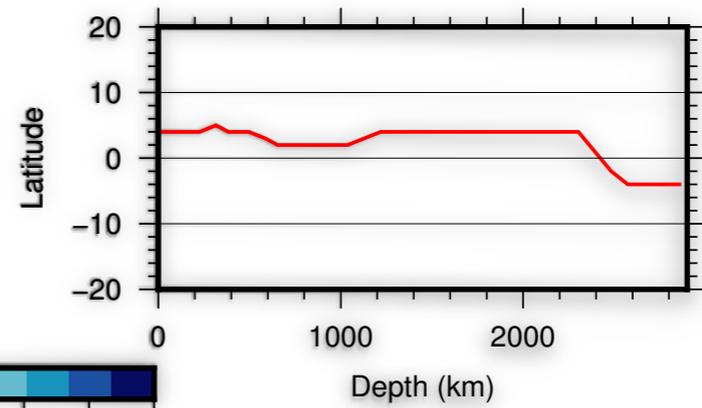
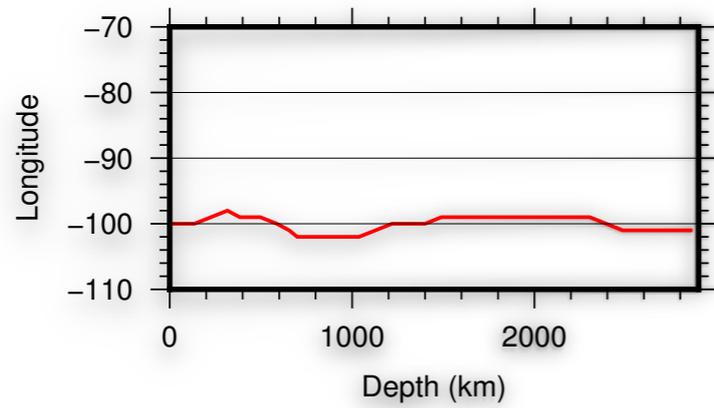
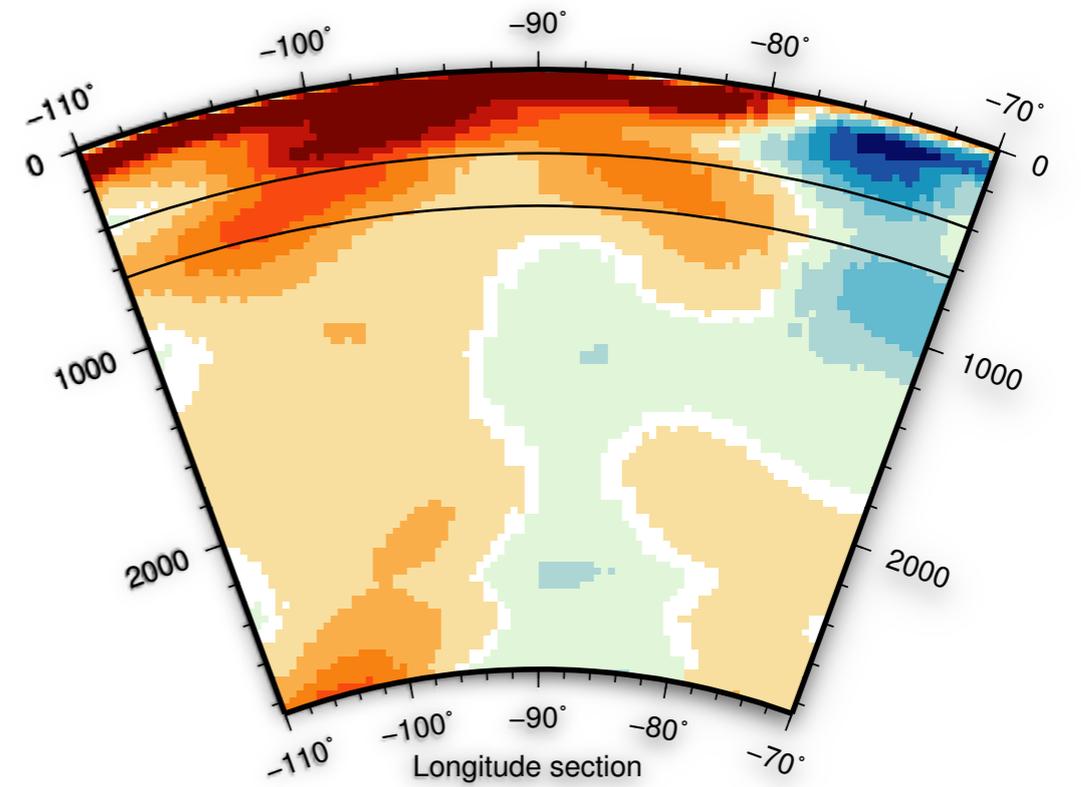
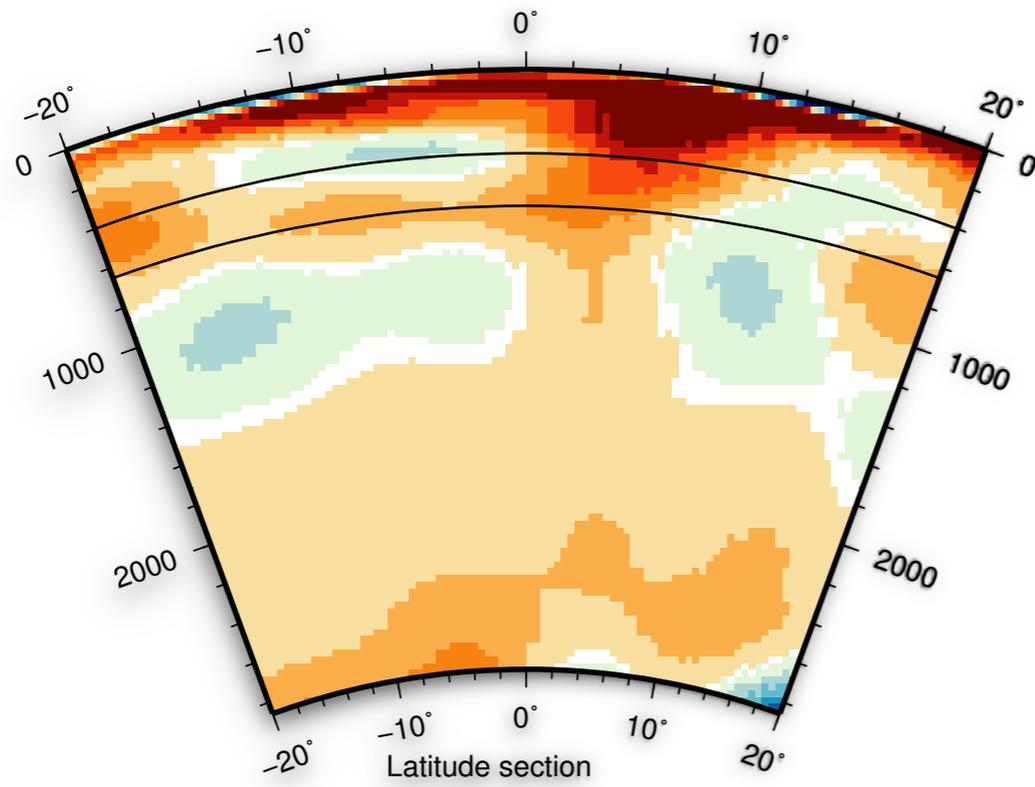
La dernière mission d'essai des MERMAID a été consacrée à l'étude des Galapagos et de son hypothétique 'panache'. En déployant des MERMAID autour de cette zone, l'objectif était de scanner un éventuel panache sous les îles. Cette étude a été menée en 2014.

Vp

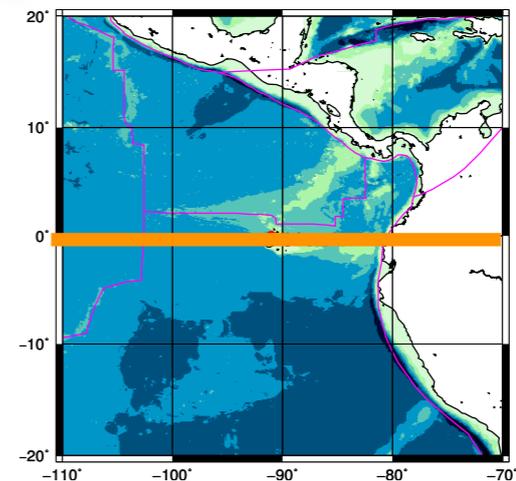
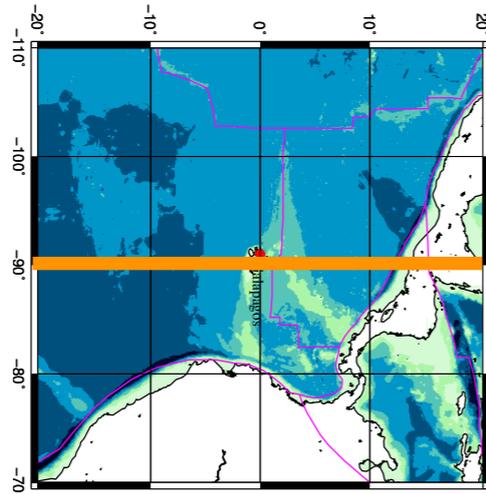
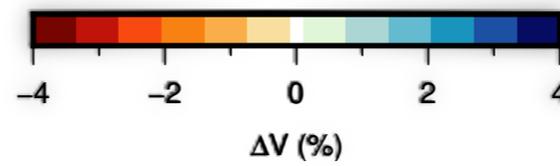
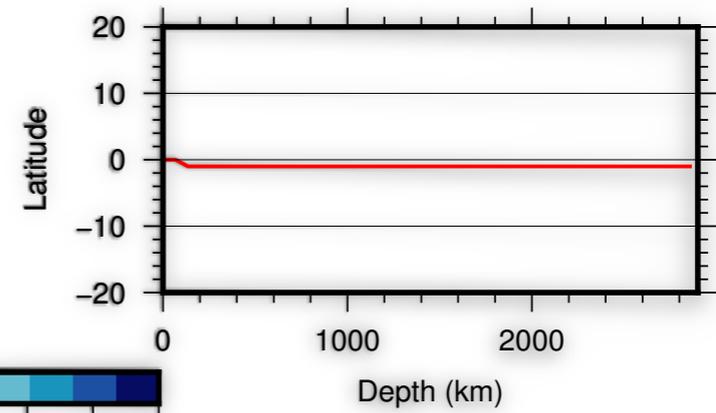
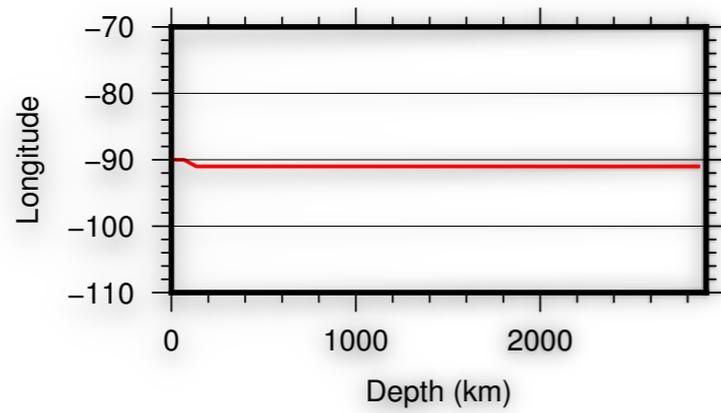
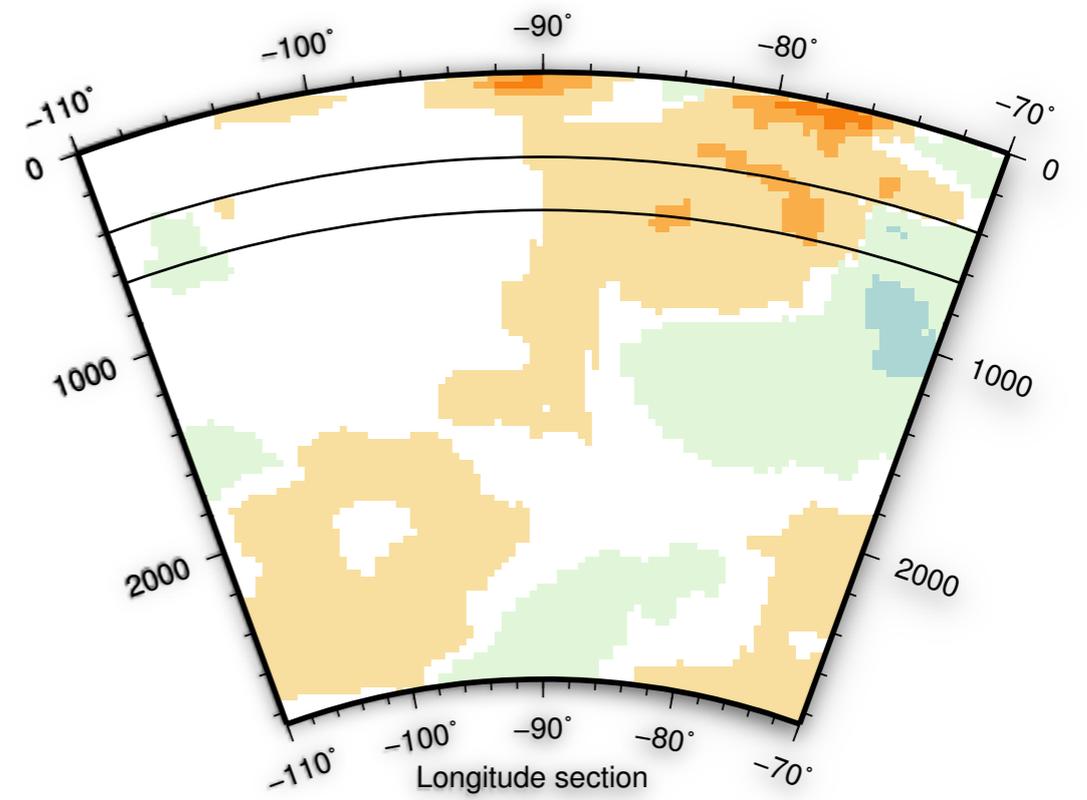
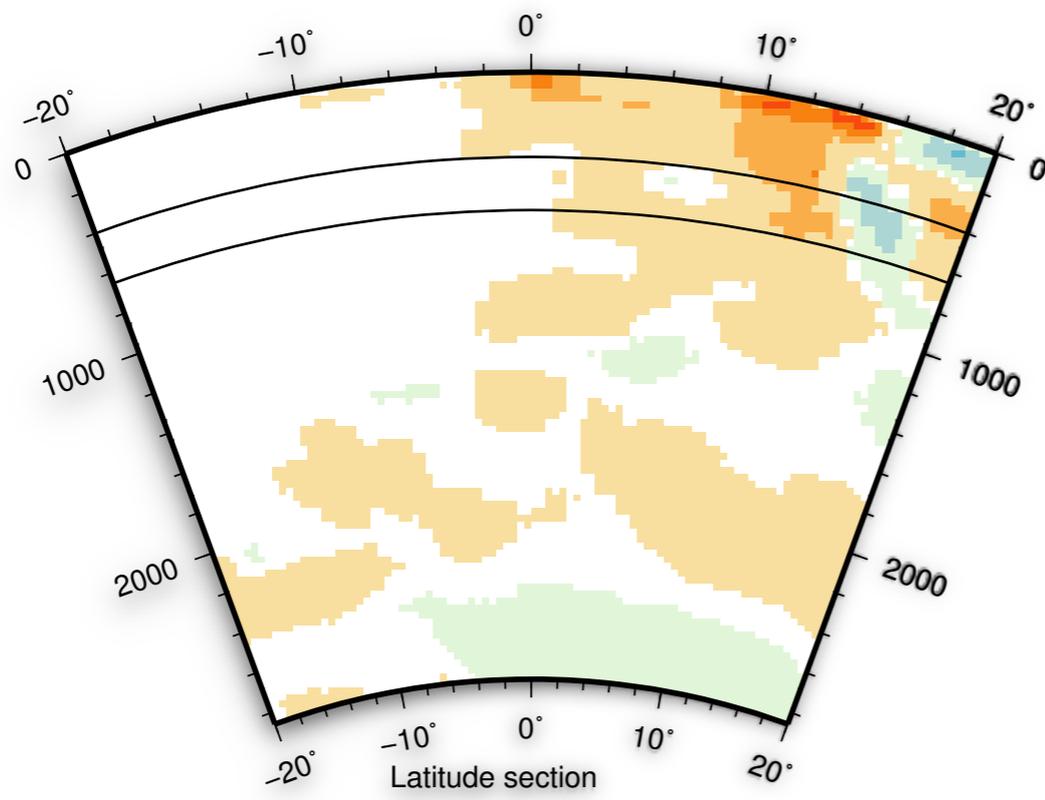


