Unveiling the heterogeneous structure of the upper-mantle beneath the Canary and Madeira volcanic provinces

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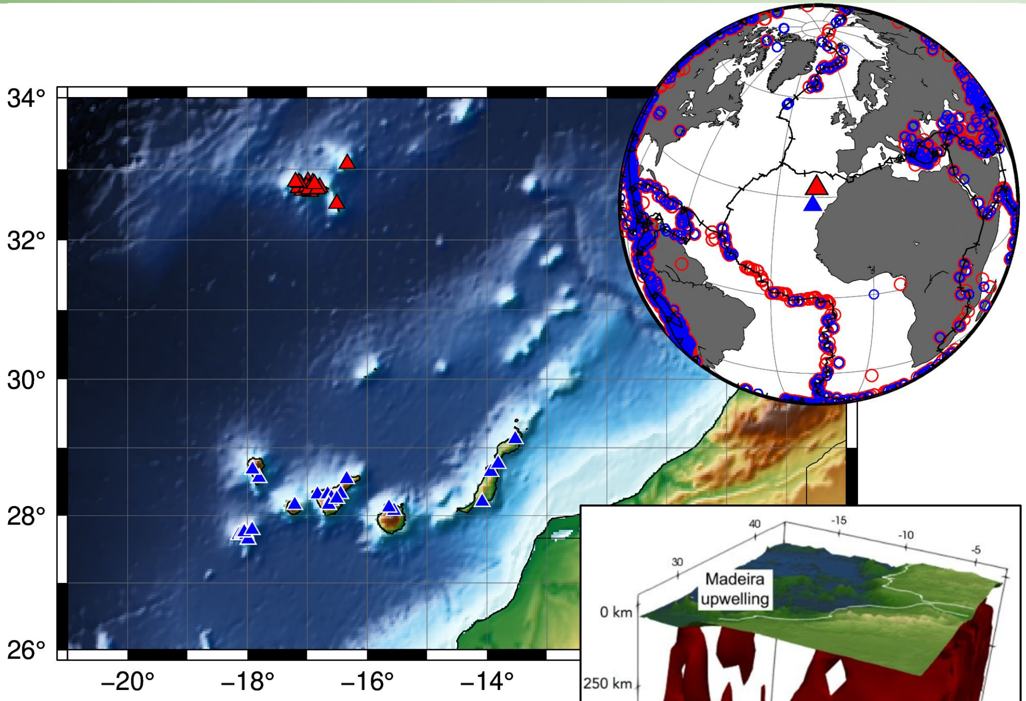
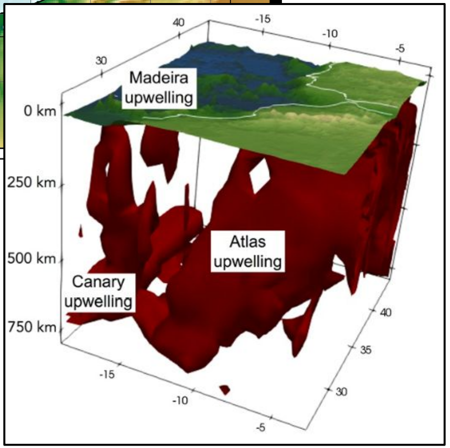
Introduction and Motivation



(Bonatto et al., in prep.)



