How Many Hotspots can be Explained by Edge Driven Convection?

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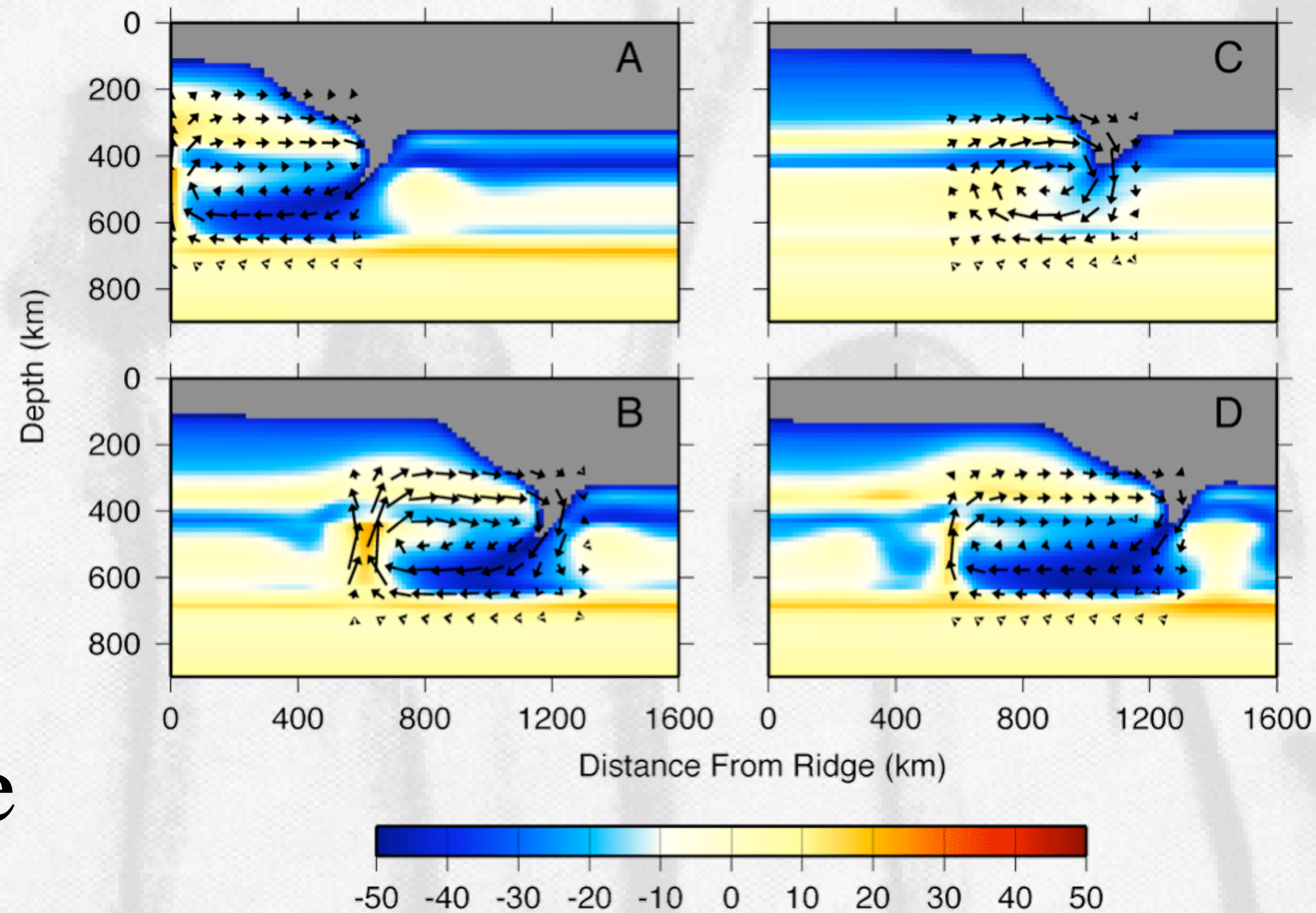
What is Edge Driven Convection?

