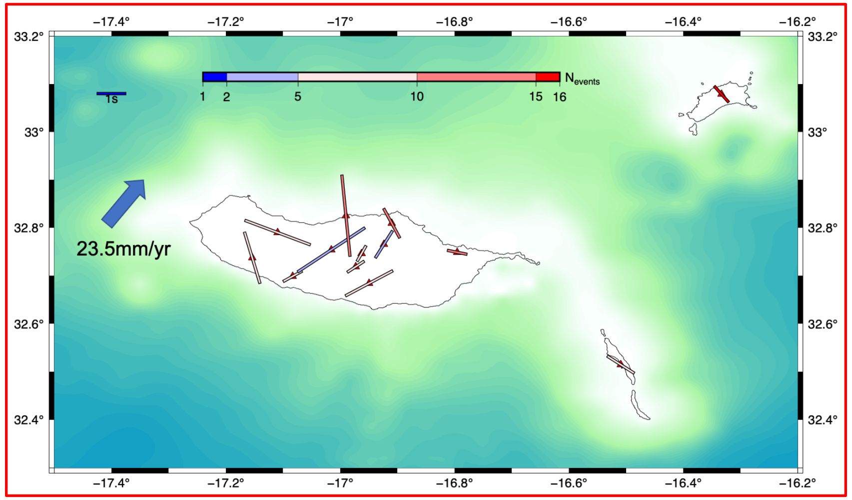
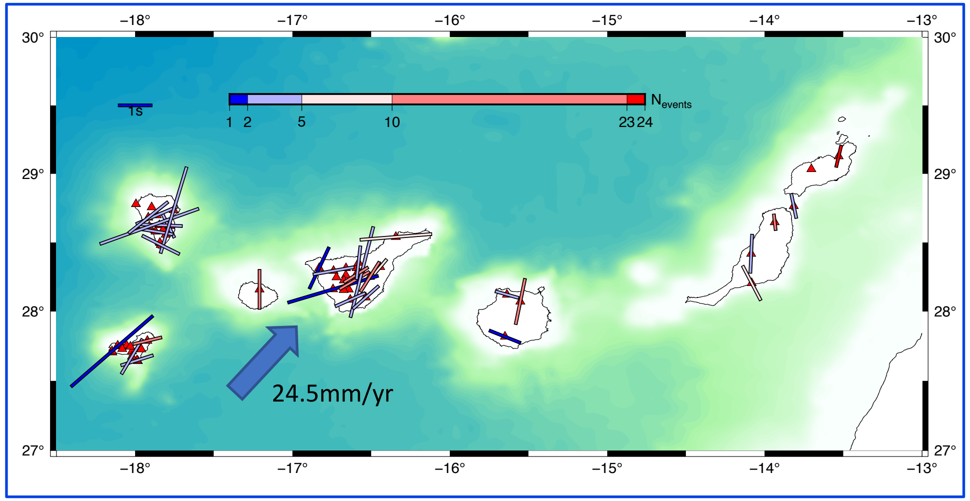
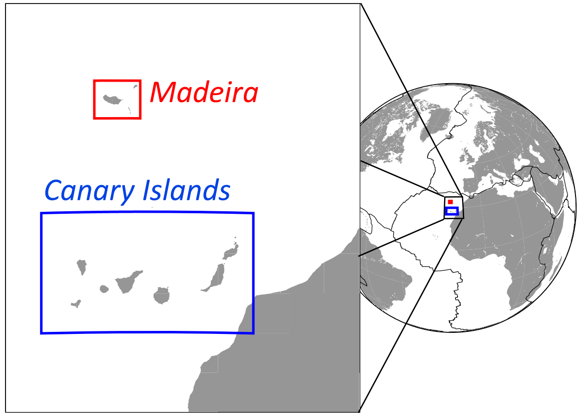
D1503 | EGU2020-9340

Investigating Seismic Anisotropy of the Madeira and Canaries Hotspots Using Teleseismic and Local Shear-Wave Splitting with the SIGHT project.

David Schlaphorst (dschlaphorst@fc.ul.pt)[1], Graça Silveira[1,2], João Mata[1]







Please be aware, that this is the non-interactive version of this presentation that I had to create due to problems on Linux machines. An interactive version exists as an older version that you can still access ("Presentation Version 6").

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Outline of presentation

Motivation
Why do we care?

Method
How do we do it?

Results
What do we observe?

Conclusions
What does it all mean?

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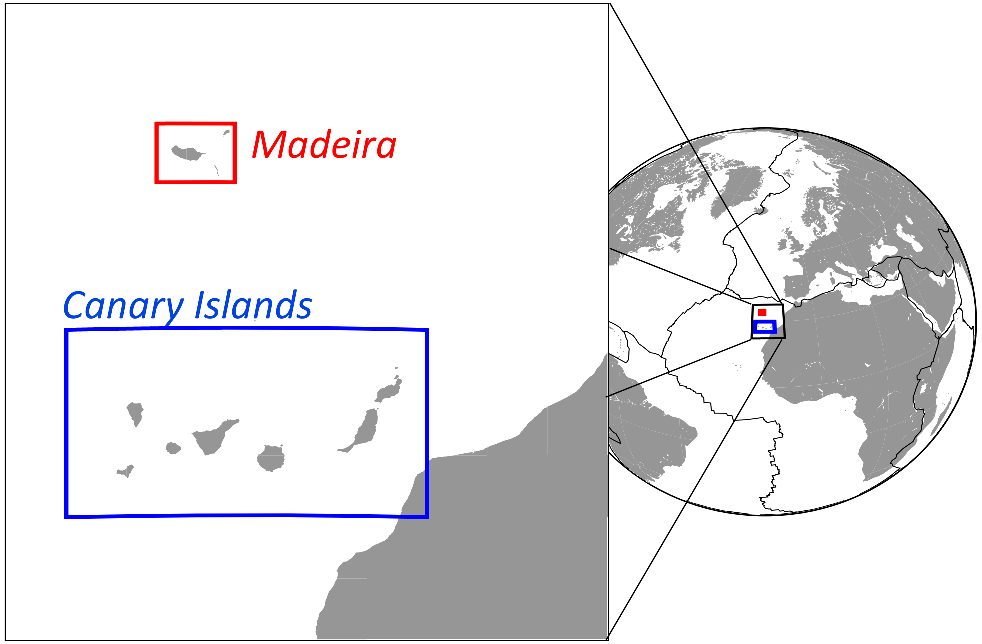
Who am I?