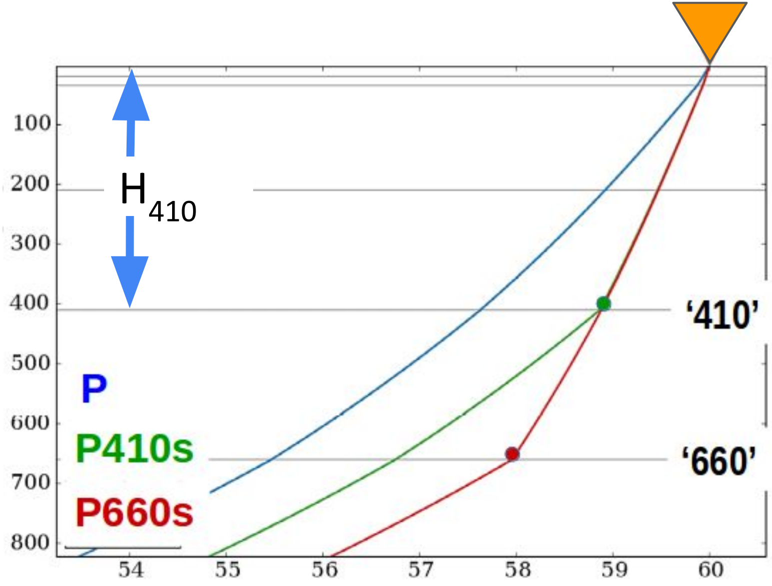
(Civiero et al., 2021)

- Canary and Madeira archipelagos:
  - Two hotspot systems in close proximity.
  - Shows similarities in various parameters (e.g., anisotropy).
  - Both fed by plume-like structures.
  - BUT: difference in connection of plume to Central-East Atlantic Anomaly (CEEA).
    - Canary Islands: still attached.
    - Madeira: detached → dying stage? (negative buoyancy surpasses positive → downward material flow → upwelling begins to vanish from bottom up [Davaille and Vatteville, 2005]).
- This study: investigate this question by observing upper mantle discontinuity structure with receiver functions.

Method: P-to-s conversions

Detection of P-to-s conversions at the base of the discontinuity in records of teleseismic earthquakes (Δ: 30° - 90°):

- High horizontal resolution (~ 100 km at 0.2 Hz).
- Suitable to study discontinuities beneath seismic stations.



Differential travel times between P and Pds provide a measure of the one-way S travel time between the surface and the discontinuity.

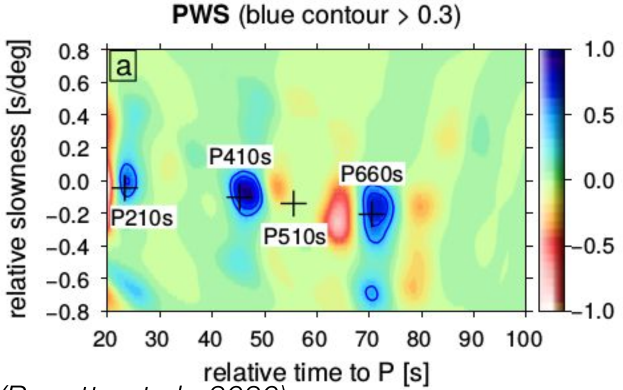
$\Delta t_S = t_{Pds} - t_P$ → depth

velocity model

Detection of seismic phases: in practice

Stacking of RFs with move-out corrections

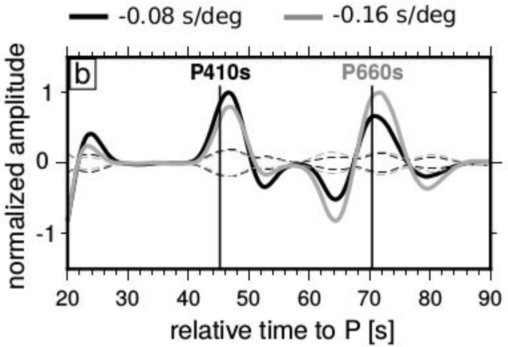
1. Stack RFs in *(Δt, Δs)* domain =>
signal identification and slowness estimation.



(Bonatto et al., 2020)

Δs_P410s = - 0.08 s/deg
Δs_P660s = - 0.16 s/deg

2. Stacking with correct slowness value =>
time and amplitude estimation



(Bonatto et al., 2020)

PWS with a bootstrap resampling
of 20 repetitions:
Estimate time and standard deviation for each maximum that satisfies the 95 % confidence criteria (amplitude < 2σ).