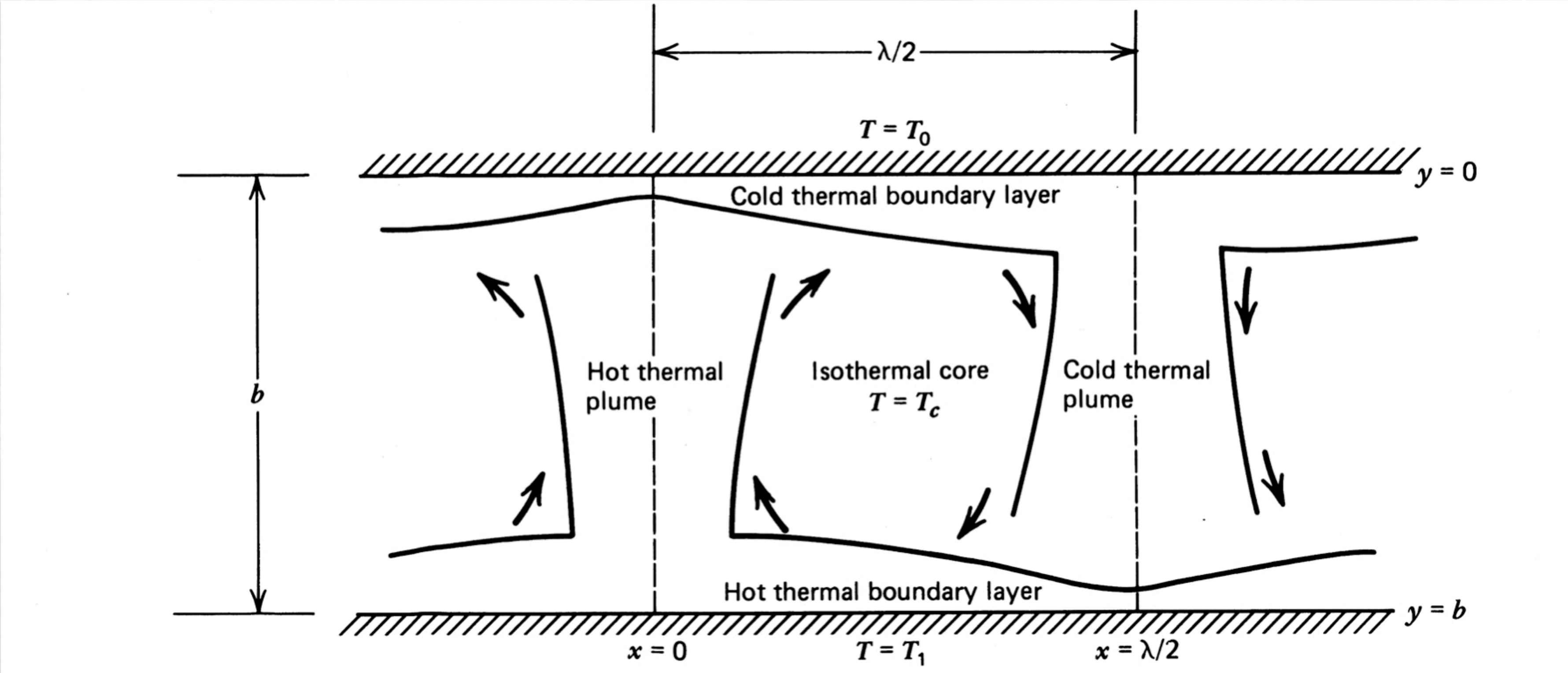
A form of small-scale convection driven by a step in the thickness of the lithosphere.



From King and Ritsema, *Science*, 2000

What is the natural length-scale of edge-driven convection?

- The most unstable convective mode occurs at $\sqrt{2}D$
- The transition zone acts as an effective barrier to short-wavelength convection (Tackley, 1995), hence I take D=660 km