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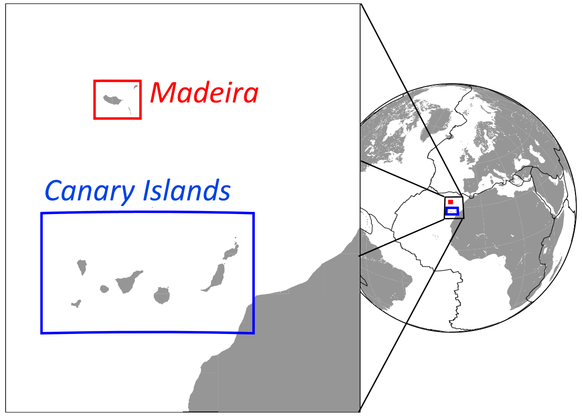
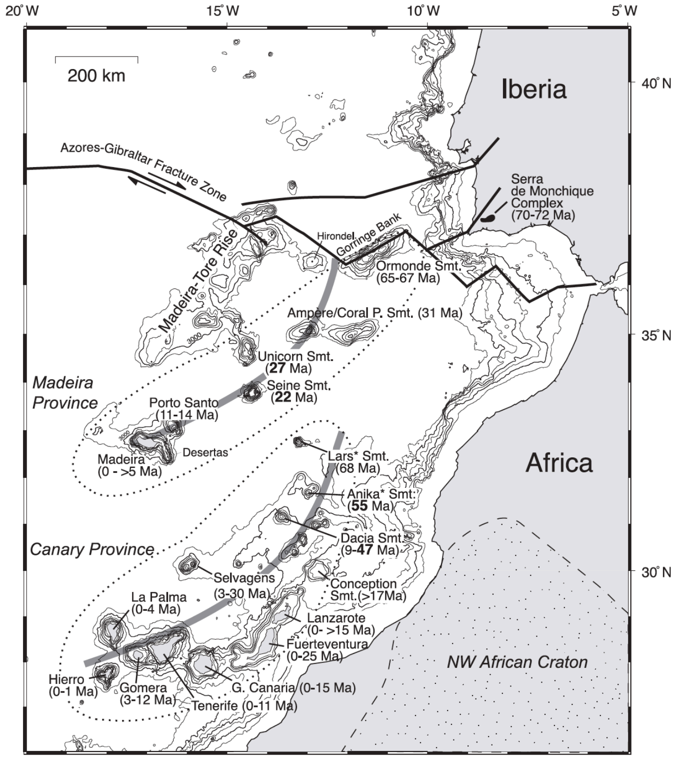
Motivation

Why do we care?

- Islands of Madeira and Canaries: two examples of hotspot surface expressions.
- Hotspot tracks have been reconstructed to past locations close to south-western part of Iberian Peninsula and north-western Africa.
- Due to their proximity, interconnected origin of these two hotspots has been proposed but details remain unclear.
- Better understanding of the crust and upper mantle structure beneath these islands is needed to investigate this potential connection.





Geldmacher et al. (2005)

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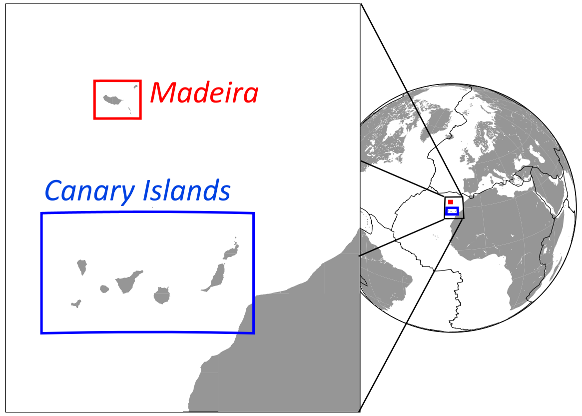
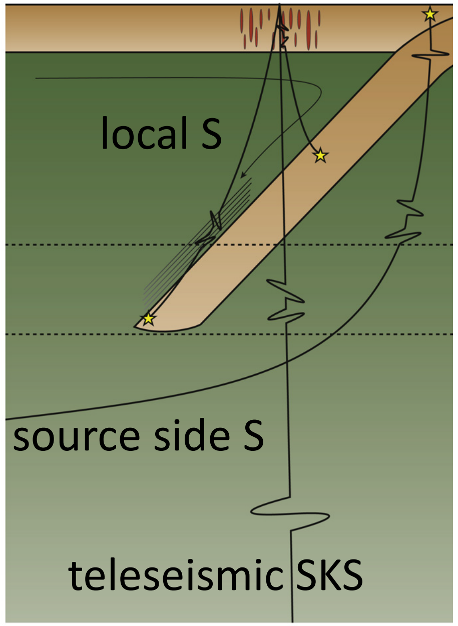
Motivation

Why do we care?

- Subsurface structure has influence on stress field.
    - Can be investigated studying seismic anisotropy patterns of the region.
    - In crust: orientation in the direction of maximum stress is observed → parallel to alignment of fractures or cracks.
    - Upper mantle: orientation influenced by mantle flow and general plate motion.
- Common method: shear-wave splitting observations of data from teleseismic events.
- Multiple anisotropic layers possible.
- Include local events to distinguish crustal from upper mantle influences.





di Leo et al. (2012)
(Example of multiple anisotropic regions at a subduction zone.)

Method

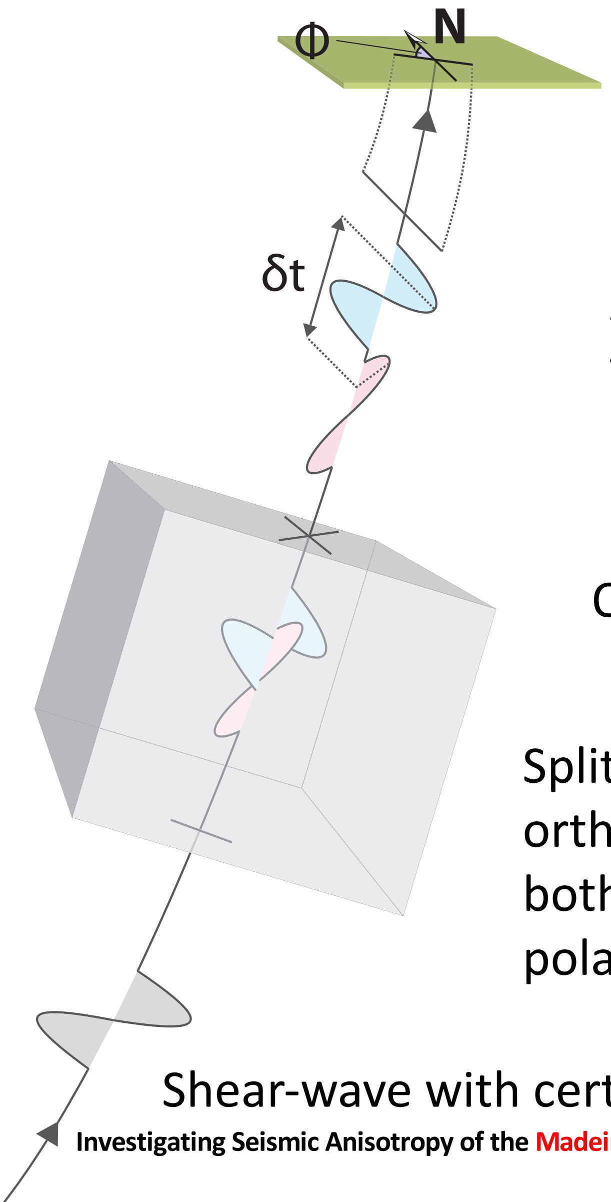
How do we do it?

What does this mean and how do we measure it? See next slide.

- Anisotropic layers cause seismic waves speed variations with different wave propagation direction.
- Stress patterns influence seismic anisotropy.
- Mantle flow can be constrained by investigating the structure of anisotropic layers.

Method

How do we do it?



At the surface, using a broadband 3-component seismic station, we can measure the orientation (φ) and time delay (δt).

What does such a measurement look like?
See next slide.

After leaving the anisotropic region, the waves retain their polarisation and time difference.

One wave travels faster than the other.

Splits in two shear-waves with orthogonal polarisation (that may both be different to the initial polarisation) in anisotropic medium.