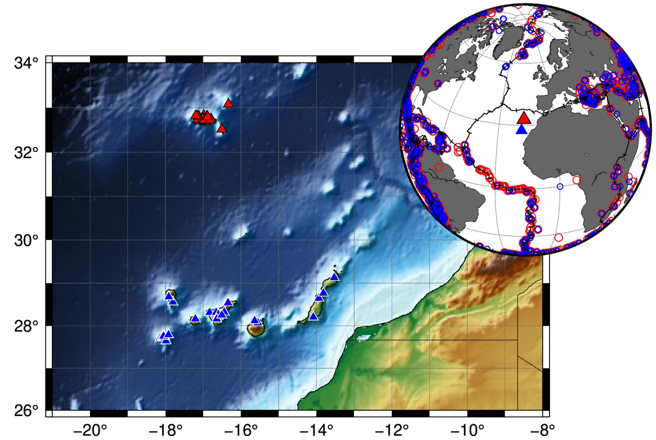
3. Conversion to depth

Δt P410s +/- σ
Δt P660s +/- σ

Ak135 + MITP08
(Li et al., 2008)

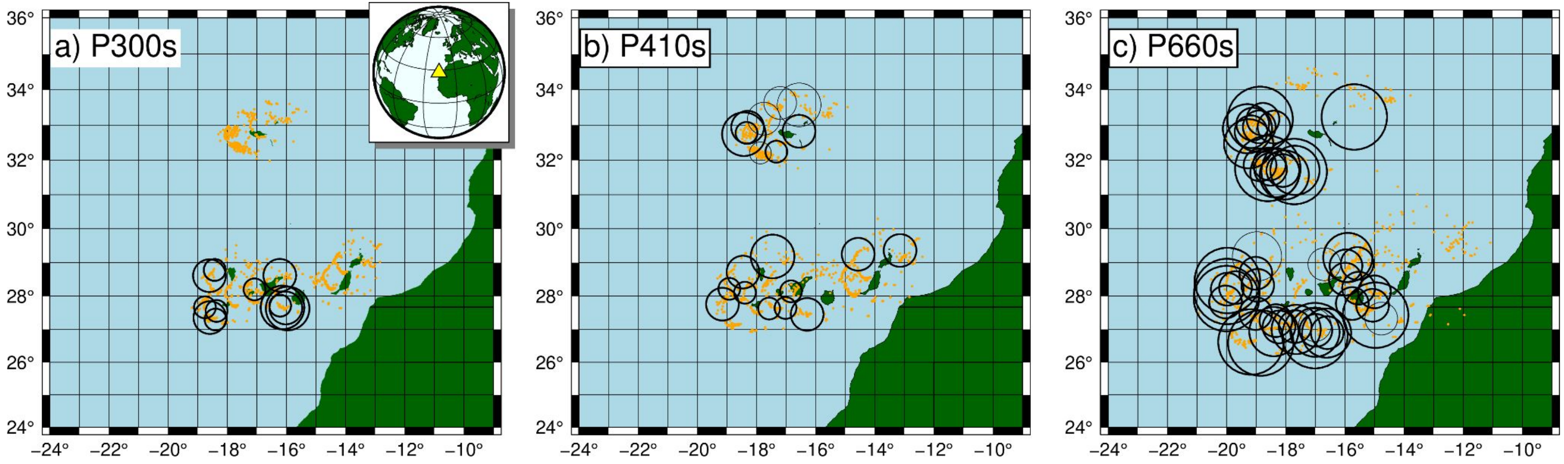
H 410 +/- σ
H 660 +/- σ

Data



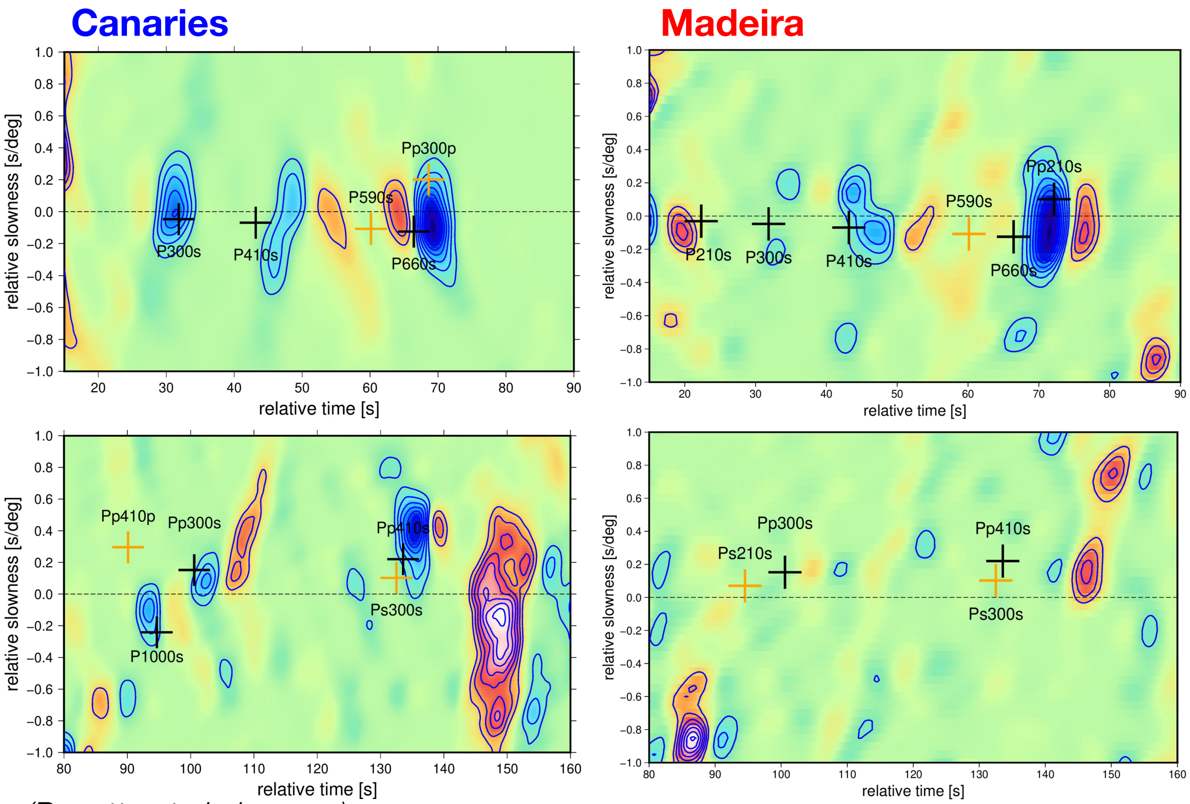
Archipelago	Canaries	Madeira
No. stations	23 permanent	16 temp. + 2 perm.
No. good events	1241	1268

Data providers: IPMA (ipma.pt), IGN (ign.es), DOCTAR(fdsn.org/networks/detail/Y7_2011), IRIS (iris.edu).



(Bonatto et al., in prep.)