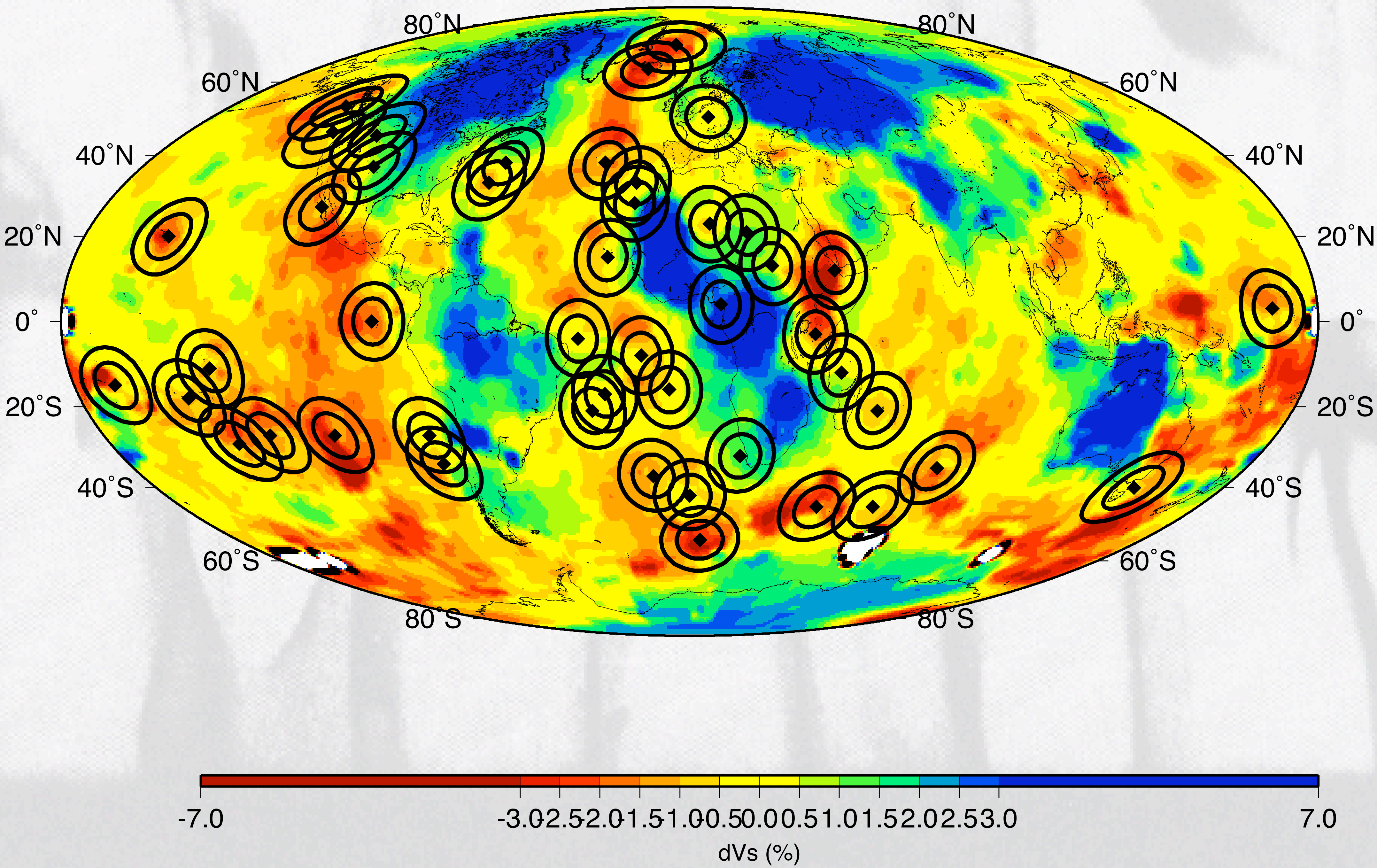


From Turcotte and Schubert

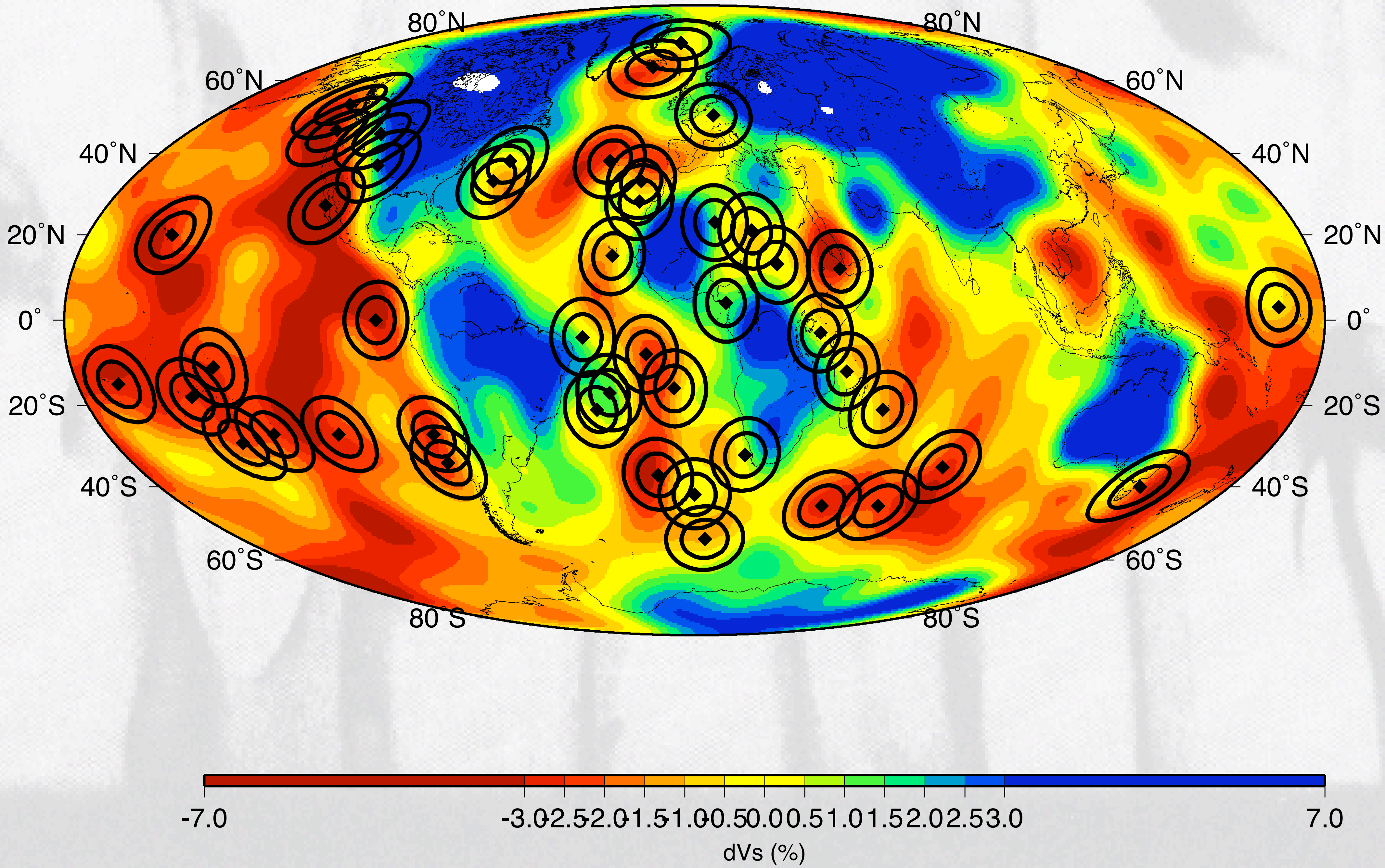
A little physical insight, a tomography model, a list of hotspots, and GMT...