Etat de la connaissance de la tomographie sismique sous les Galapagos en 2006. On devine des secteurs plus chauds mais la définition reste faible et peu précise.

Vs



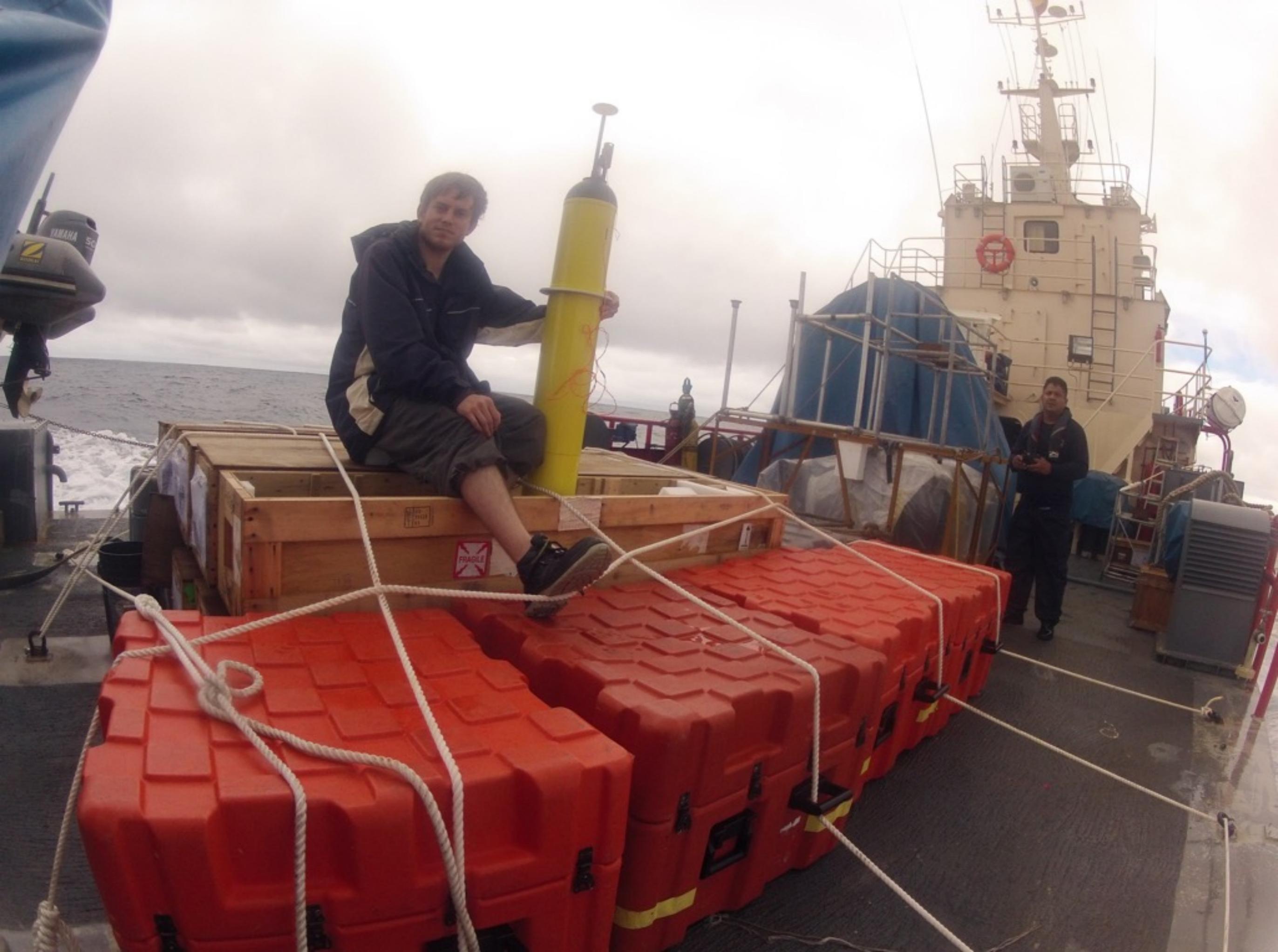
Vp





Les MERMAID en préparation avant leur départ pour les Galapagos.