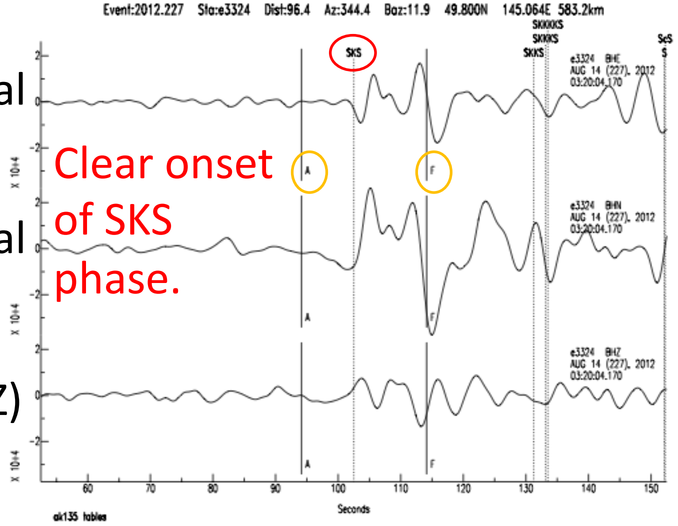
Shear-wave with certain polarisation.

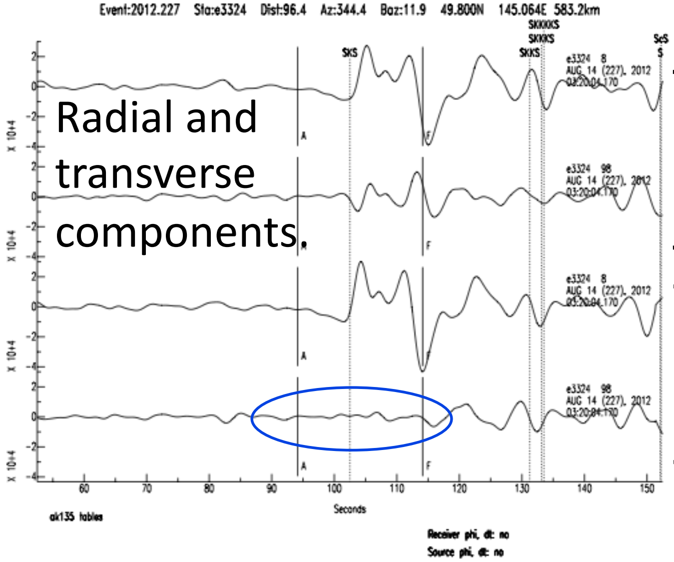
Method

How do we do it?

We use the SHEBA code, based on Teanby et al. (2004).

3 components: horizontal (E–W), horizontal (N–S), vertical (Z)

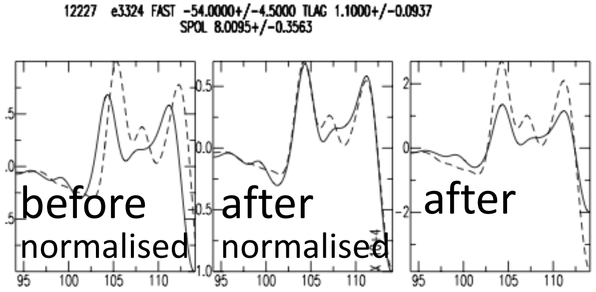




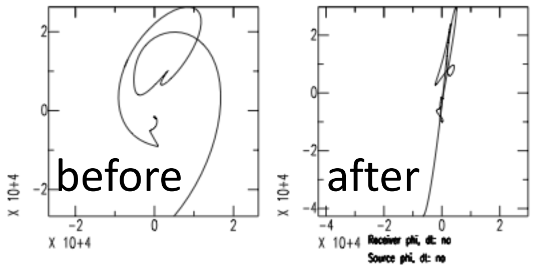
Before correction.

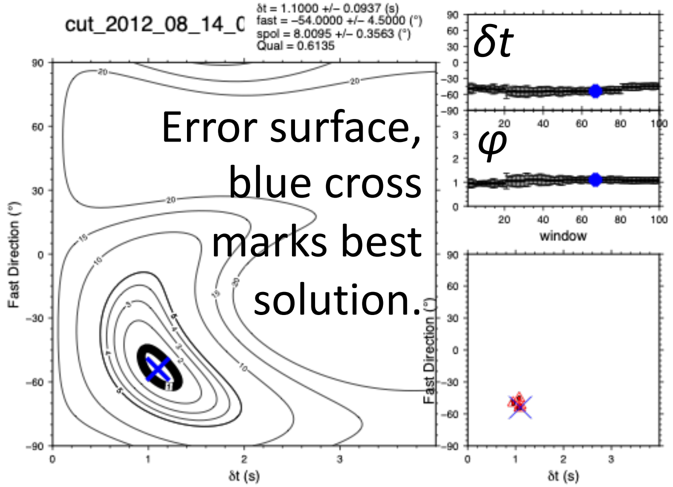
After correction.
(Notice how energy is ***almost absent*** *from second component.)*

Fast (solid) and slow (hashed) shear wave before and after correction.
(Notice how they almost lie completely on top of each other.)



Particle motion before and after correction.
(Notice how the circular motion becomes almost completely straight.)





Cluster analysis.
(Notice how both δt and φ are stable over different start (A) and end (F) times of the observation window. Also, the error surface shows one clear result.)

Method

How do we do it?

SKS event search criteria:

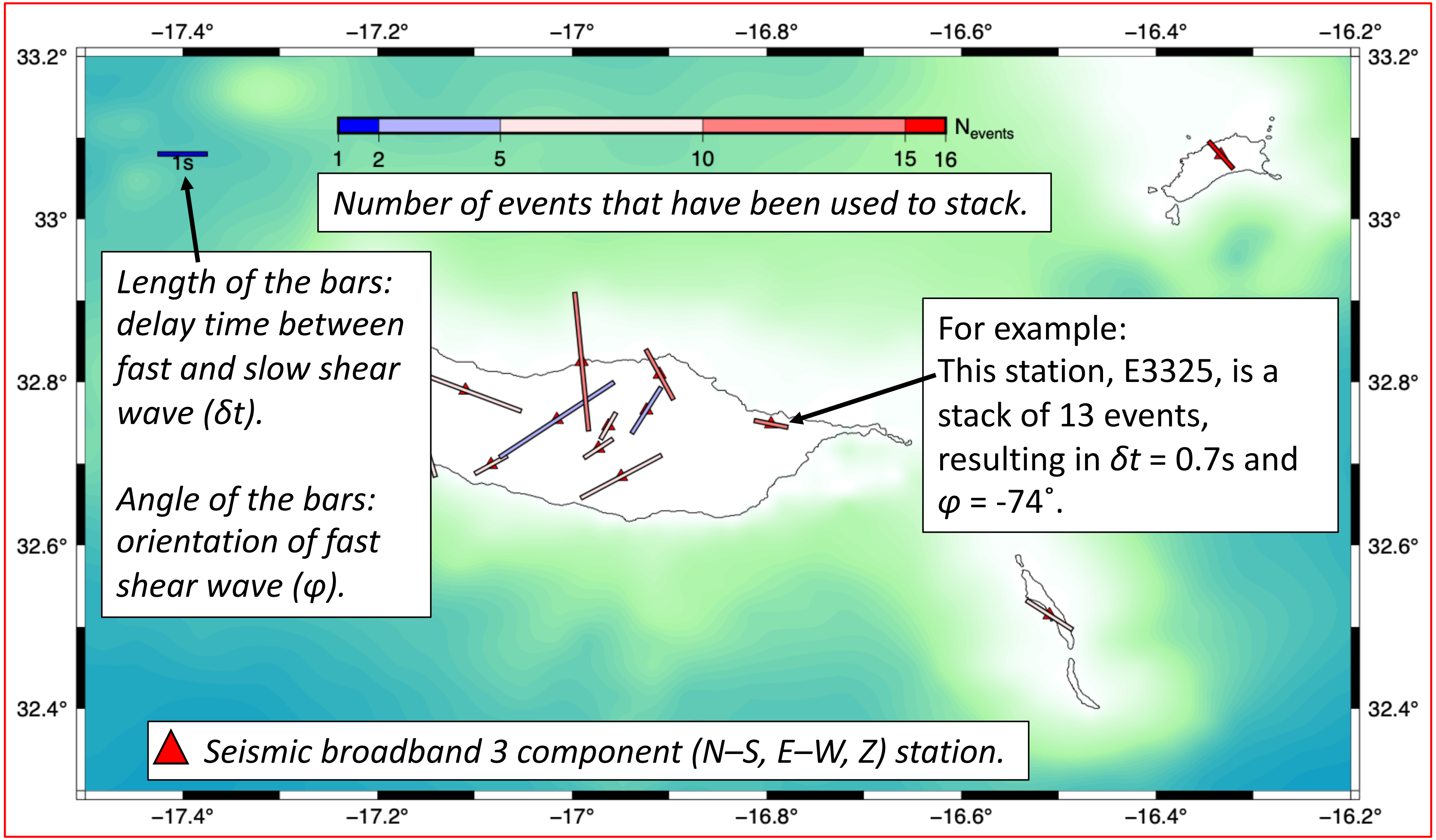
- Minimum Magnitude: 5.5
- Distance: 85˚ – 135˚
- Date search interval:
  - 15/04/2011 – 22/09/2012 (Madeira)
  - 21/07/2010 – 16/10/2019 (station PMPST on Porto Santo, island NE of Madeira)
  - 21/07/2010 – 16/10/2019 (Canaries)

- No. good+fair results/no. total results (no. eq):
  - 221 / 4344 (276) $_{\text{Madeira}}$ + 1442 (1442) $_{\text{PMPST}}$
  - 393 / 20074(1930)

Results

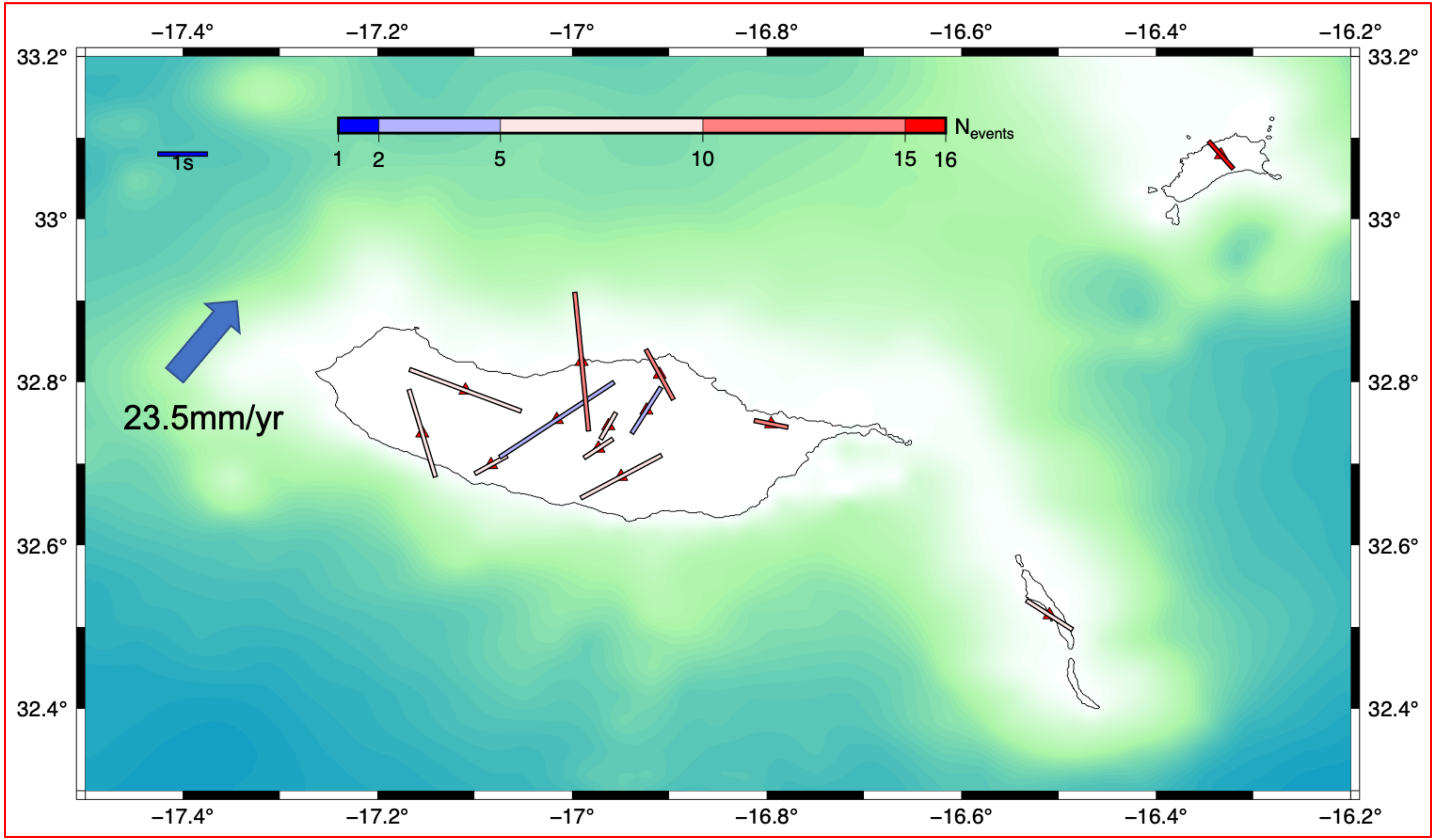
What do we observe?

First, a short explanation what this image shows?



Results Madeira

What do we observe?