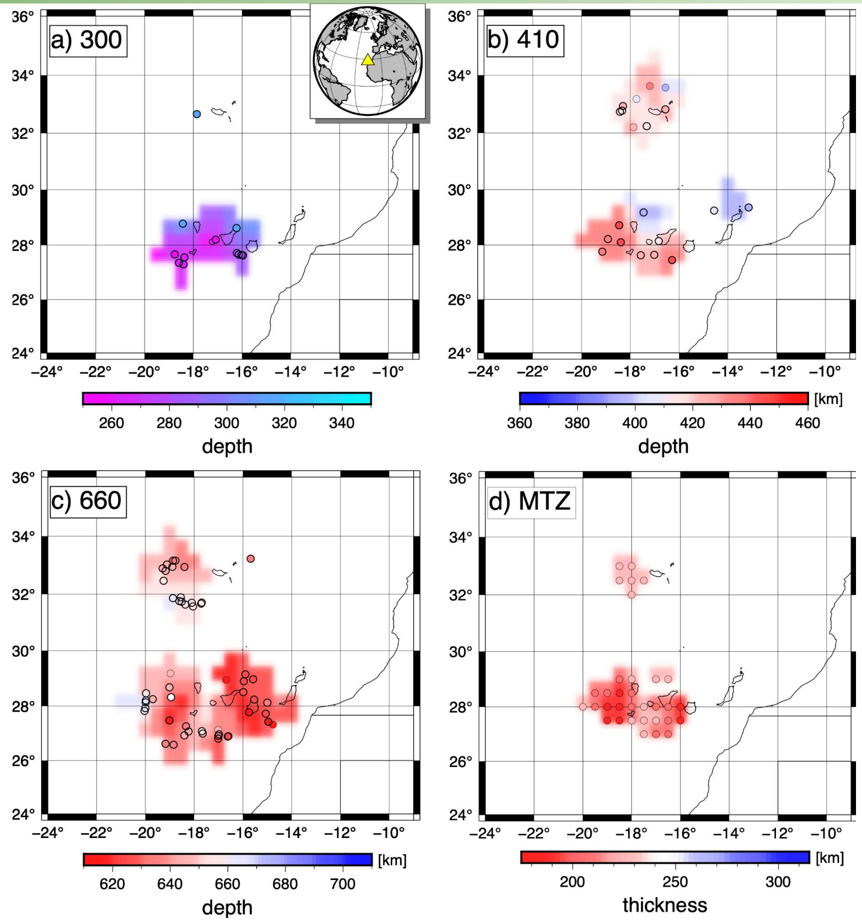
Results: global stacks



(Bonatto et al., in prep.)

- Similarities:
  - P410s strong with robust detection.
  - P660s strong with robust detection.
- Differences:
  - P300s (sometimes also: X-discontinuity) strong in Canaries but almost absent in Madeira.
    - Likely result from detached plume.
  - Pp410s multiple strong in Canaries but absent in Madeira.
    - Results not significant in that frequency band due to noisy data?
    - Strong topography and/or heterogeneity (multiples do not sample the same area)?