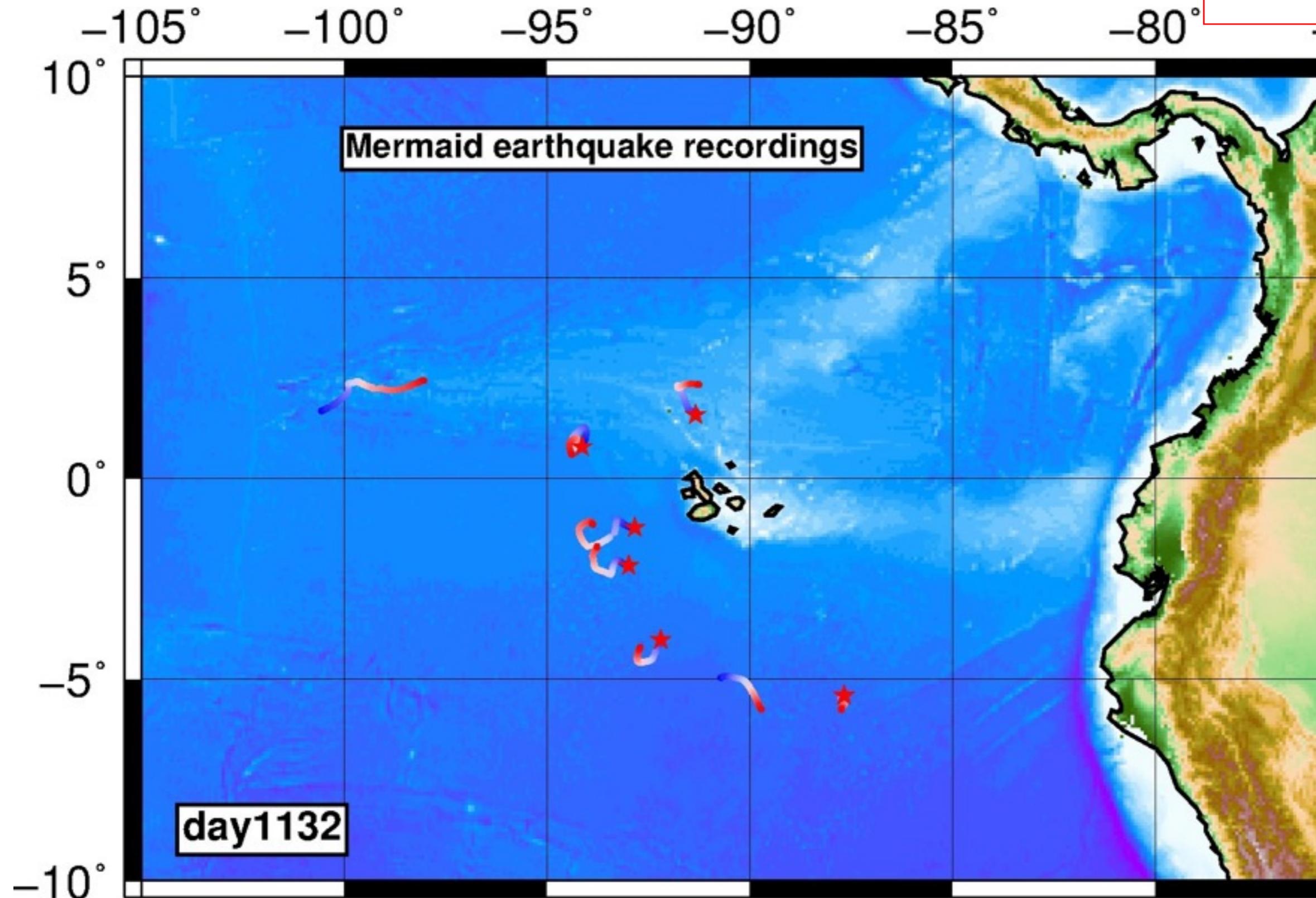




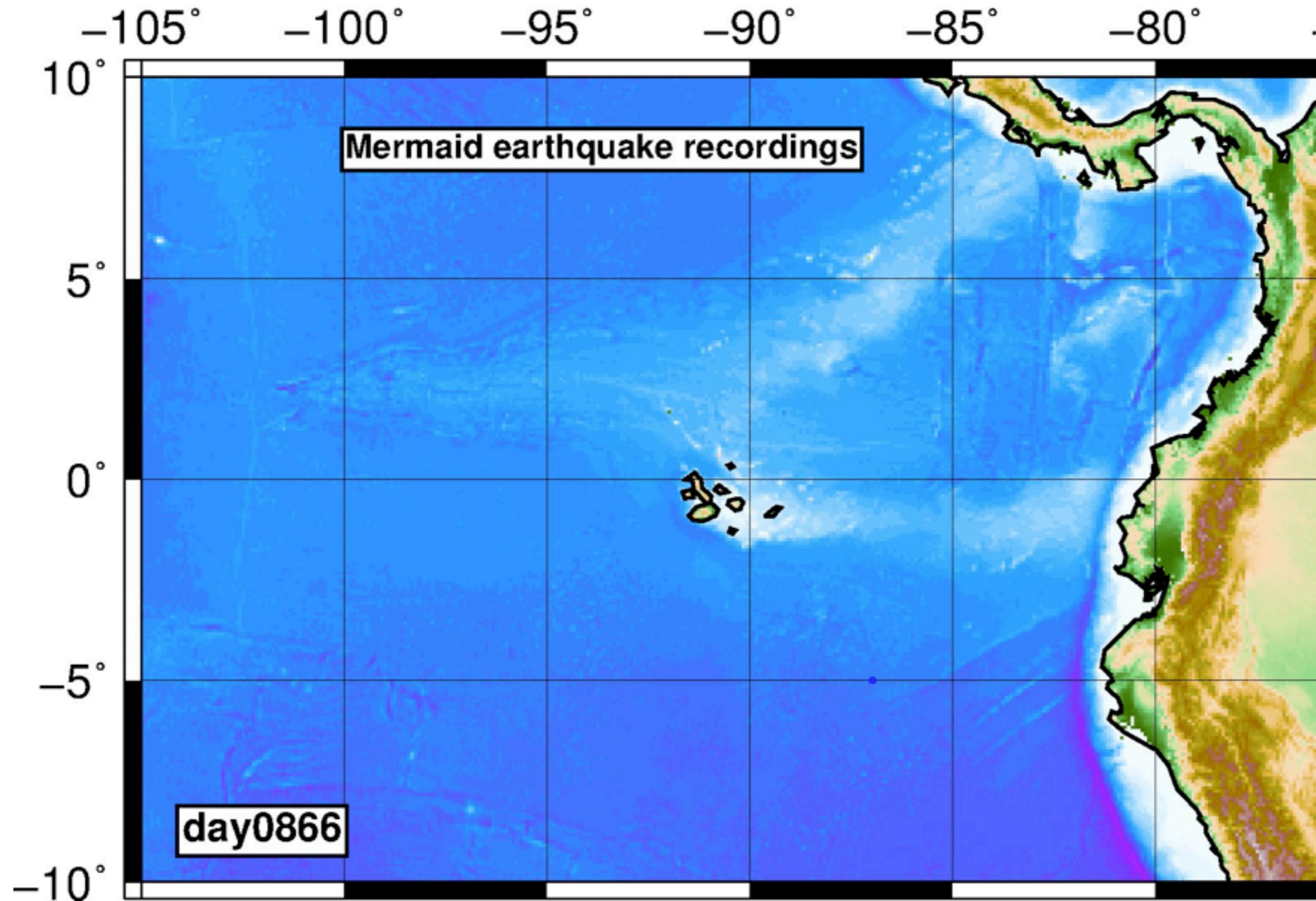


Galapagos Experiment

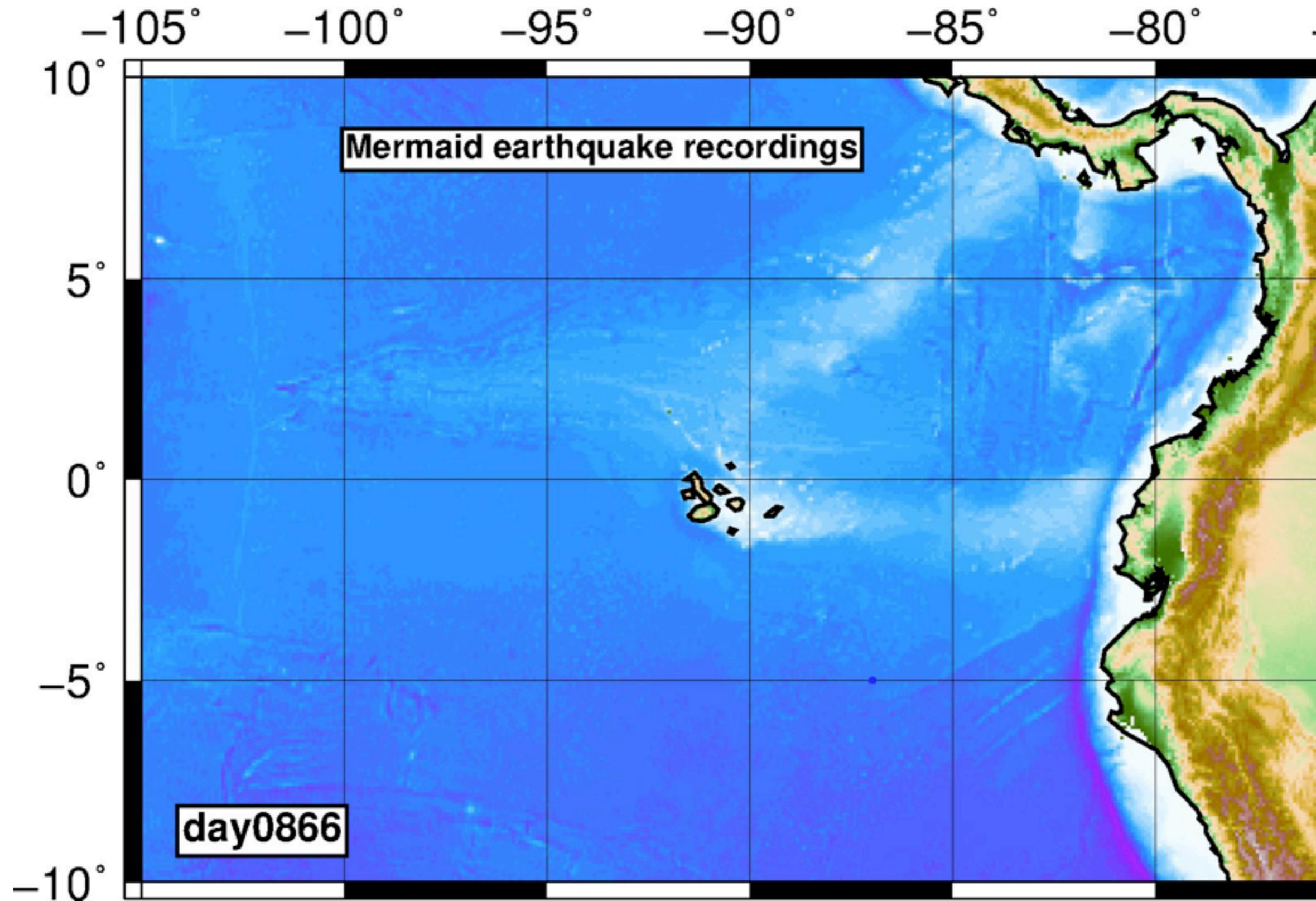
Localisation des MERMAID mises à l'eau dans la zone d'étude.



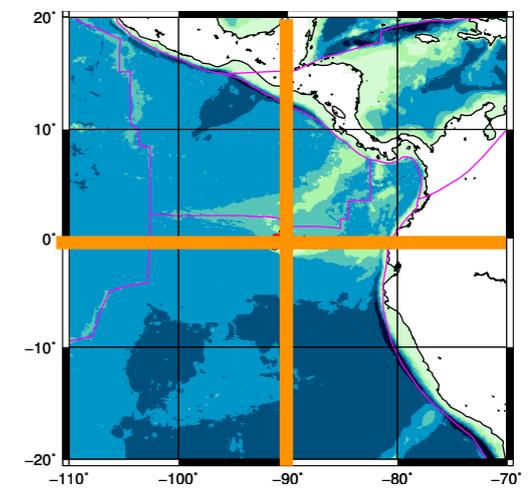
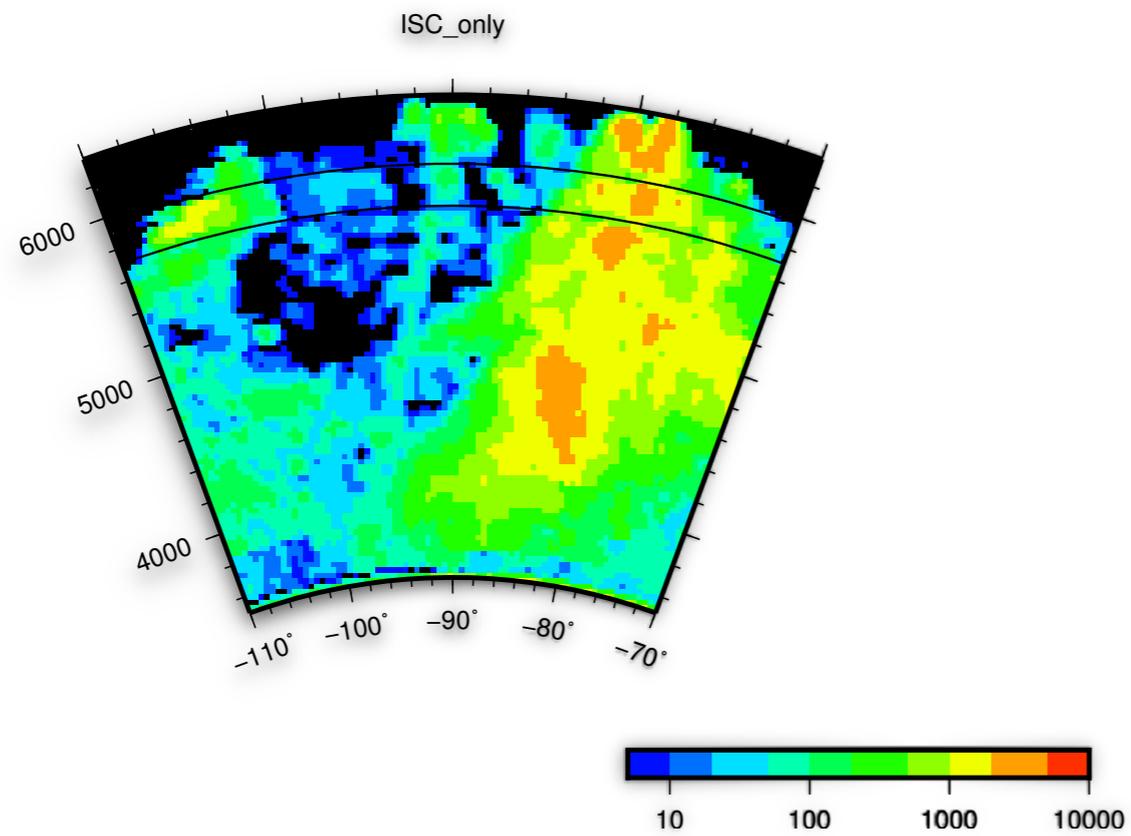
Galapos Experiment