- take a list of hotspot locations (Sleep, 1990)
- plot these on a tomographic model (e.g., Grand, 175-250 km depth)
- observe which hotspots are within 600-1000 km of a fast anomaly (i.e., continental root).

Global Hotspot Distribution and S-Wave Tomography (Grand) at 175-250 km Depth



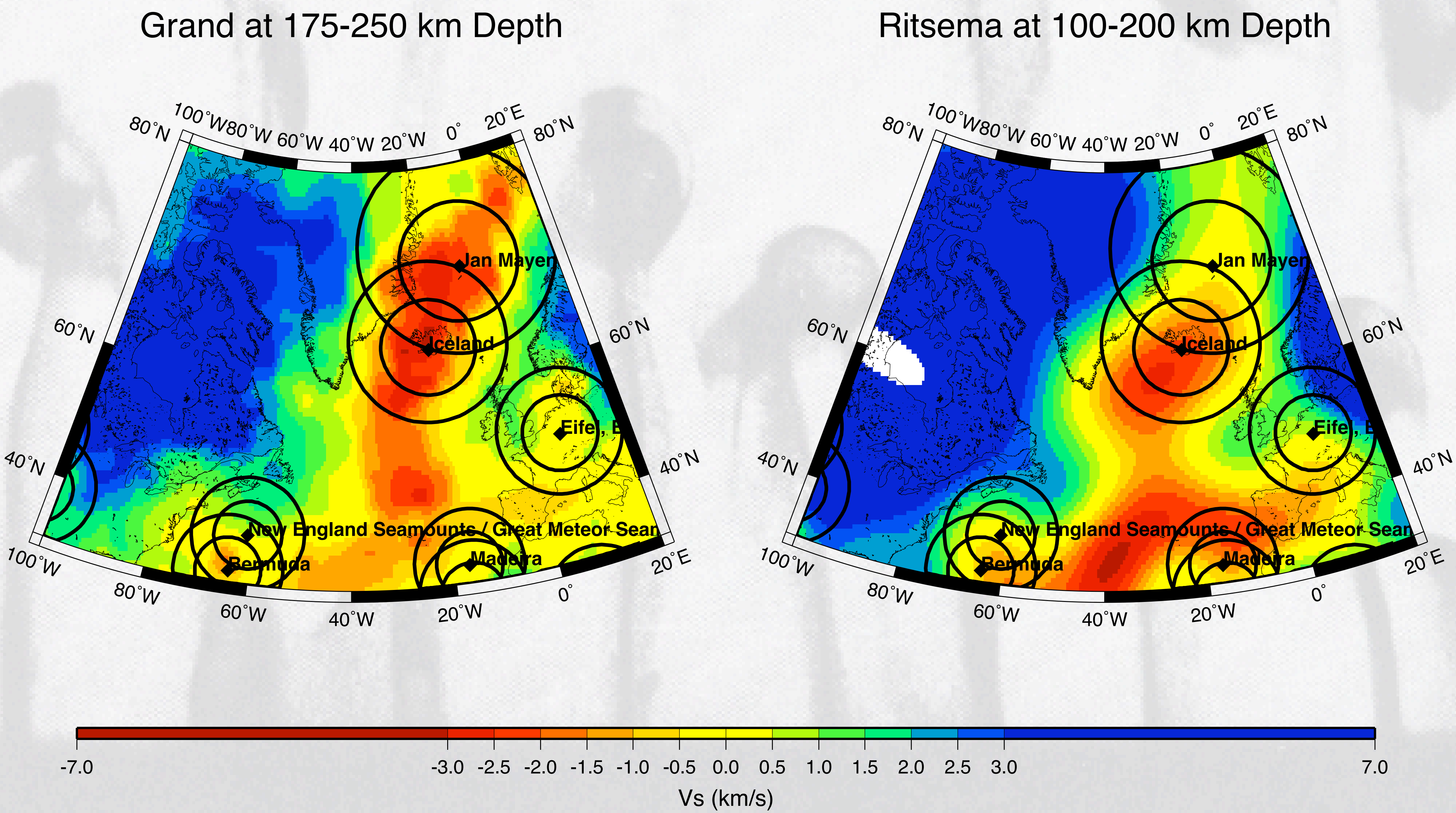
Global Hotspot Distribution and S-Wave Tomography (Ritsema) at 100-200 km Depth