Results: topography of detected discontinuities

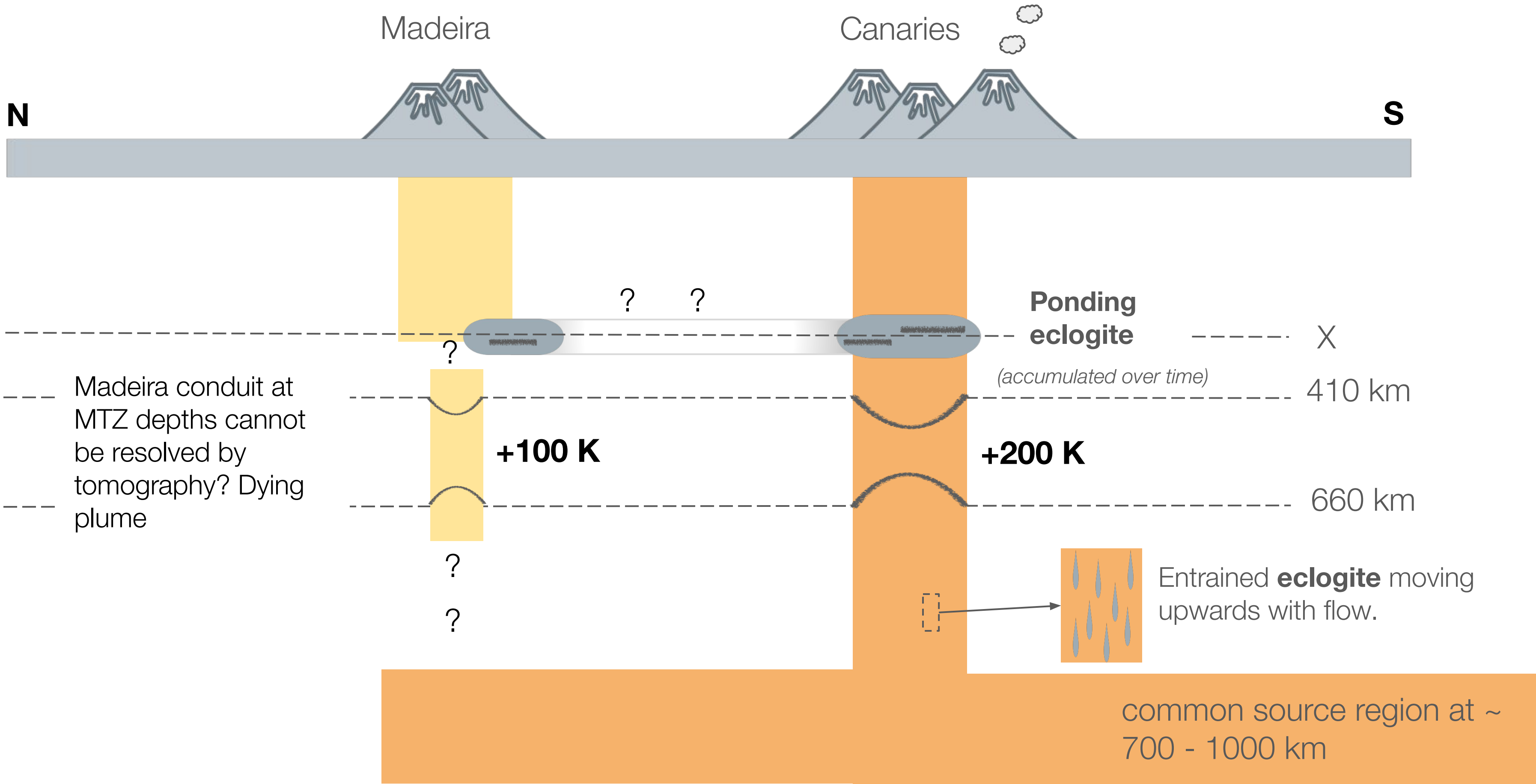


(Bonatto et al., in prep.)

- 300 much wider detectable in Canaries.
- 410 generally deeper than global average.
- 660 generally shallower than global average.
- Mantle transition zone (MTZ) in both archipelagos thinner than global average. → Hot MTZ.
- On average MTZ thinner in Canaries than Madeira (214±6 km, 232±4 km) → temperature anomalies: +200℃, +100℃.
- If 300 is due to coesite-stishovite phase transition:
  - Thermodynamic differences (temperature, flow rate, width) draw different amount of silica and/or let it pond differently around 300 km depth.

Similar origin of archipelagos likely but different state of connection to CEEA leads to difference in temperature and discontinuity structure.