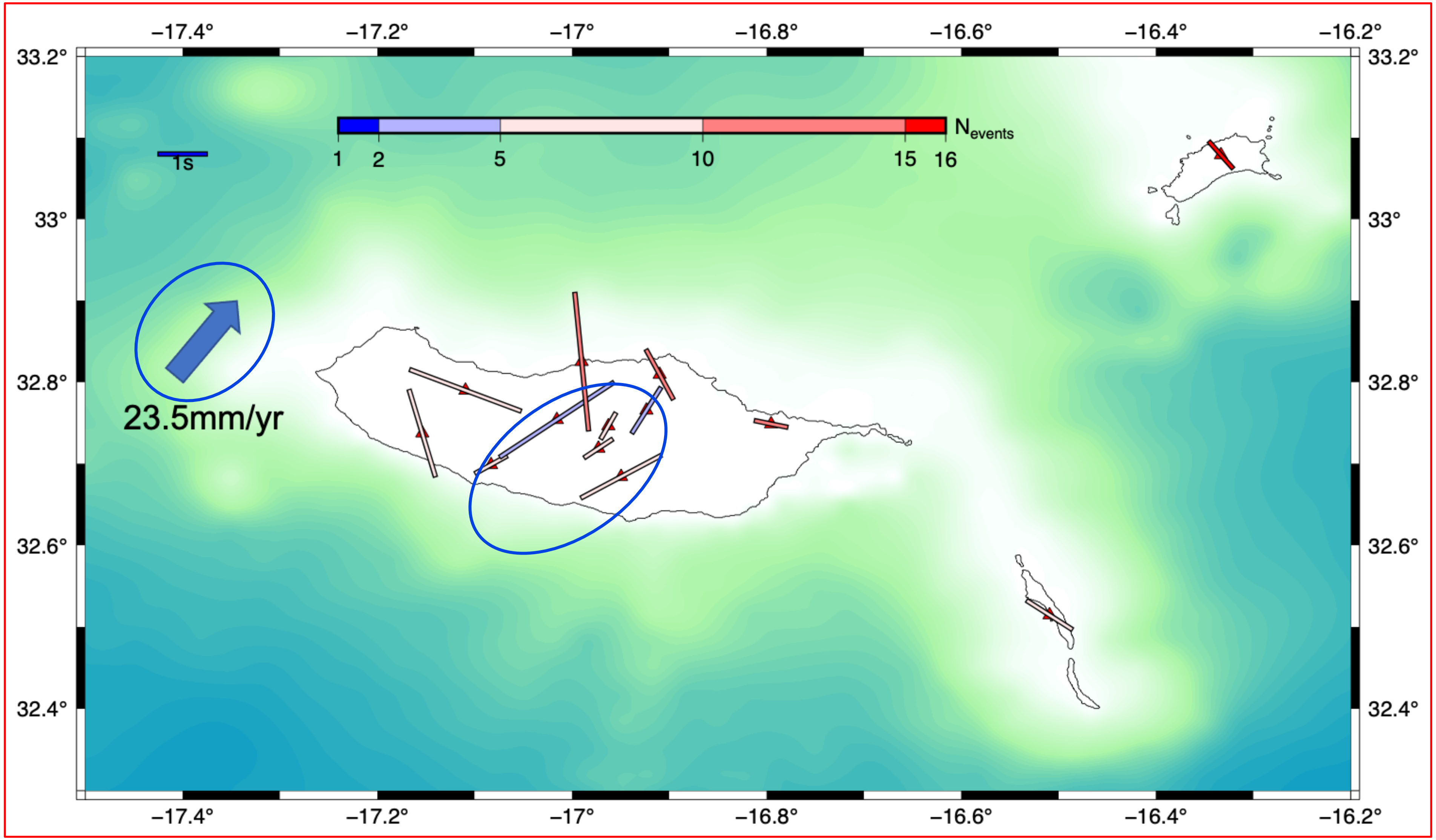
Two predominant orientations can be observed.

1) Close to general plate motion.
2) Close to major fault zone orientation.

Stacked results have small uncertainties in δt and φ, but unfortunately only small backazimuthal coverage.

Results Madeira

What do we observe?



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Results Madeira

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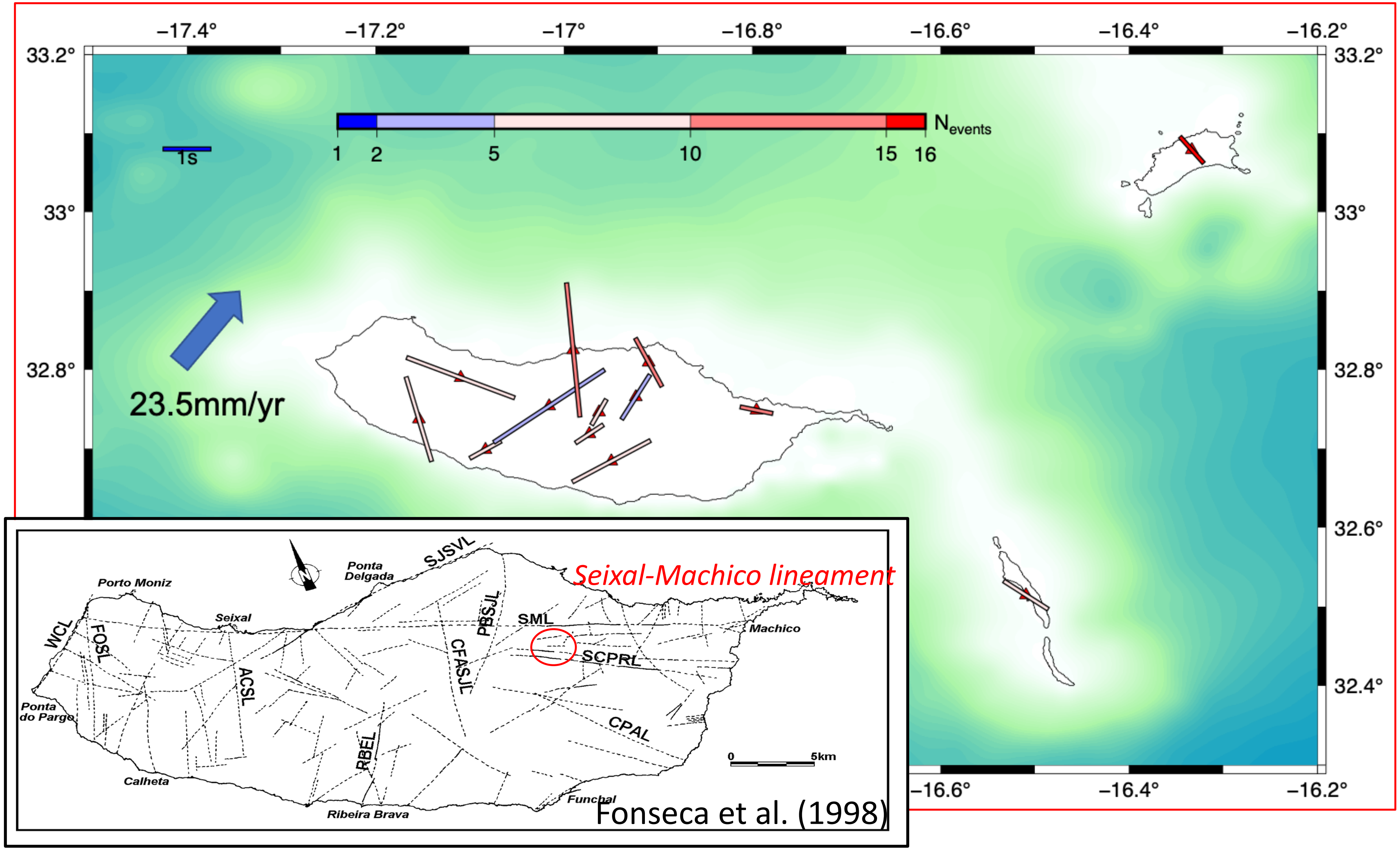