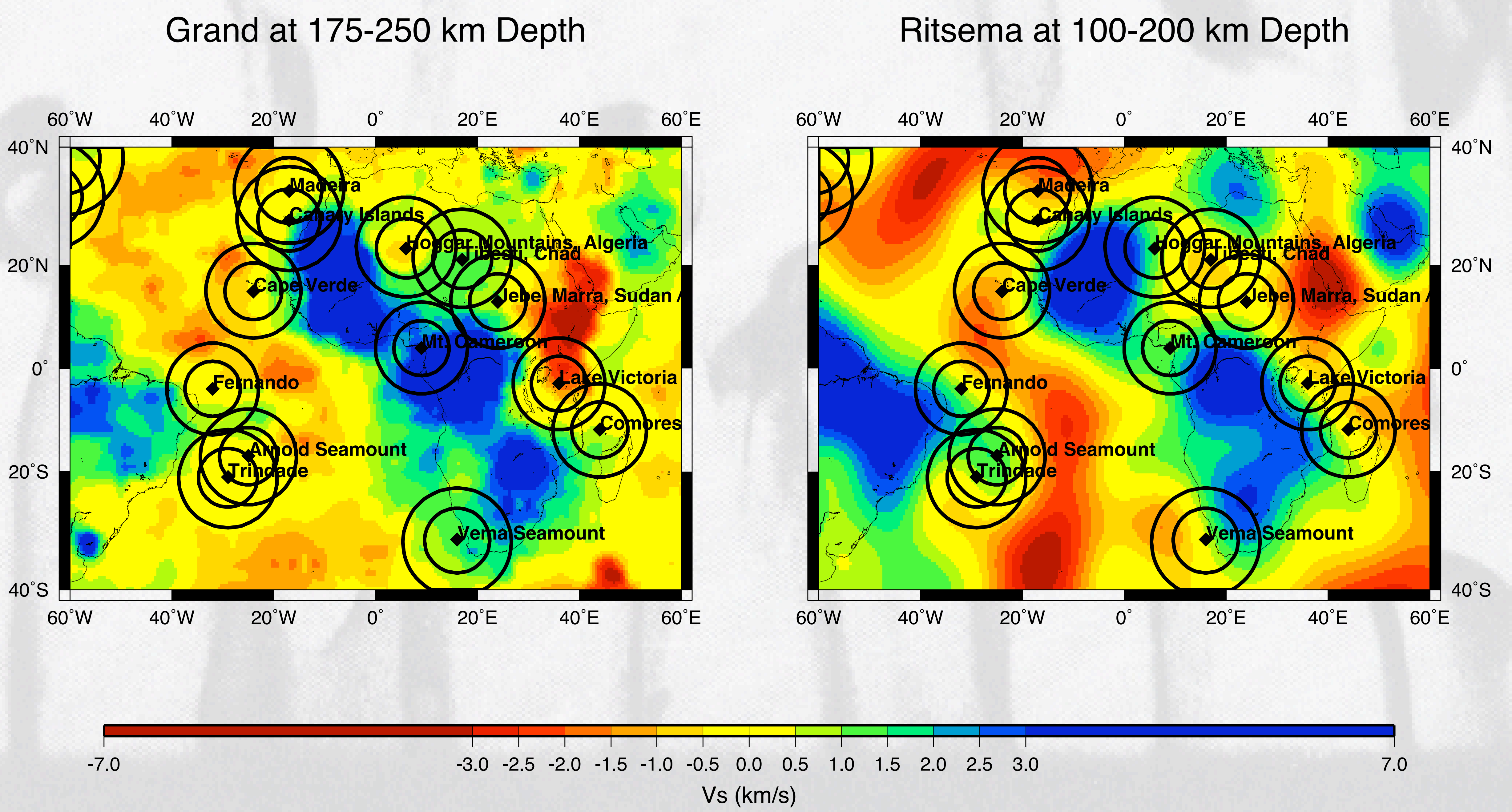


Courtillot et al., 2003 *Primary*	*Montelli et al., 2003* *Science Express*	***Not*** ***within 600-1000 km*** ***(this analysis)***
Afar	Afar (?)	Afar
Easter	Easter	Easter
Hawaii	Hawaii	Hawaii
Iceland		**?**
Louisville	Louisville (weak)	Louisville
Reunion	Reunion	Reunion
Samoa	Samoa	Samoa
Tristan	?	Tristan
	Ascension	Ascension
	Azores (?)	Azores
	Canary	
	Crozet	Crozet
	Eifel	
	Kerguelen	Kerguelen
	Tahiti	Tahiti