Interpretation



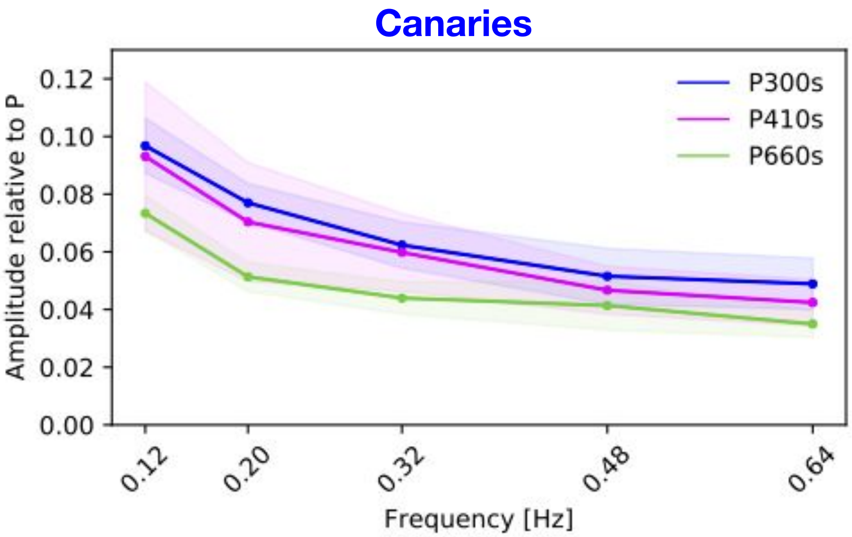
Summary

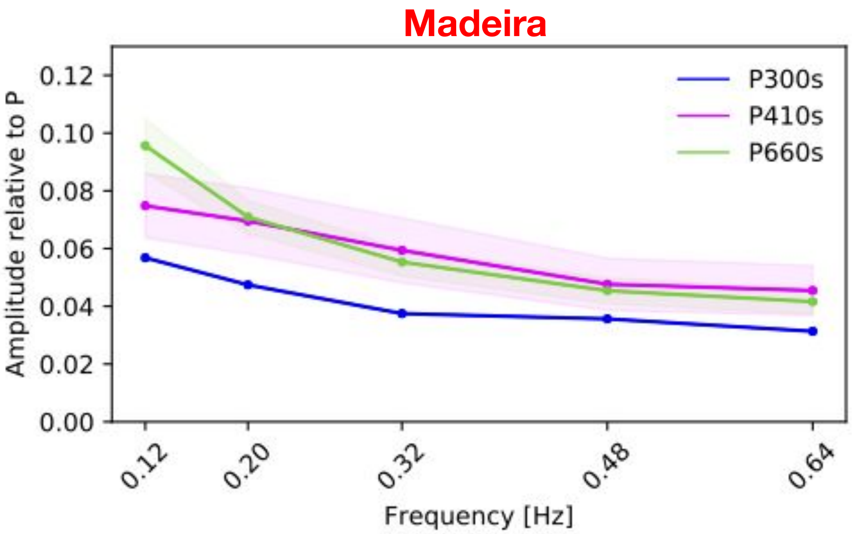
- P300s with robust detections beneath Canaries, almost completely absent beneath Madeira.
  → detached plume?
- P410s and P660s strong with robust detections beneath both archipelagos.
- 410 deeper than global average beneath both archipelagos.
- 660 shallower than global average beneath both archipelagos.
- Mantle transition zone (MTZ) in both archipelagos thinner than global average. → Hot MTZ.
- On average MTZ thinner in Canaries than Madeira → temperature anomalies: +200°C, +100°C.

- Presence of additional discontinuities (e.g., 300) indicates heterogeneity in the area (probably temperature and composition).
- For both archipelagos, observations support mantle plume source, rather than shallow melting anomaly.

→ Similar origin of archipelagos likely but different state of connection to CEEA leads to difference in temperature and discontinuity structure.

Financiado pela Fundação para a Ciência e a Tecnologia, I.P./MCTES através de fundos nacionais (PIDDAC)" – UIDB/50019/2020





Basalt proportion [%]	Ratio of transmission coefficient ($P'S'_{300}$ / $P'S'_{410}$) for 70 deg
20	0.1
40	0.2
60	0.6
80	1.8

Observed amplitude relation at 0.2 Hz

	A_{P300s}/A_{P410s}
Madeira	0.7
Canaries	1.1

MTZ thickness comparison between different studies

Reference	Canaries	Madeira	Method	Link to article
Lawrence & Shearer (2006)	237-241 km	237-241 km	P receiver functions	https://doi.org/10.1029/2005JB003973
Li et al. (2003)	228 km		P receiver functions	https://doi.org/10.1016/S0031-9201(03)00021-9
Martinez-Arevalo et al. (2013)	236-250 km		P receiver functions	https://doi.org/10.1016/j.tecto.2013.08.021
Bonatto et al (in prep.)	214 +/- 6 km	232 +/- 4 km	P receiver functions	