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Results Madeira

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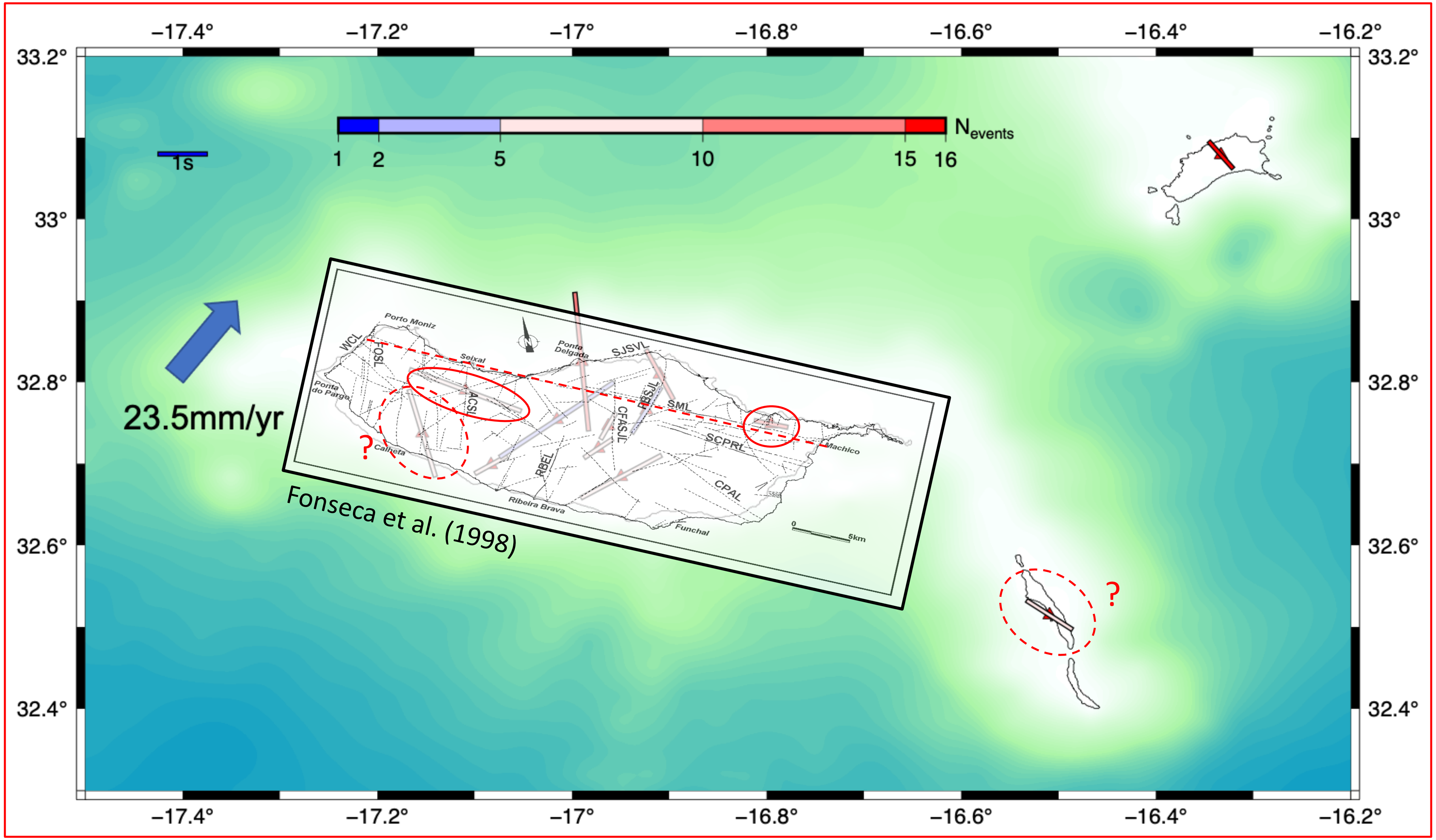

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1) Close to general plate motion.
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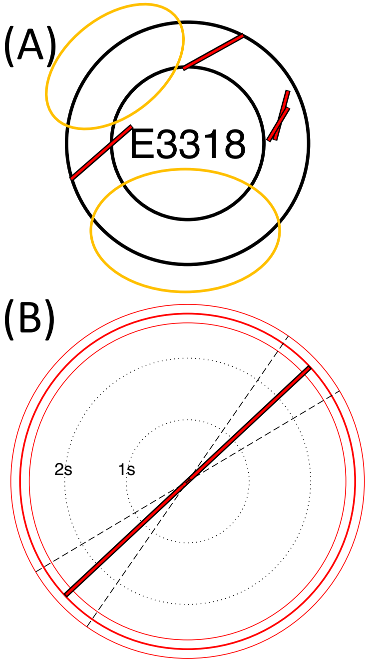
Stacked results have small uncertainties in δt and φ, but unfortunately only small backazimuthal coverage.

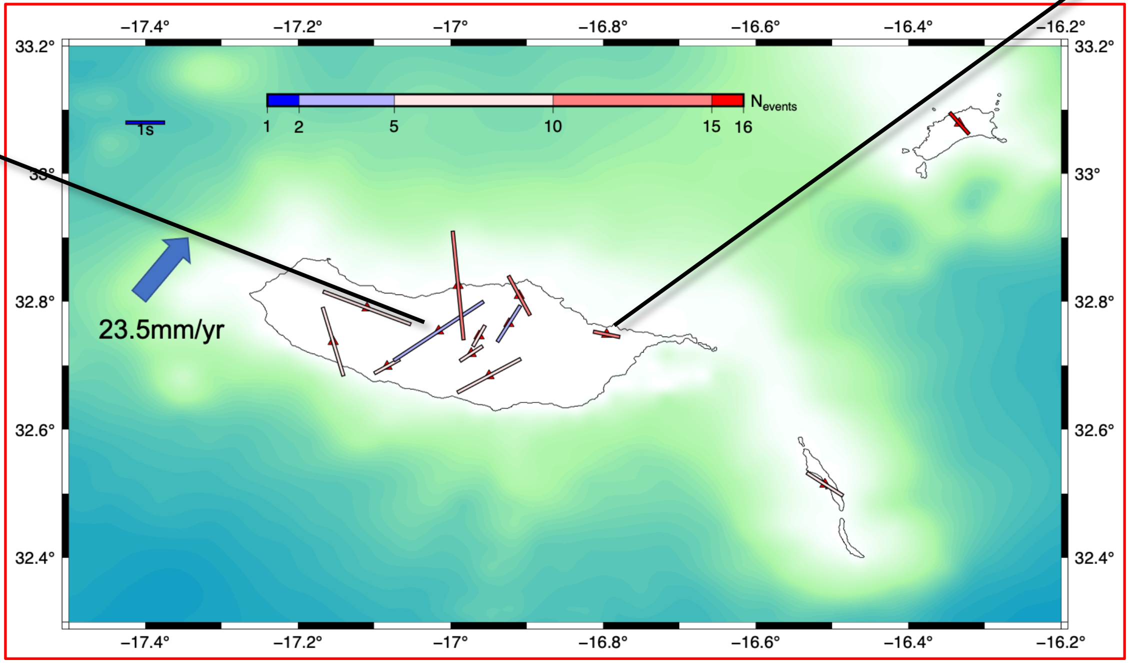
Results Madeira

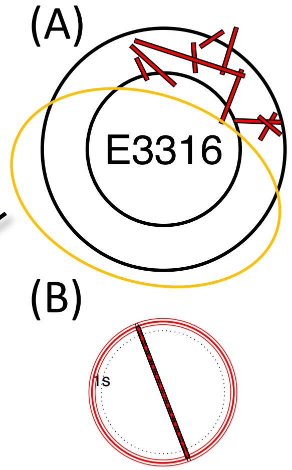
What do we observe?