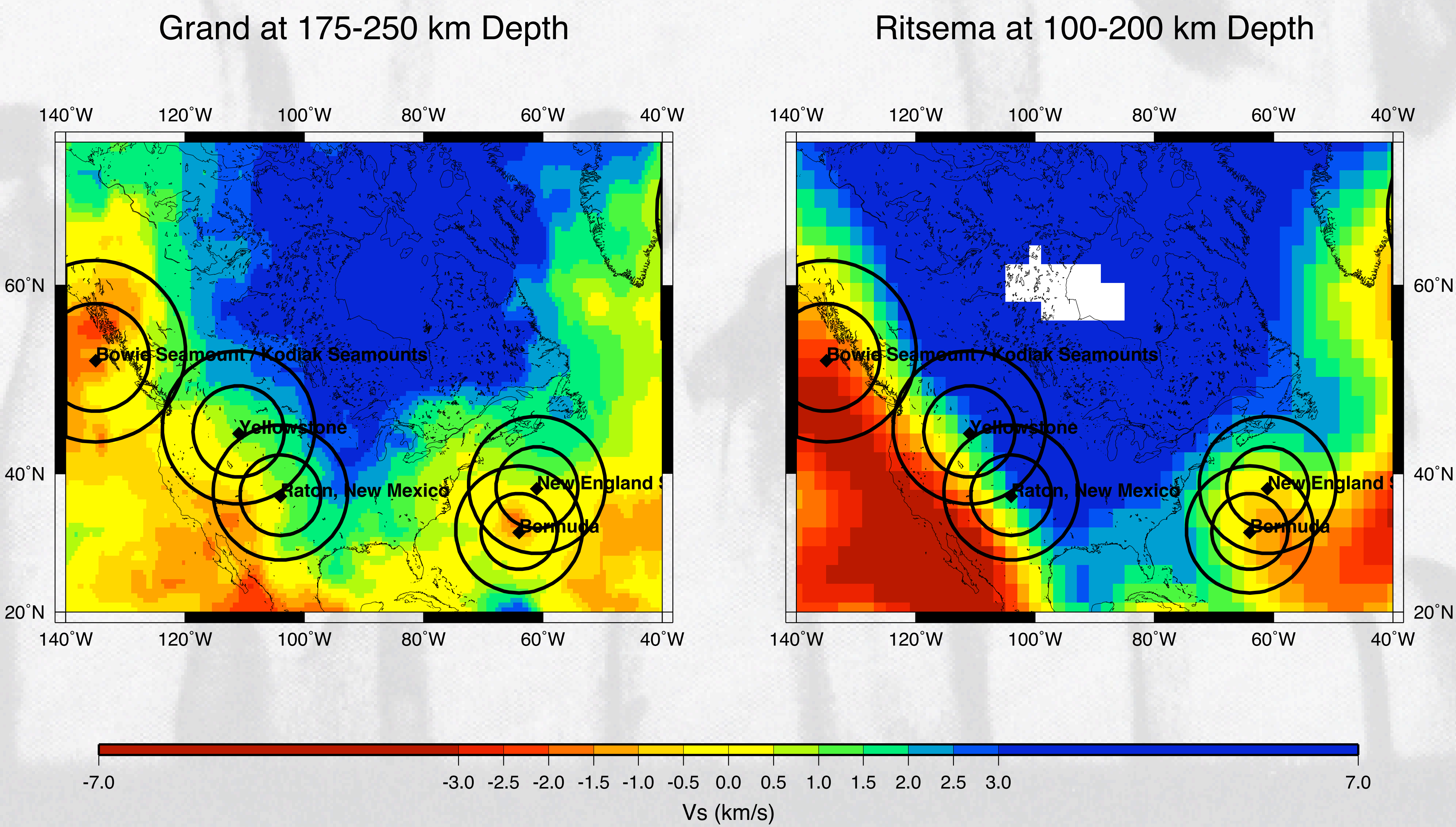
Groups of Edge Driven Convection Hotspots