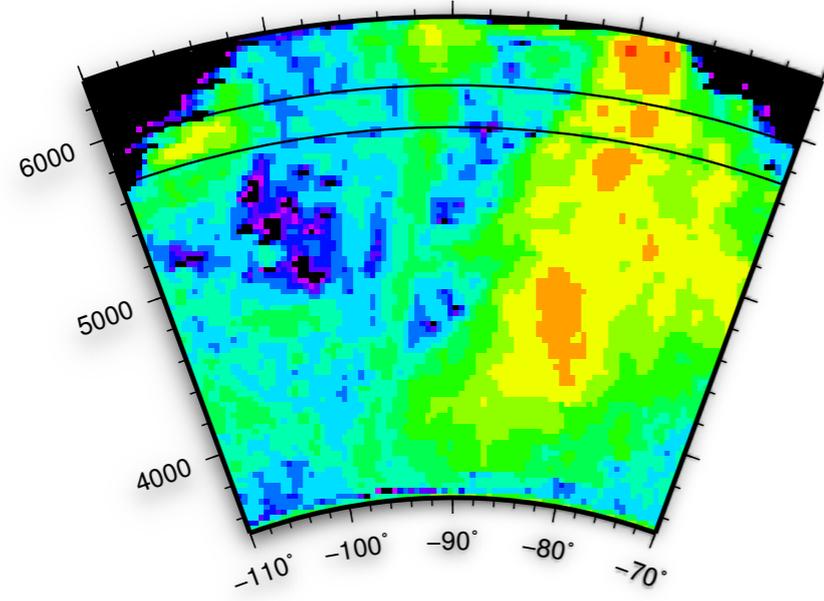
Galapos Experiment



Illumination par rayons sismiques

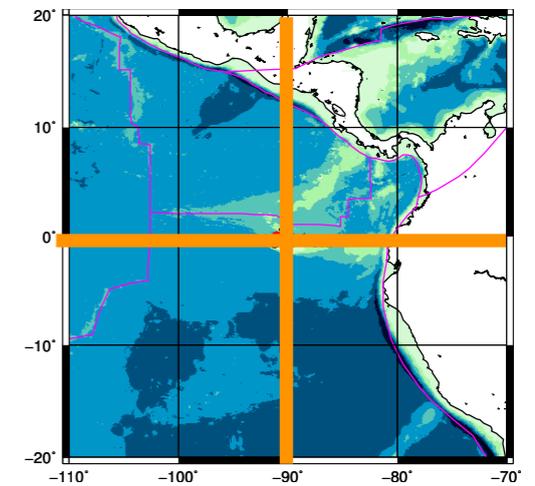
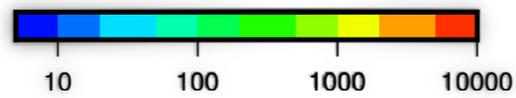
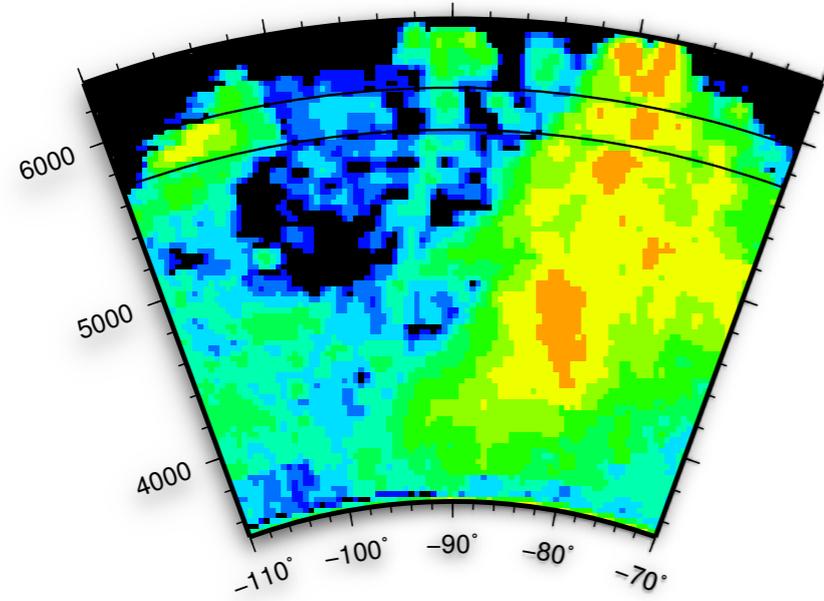


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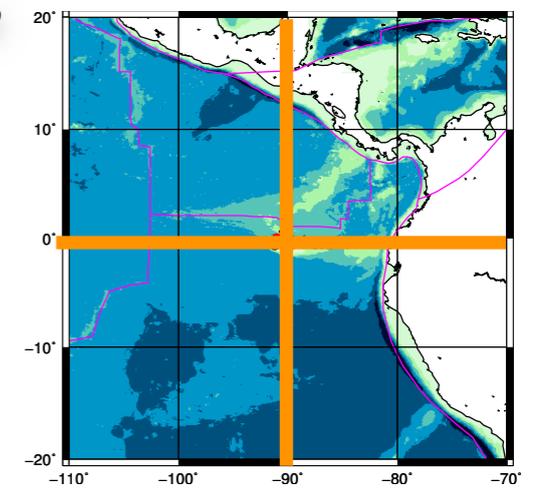
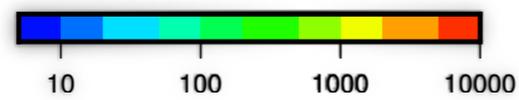
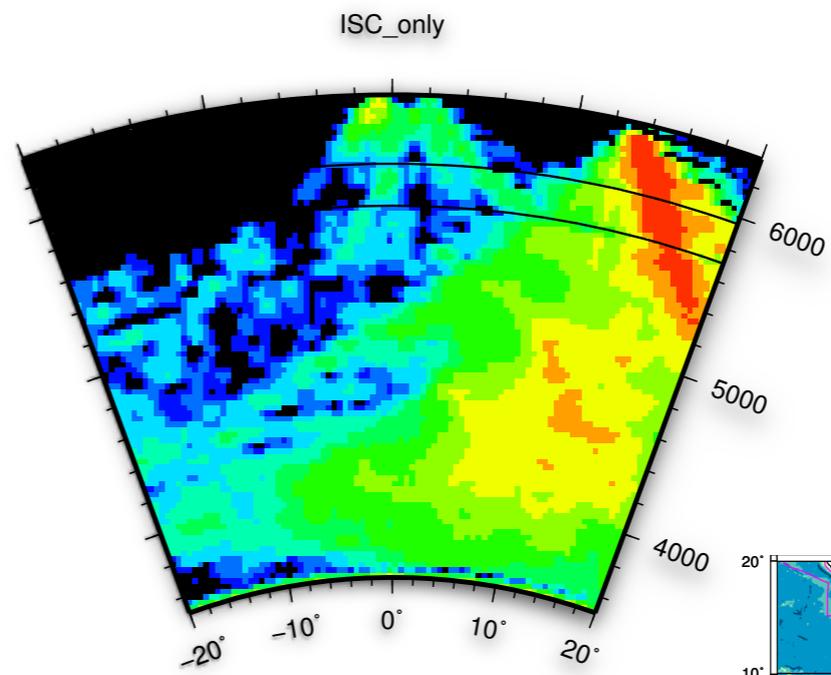
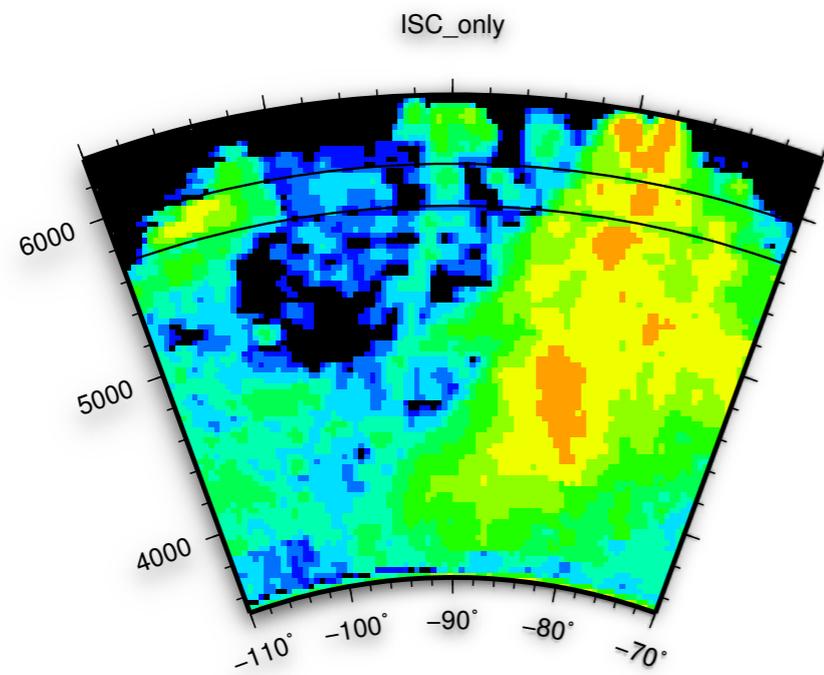
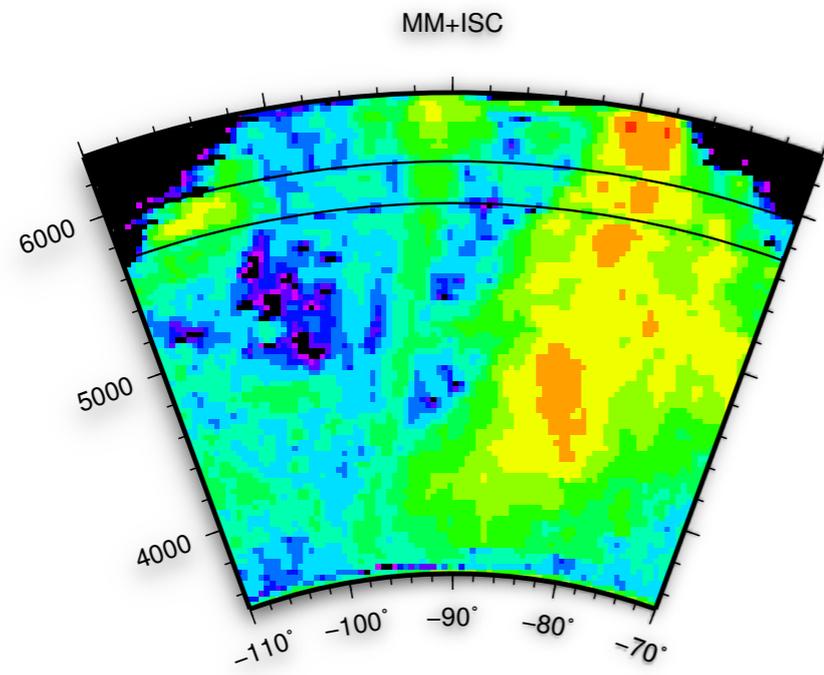


Illumination par rayons sismiques

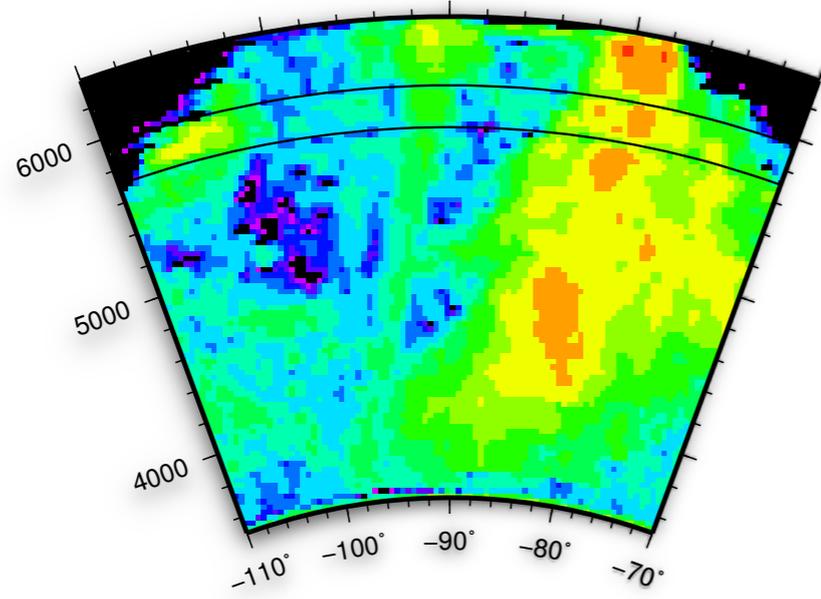
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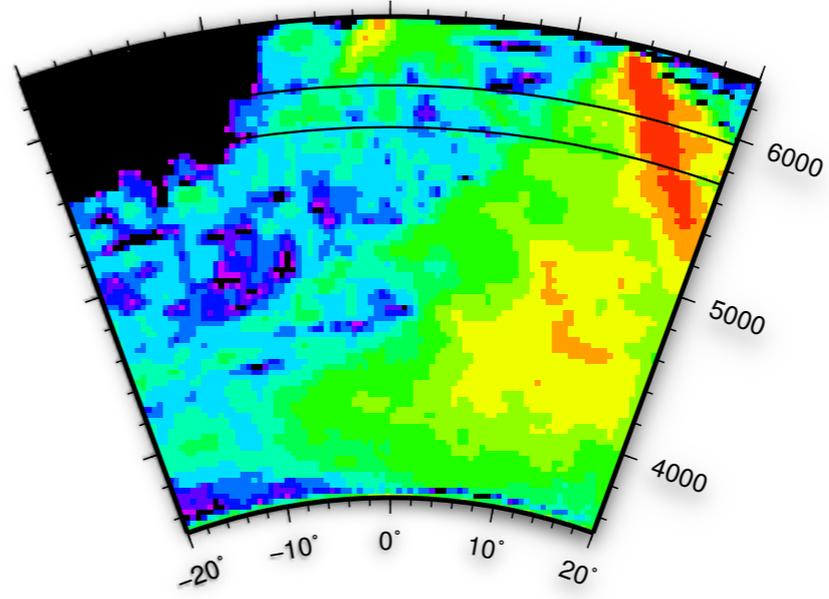
Illumination par rayons sismiques