A) Individual results, placed by backazimuth and distance (inner circle: 85˚, outer circle: 135˚).
B) Uncertainty in δt (thin red circles) and φ (black hashed lines).



Station with biggest uncertainty in φ.





Station with smallest uncertainty in φ.

Stacked results have small uncertainties in δt and φ, but unfortunately only small backazimuthal coverage.

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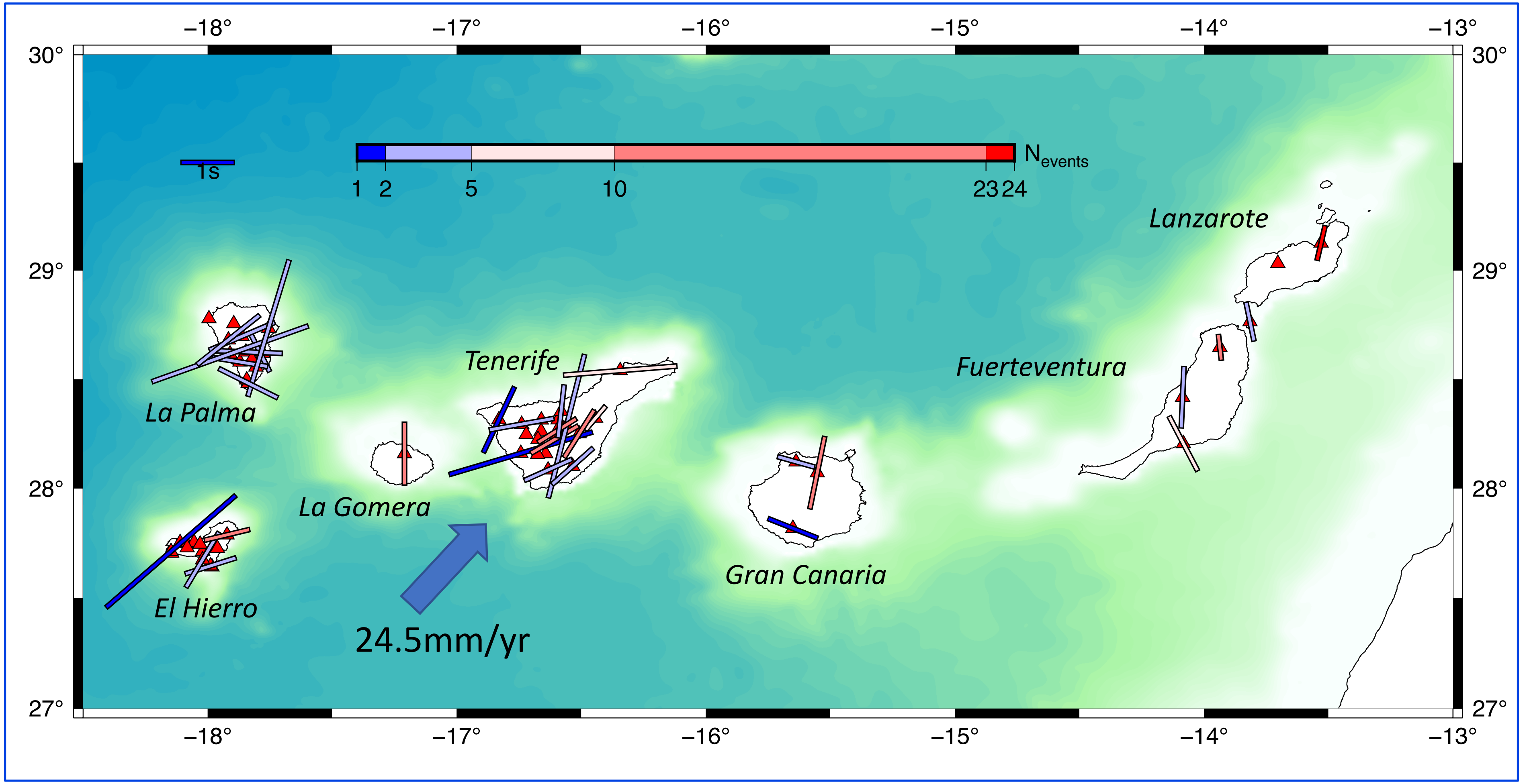
Results Canary Islands

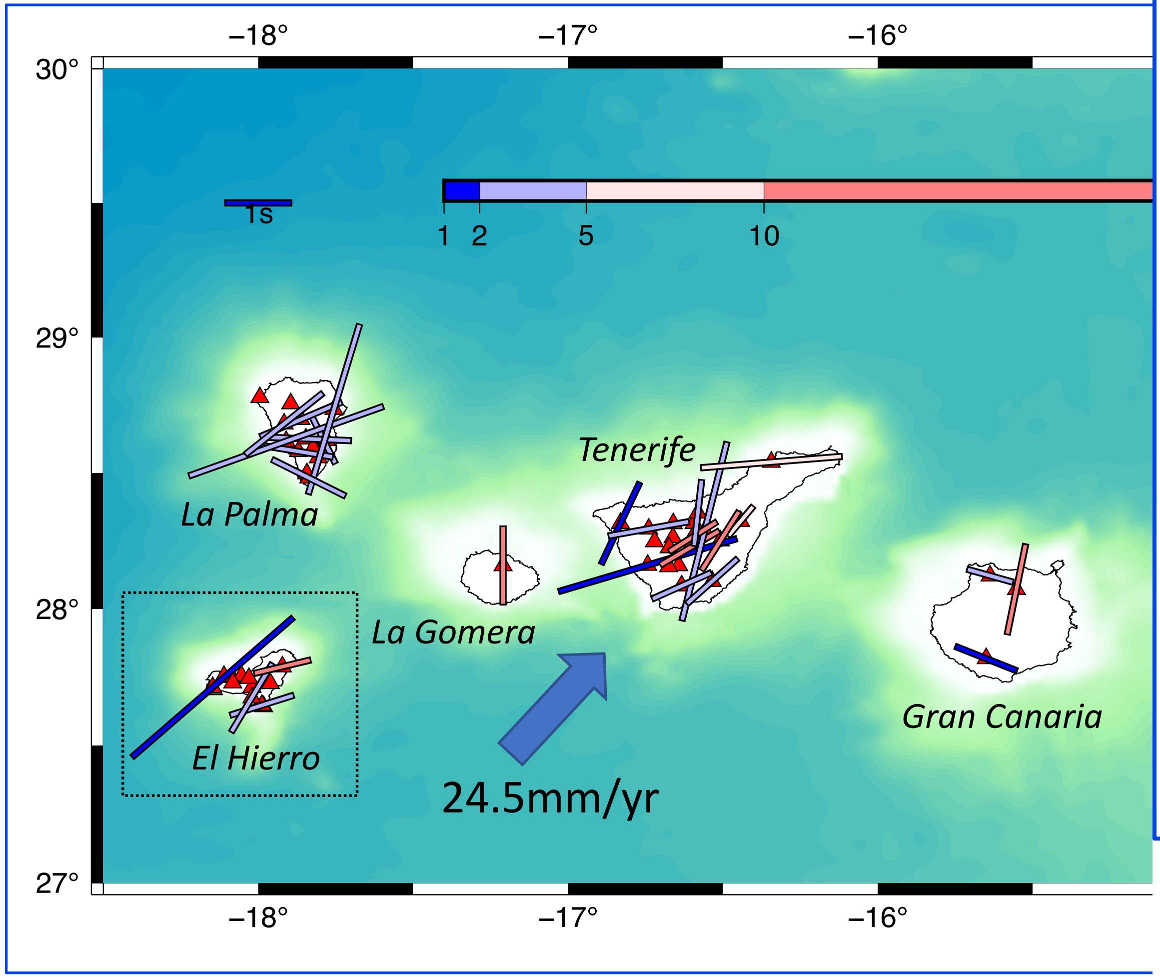
What do we observe?