- North Atlantic
- Africa/South America
- other


Grand at 175-250 km Depth
Ritsema at 100-200 km Depth
Jan Mayen
Iceland
Eifel, E
New England Seamounts / Great Meteor Sean
Bermuda
Madeira
80°N
60°N
40°N
100°W
80°W
60°W
40°W
20°W
0°
20°E
-7.0
-3.0
-2.5
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0
7.0
Vs (km/s)



Grand at 175-250 km Depth
Ritsema at 100-200 km Depth
60˚W
40˚W
20˚W
0˚
20˚E
40˚E
60˚E
40˚N
20˚N
0˚
20˚S
40˚S
Madeira
Canary Islands
Hoggar Mountains, Algeria
Tibesti, Chad
Cape Verde
Jebel Marra, Sudan
Mt. Cameroon
Fernando
Lake Victoria
Comores
Arnold Seamount
Trindade
Verna Seamount
-7.0
-3.0
-2.5
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0
7.0
Vs (km/s)



Grand at 175-250 km Depth
Ritsema at 100-200 km Depth
140˚W
120˚W
100˚W
80˚W
60˚W
40˚W
60˚N
40˚N
20˚N
Bowie Seamount / Kodiak Seamounts
Yellowstone
Raton, New Mexico
New England S
Bermuda
-7.0
-3.0
-2.5
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0
7.0
Vs (km/s)

North Atlantic	**Africa/South Atlantic**	**Other**
Iceland	Madeira	Yellowstone
Jan Mayen	Canary	Raton, New Mexico
New England Seamounts	Cape Verde	Bowie Seamount
Bermuda	Mt. Cameroon	Tasmania
Eifel	Hoggar Mountains, Algeria	
	Tibesti, Chad	
	Fernando	
	Arnold Seamount	
	St. Helena	
	Vema Seamount	
	Trindade	

Argument for some deep mantle plumes

- Heat is being released from the core
- If more heat is released from the core than can be conducted up an adiabat, then the lower mantle will become unstable and convect.

Lower mantle parameters

Symbol	Name	Value
ρ_o	density	4.5×10^3 kg/m^3
D	depth	2230 km
g	magnitude of gravity	10 m/s^2
ΔT	temp. drop across D	1000 °K
κ	thermal diffusivity	2×10^{-6} m^2/s
α	thermal expansivity	0.5×10^{-5} °K^{-1}
η	viscosity	10^{23} Pa s

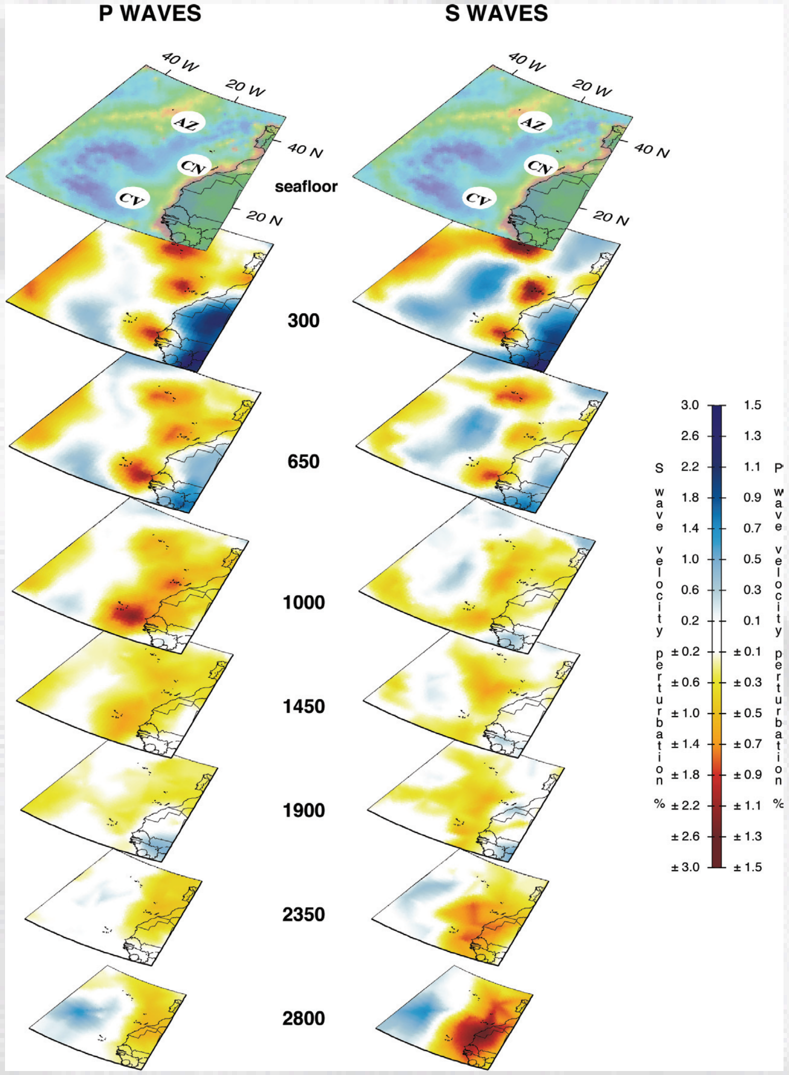
$$Ra_{LowerMantle} = 1.25 \times 10^4 > Ra_{crit} \approx 10^3$$