MM+ISC

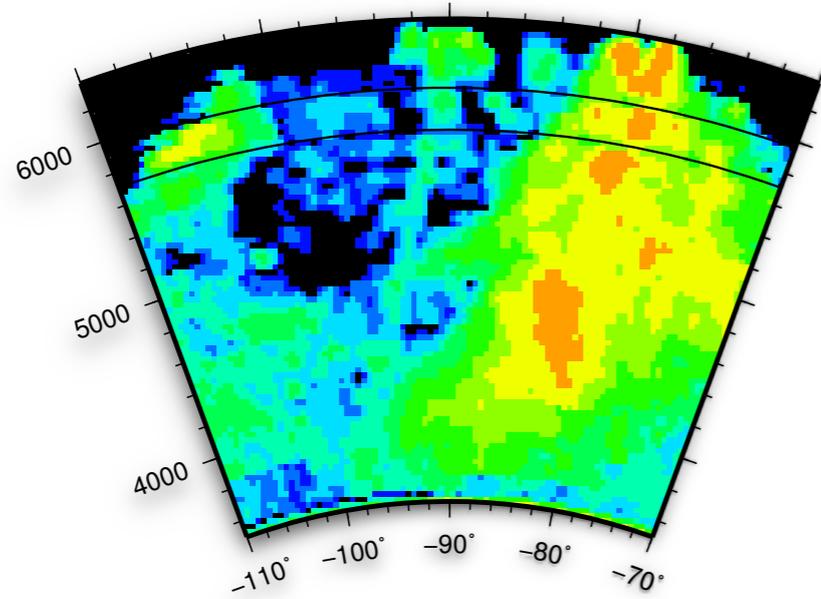


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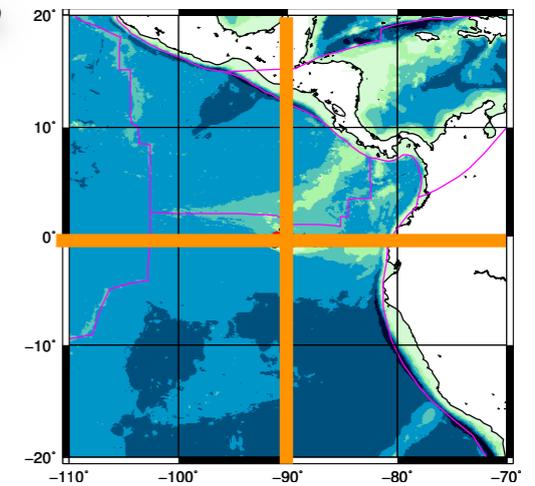
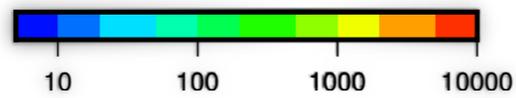
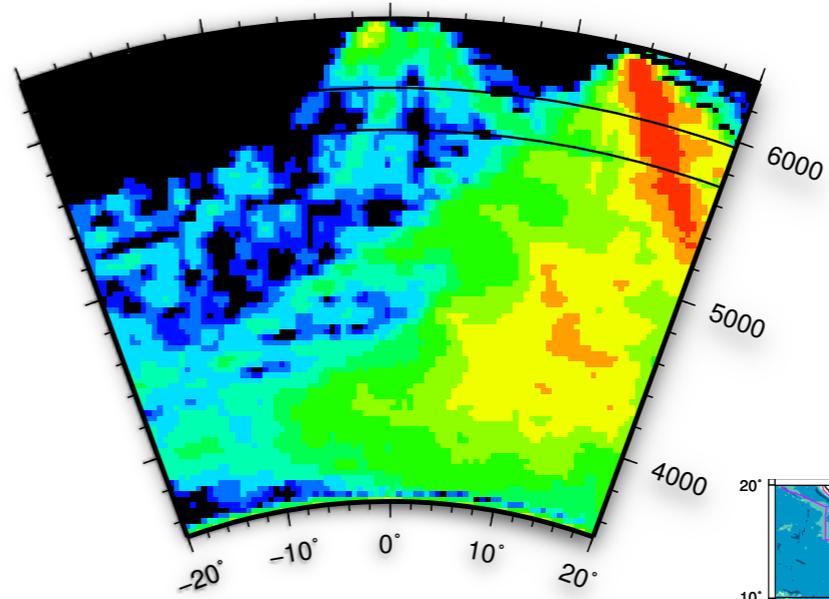


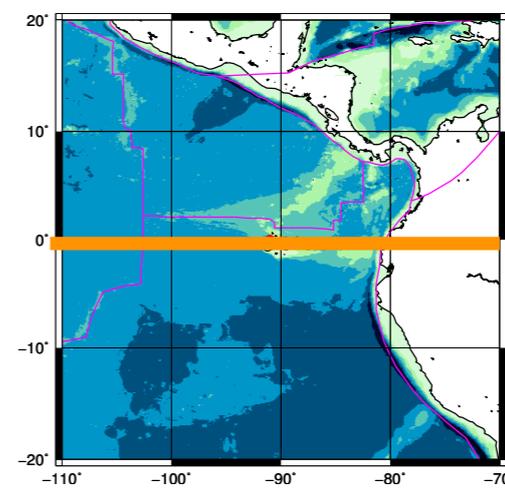
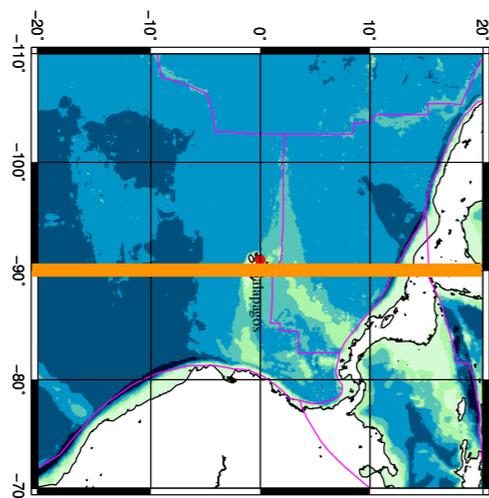
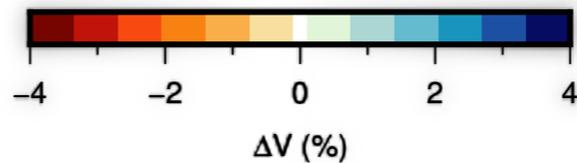
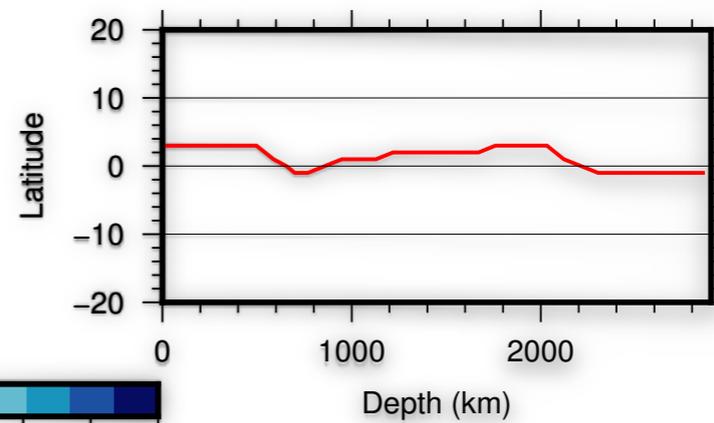
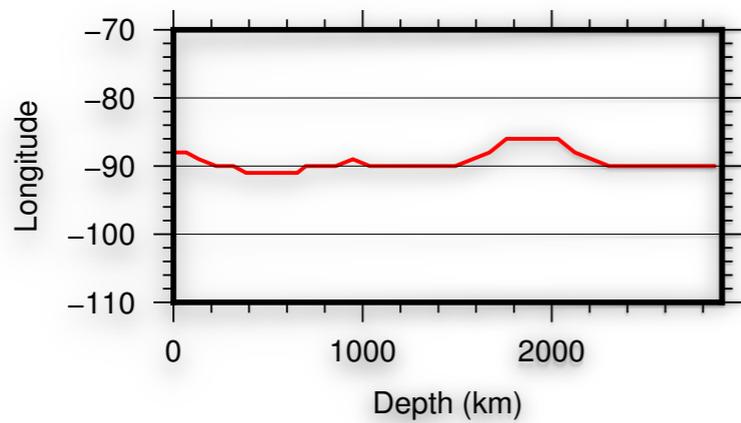
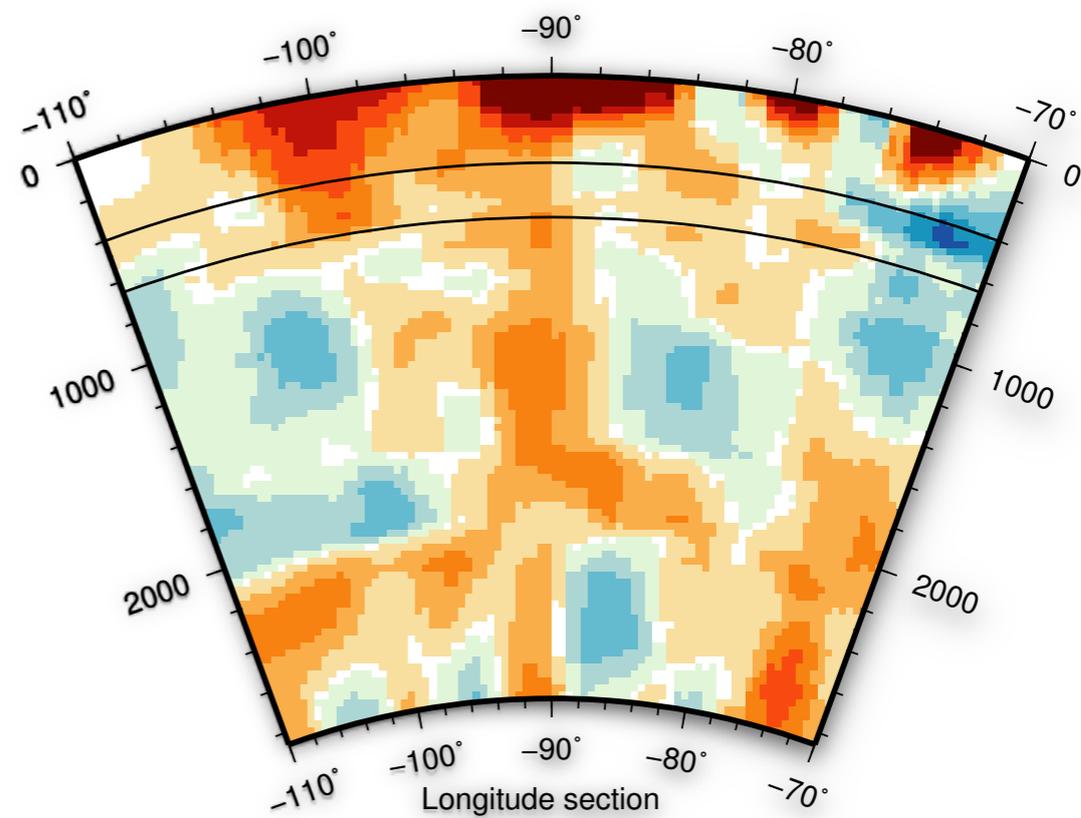
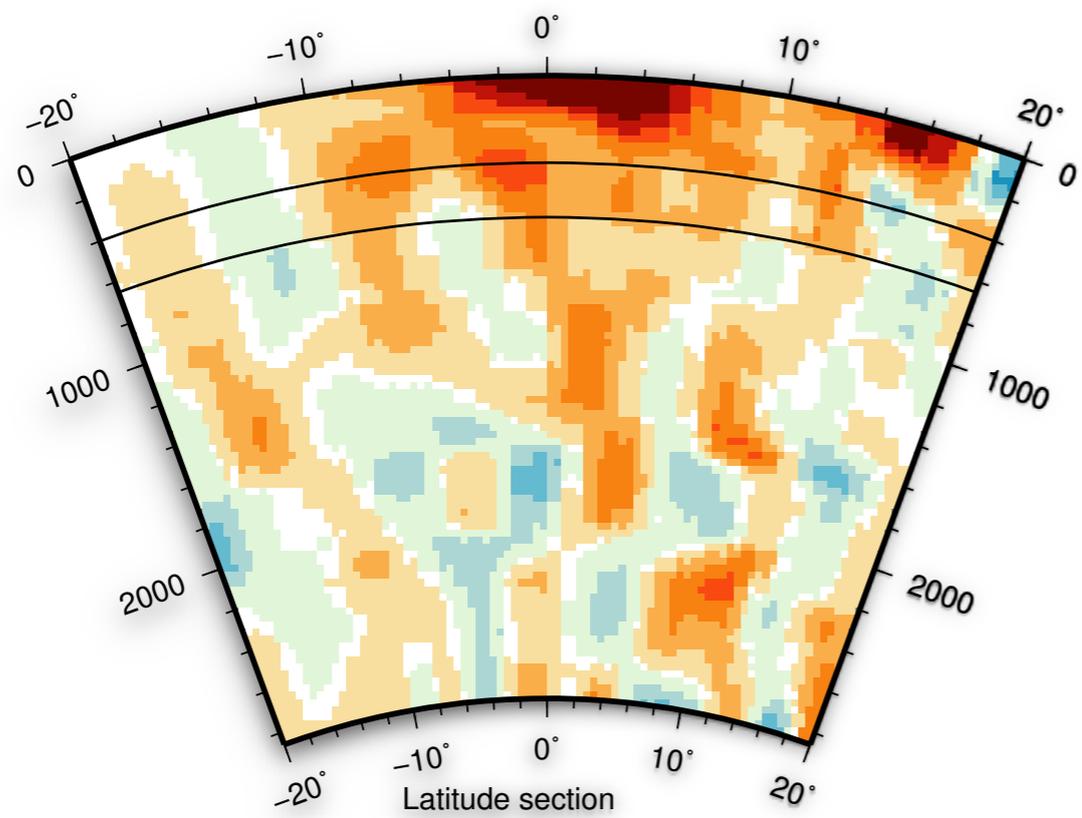
Illumination par rayons sismiques

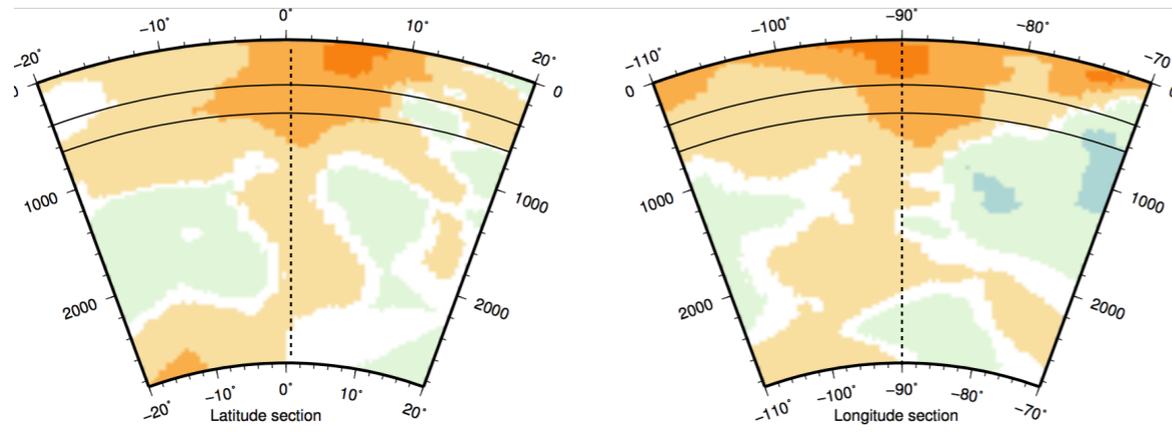
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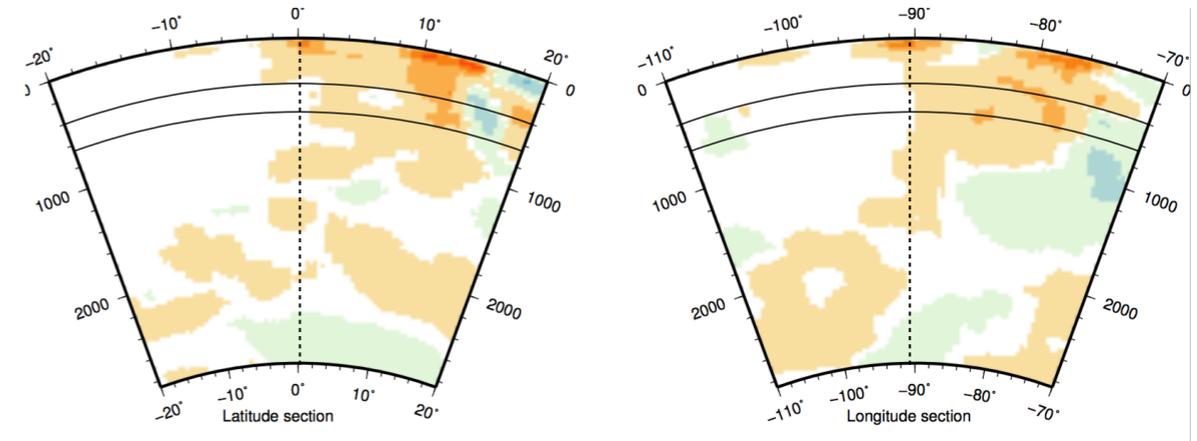
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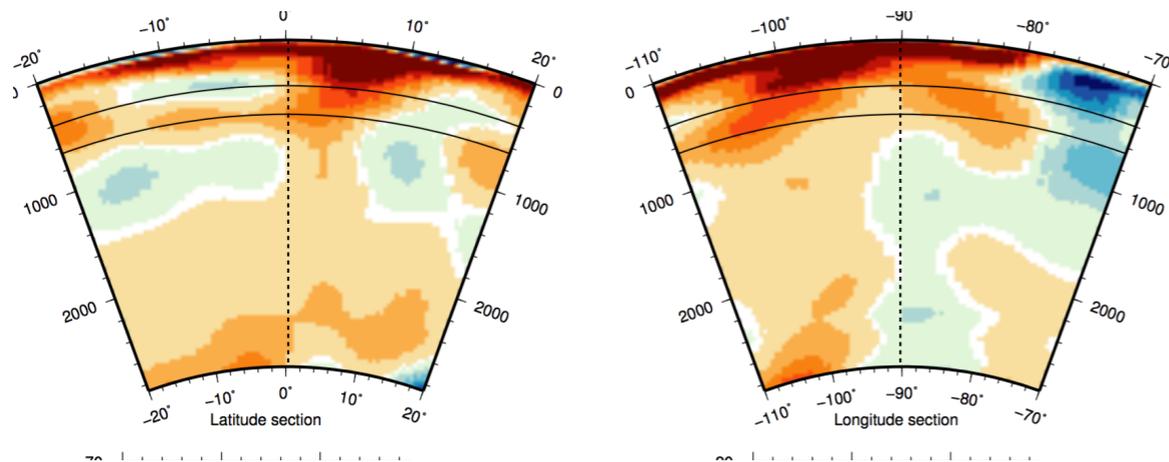




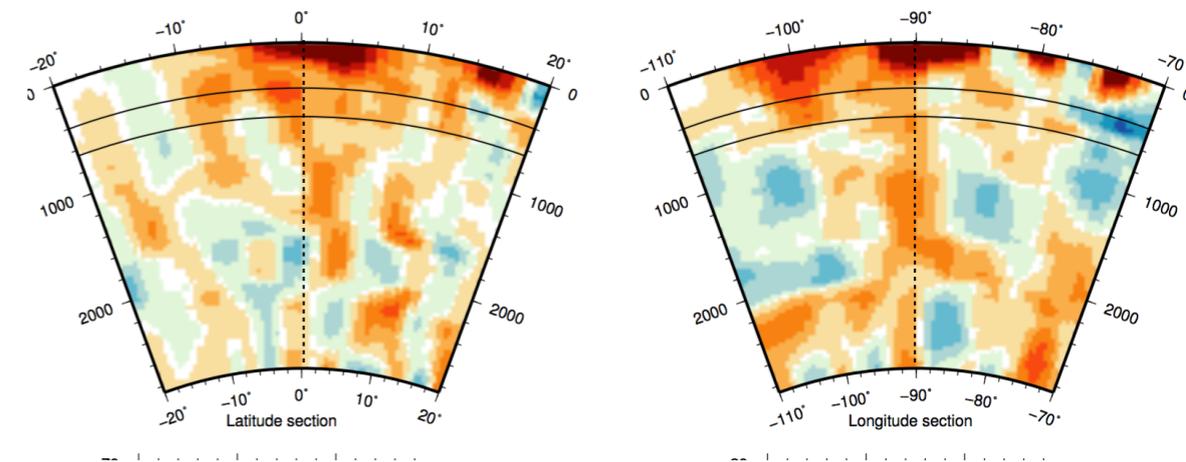
Montelli et al, 2006



Amaru, 2007



French & Romanowicz, 2015



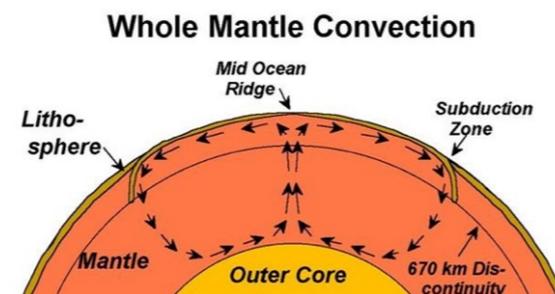
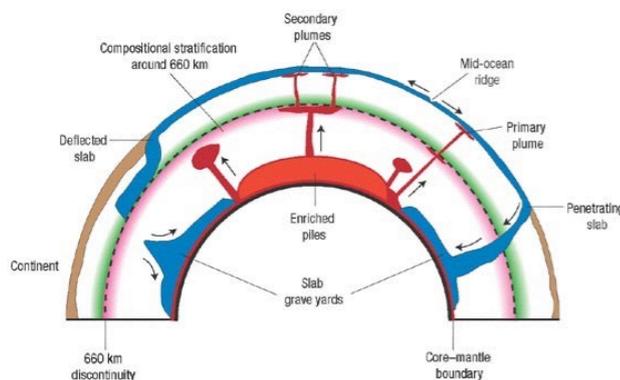
This study

L'apport des données MERMAID complète les études précédentes et permet d'une visualisation bien plus nette du panache en question.

hypothèse

(Nolet et al, EPSL, 2006)