“Nature finds a way”

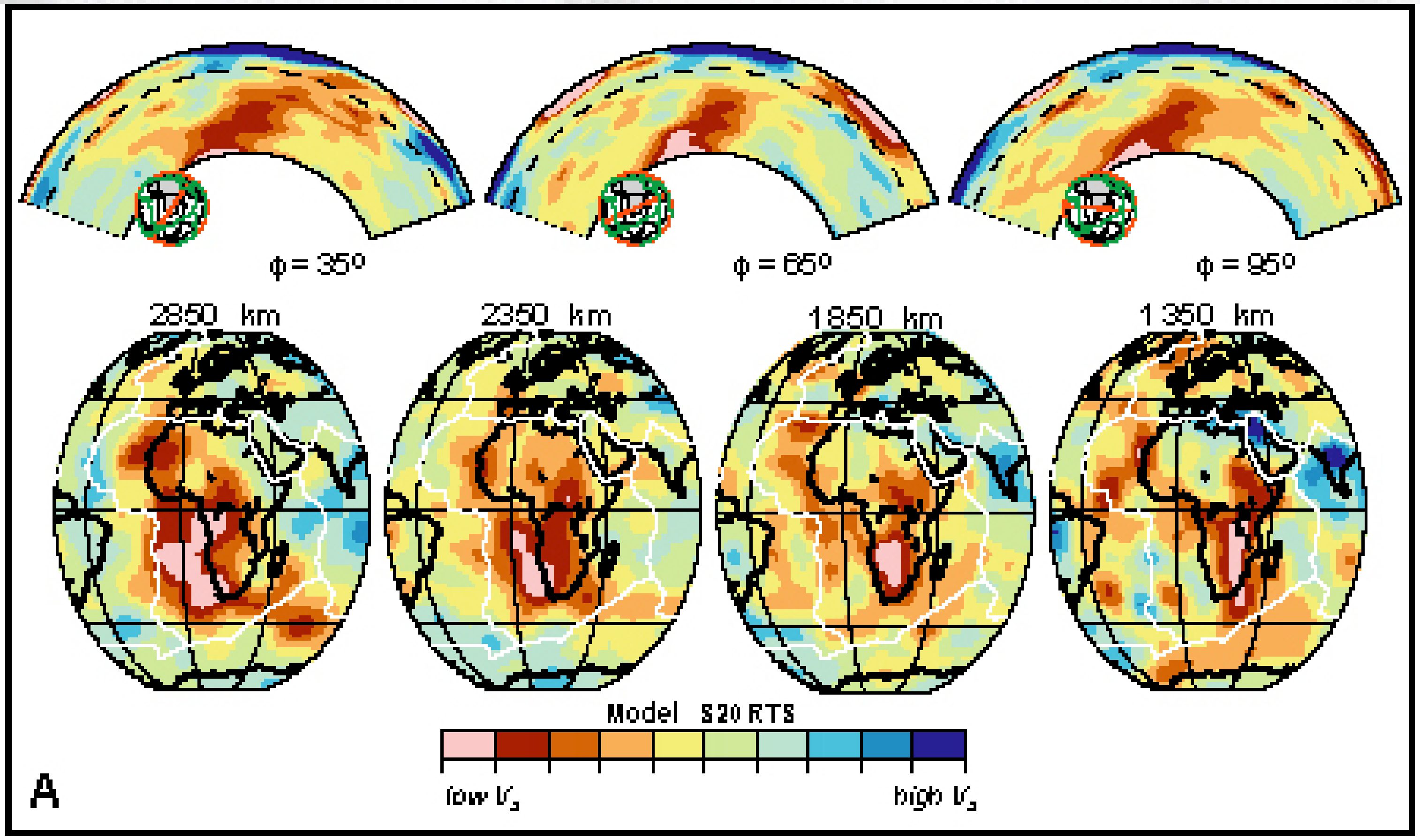
-Dr. Ian Malcolm (Jurassic Park)

- If more heat is released from the core than can be conducted along the adiabat,
- then the lower mantle will heat up.
- Because the viscosity of the mantle is a strong function of temperature, the viscosity of the lower mantle will decrease (raising the Rayleigh number) making convection more favorable to advect heat
- “Nature finds a way”

In my view, the question we should be asking is whether plumes look like this or this?



Montelli et al., 2004



Ritsema et al., 1999; 2004