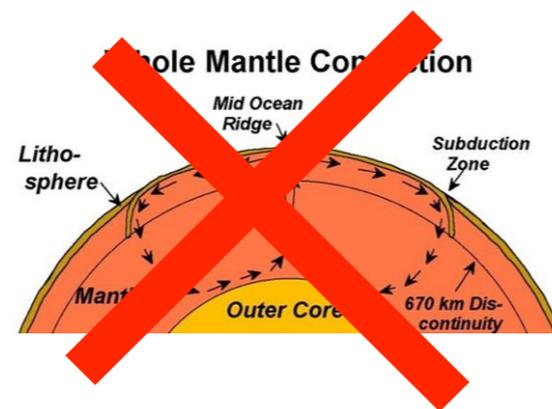
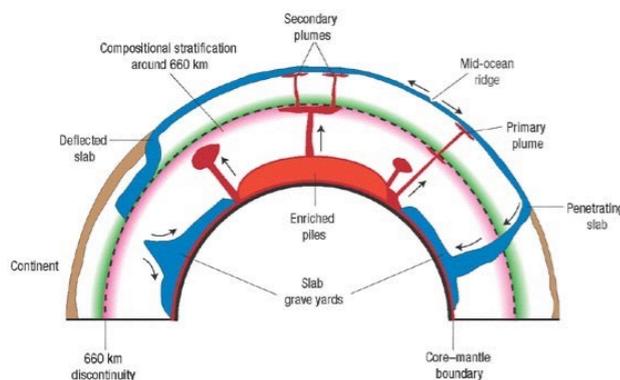
- Manteau inférieur et supérieur ont des régimes de convection séparées,
- L'échange de masse entre les deux est limité: seule subduction et panaches



hypothèse

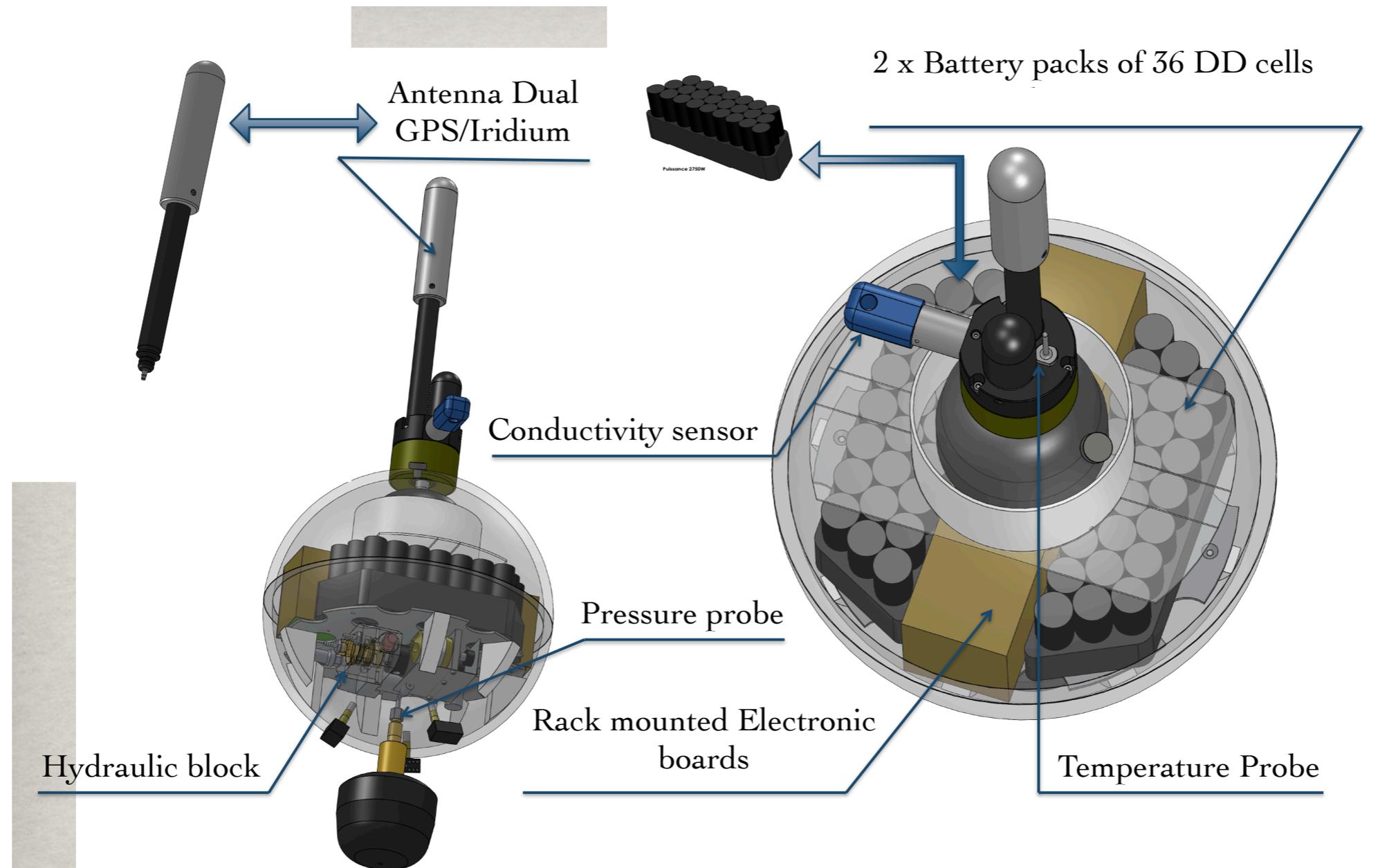
(Nolet et al, EPSL, 2006)

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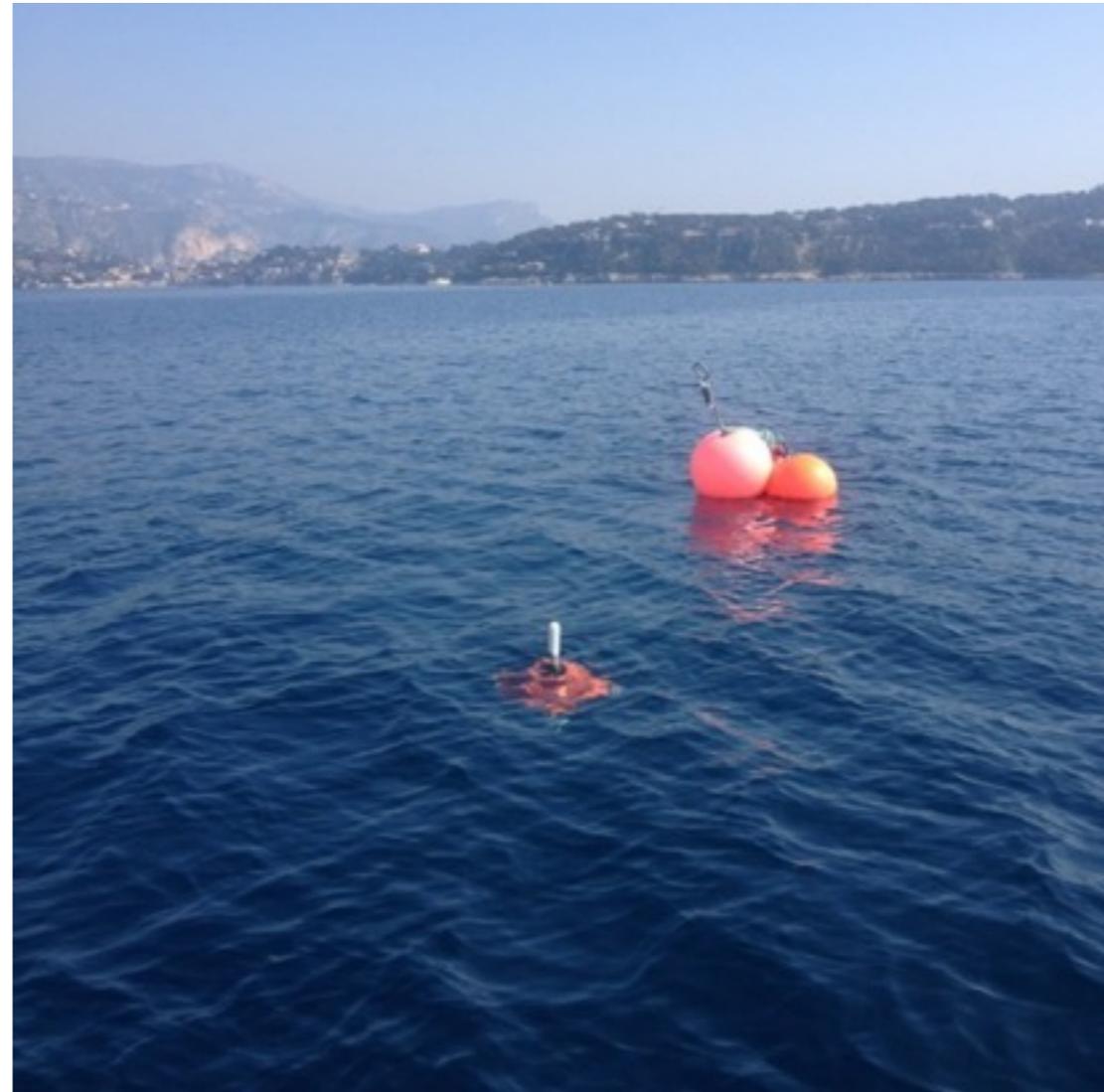
2me génération Mermaid

Bref aperçu des MERMAID de nouvelle génération :
une forme sphérique, plus d'autonomie (plus de batteries), des capteurs
complémentaires (température, conductimétrie)

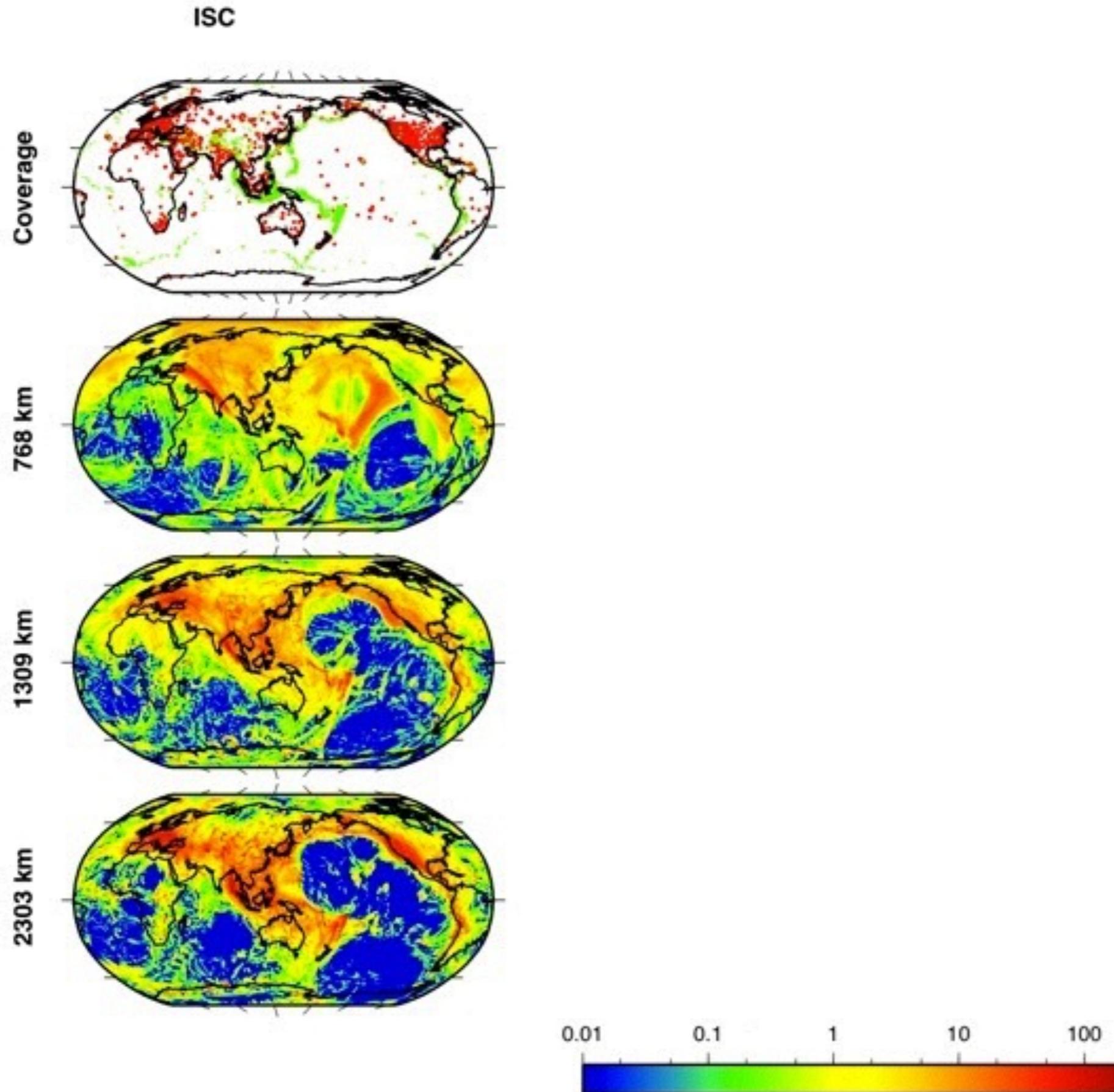


Details of the internal elements of the Multimermaid Float

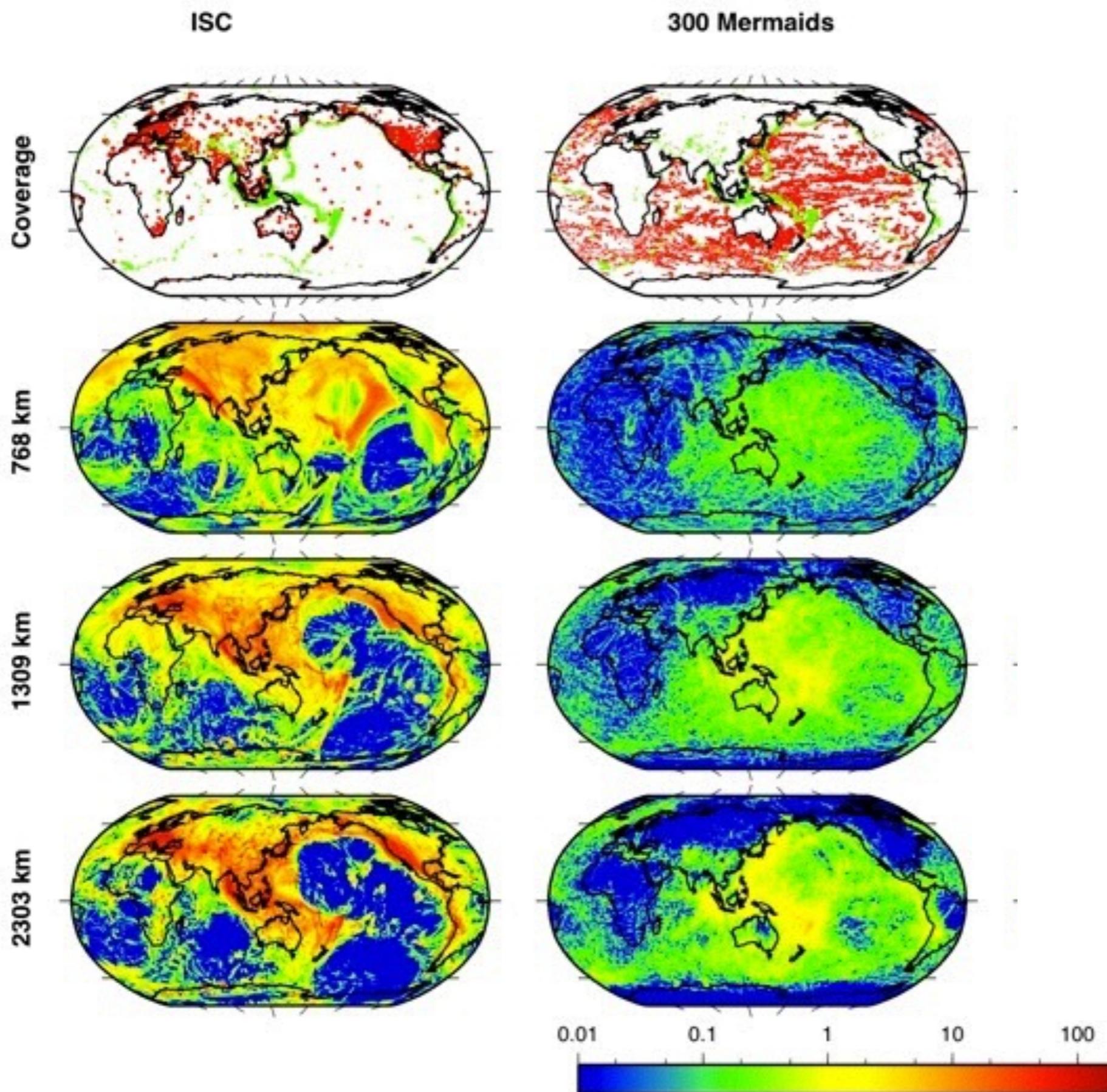
les tests



illumination du manteau inférieur (simulation 5 ans)

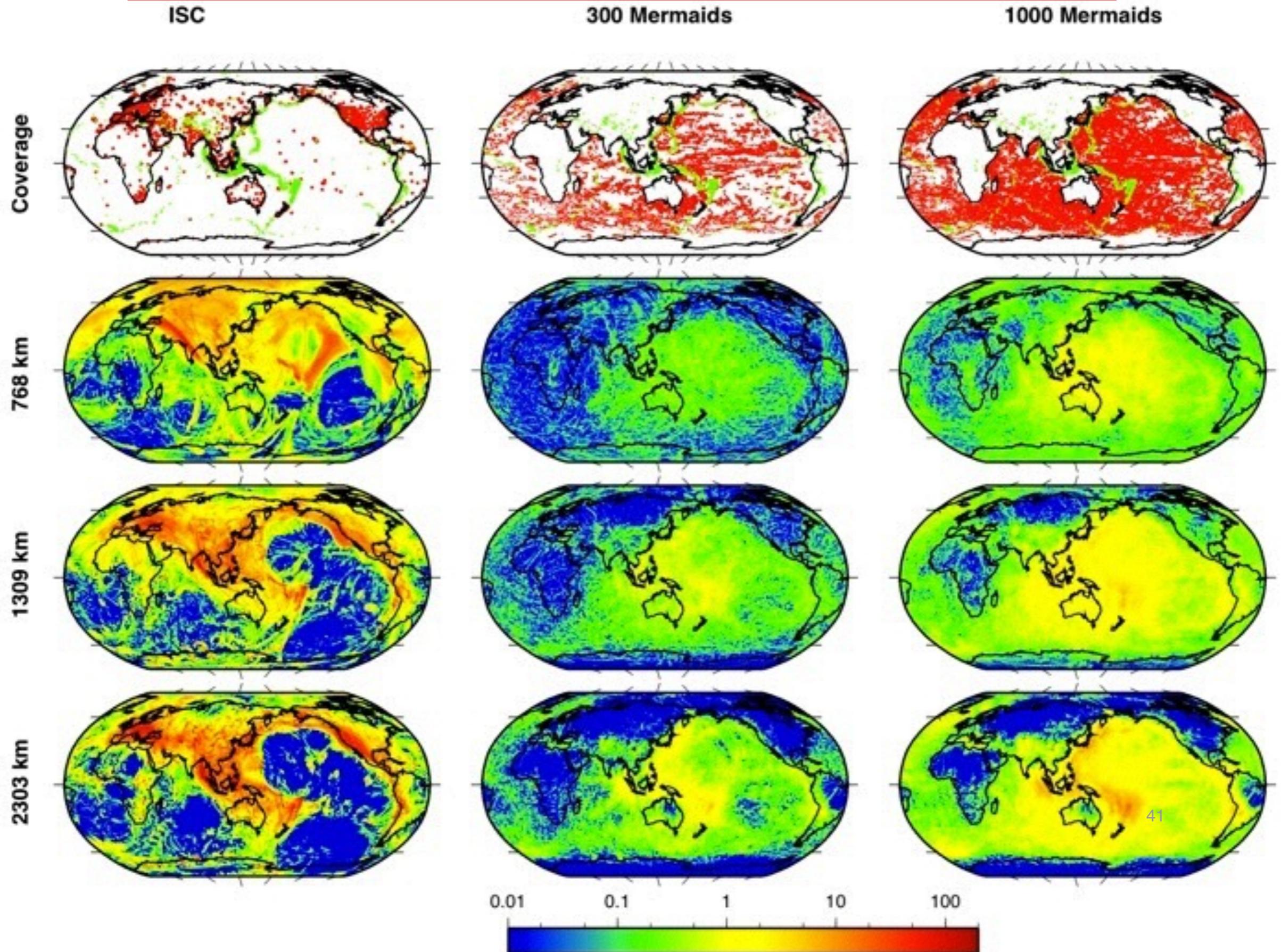


illumination du manteau inférieur (simulation 5 ans)

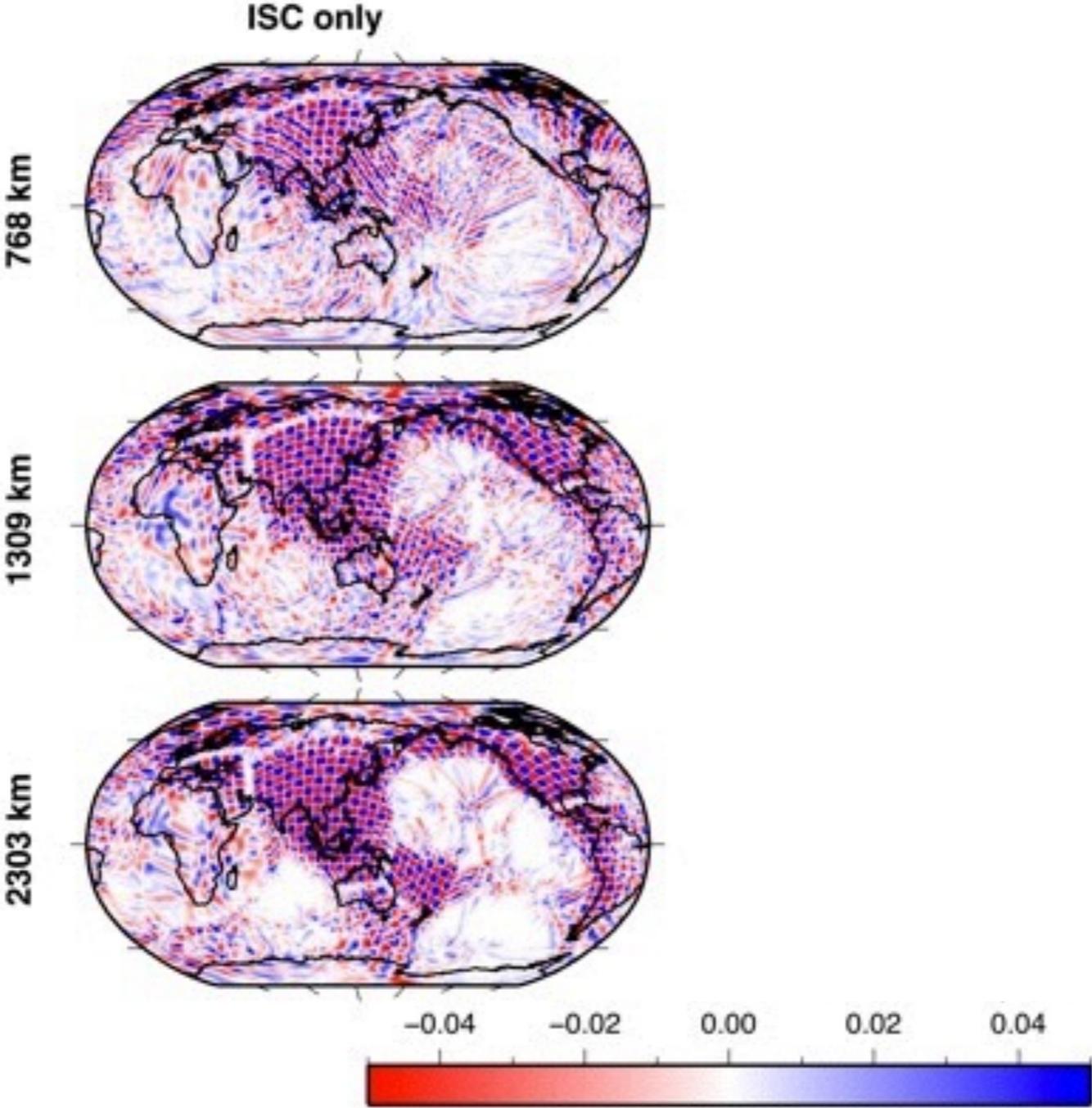


illumination du manteau inférieur (simulation 5 ans)

la connaissance de ce qui se passe en profondeur dans le manteau passe par une couverture plus conséquente des océans en MERMAID.



modélisation de résolution



modélisation de résolution

d'où une bien meilleure résolution pour les modèles de convection du manteau terrestre.