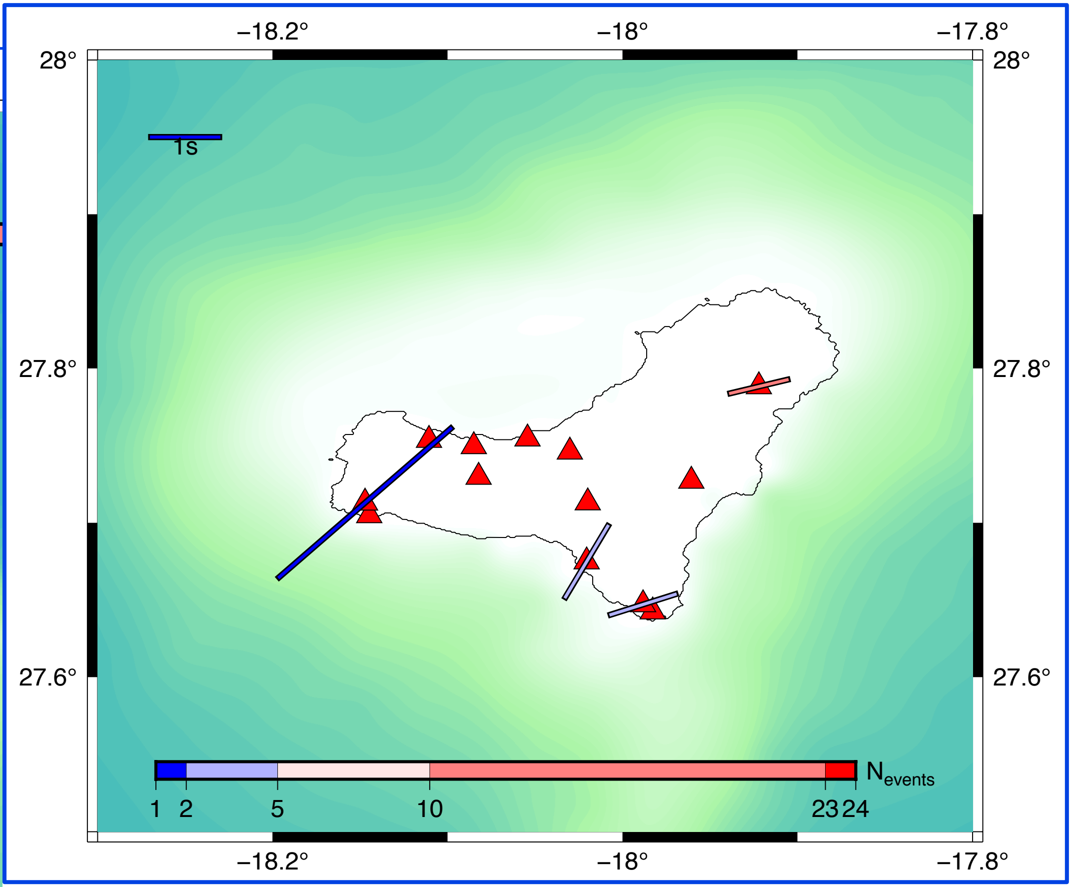


Similar delay times (generally slightly above 1s) and orientations (close to 0˚, different to general plate motion) on Fuerteventura and Lanzarote (also matched by station on La Gomera).

Results Canary Islands (El Hierro)

What do we observe?

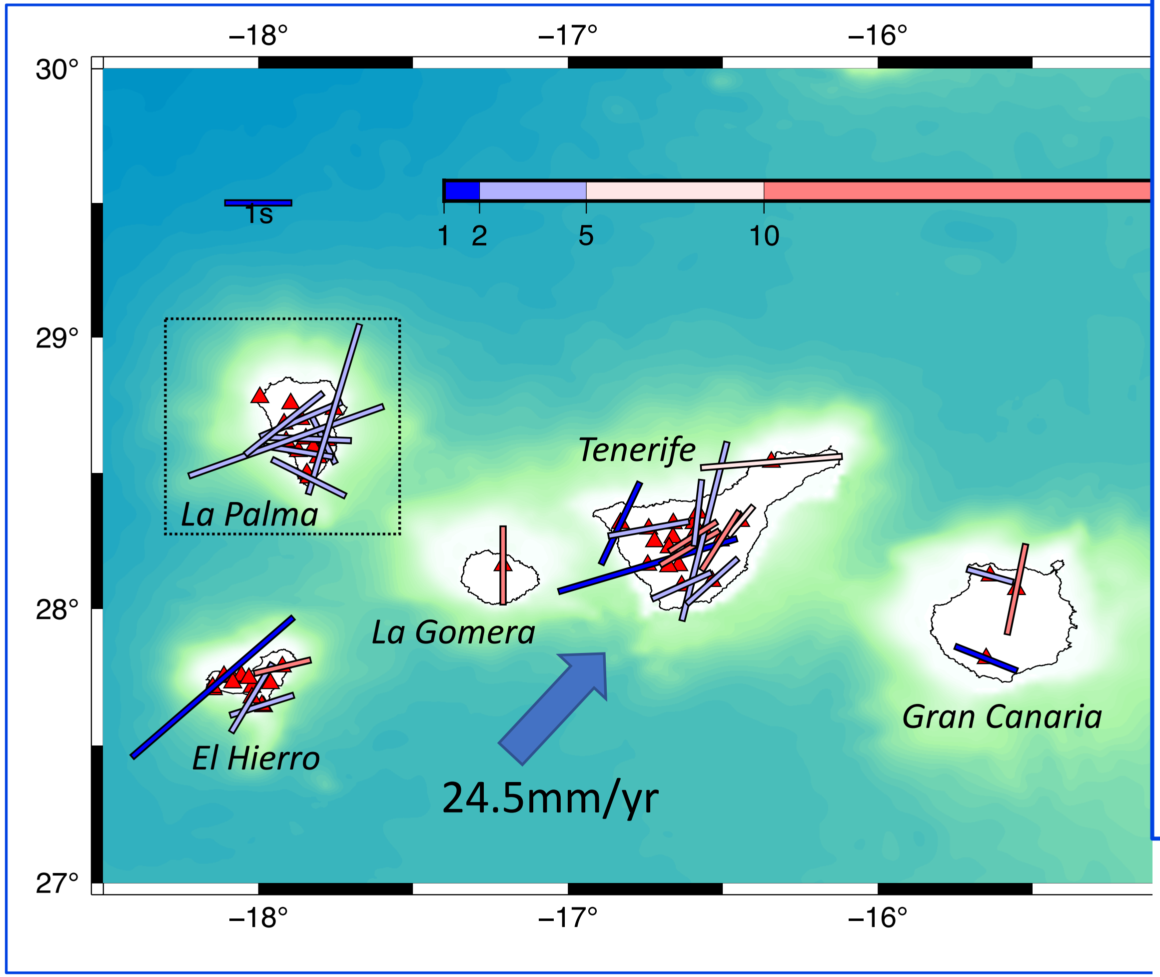


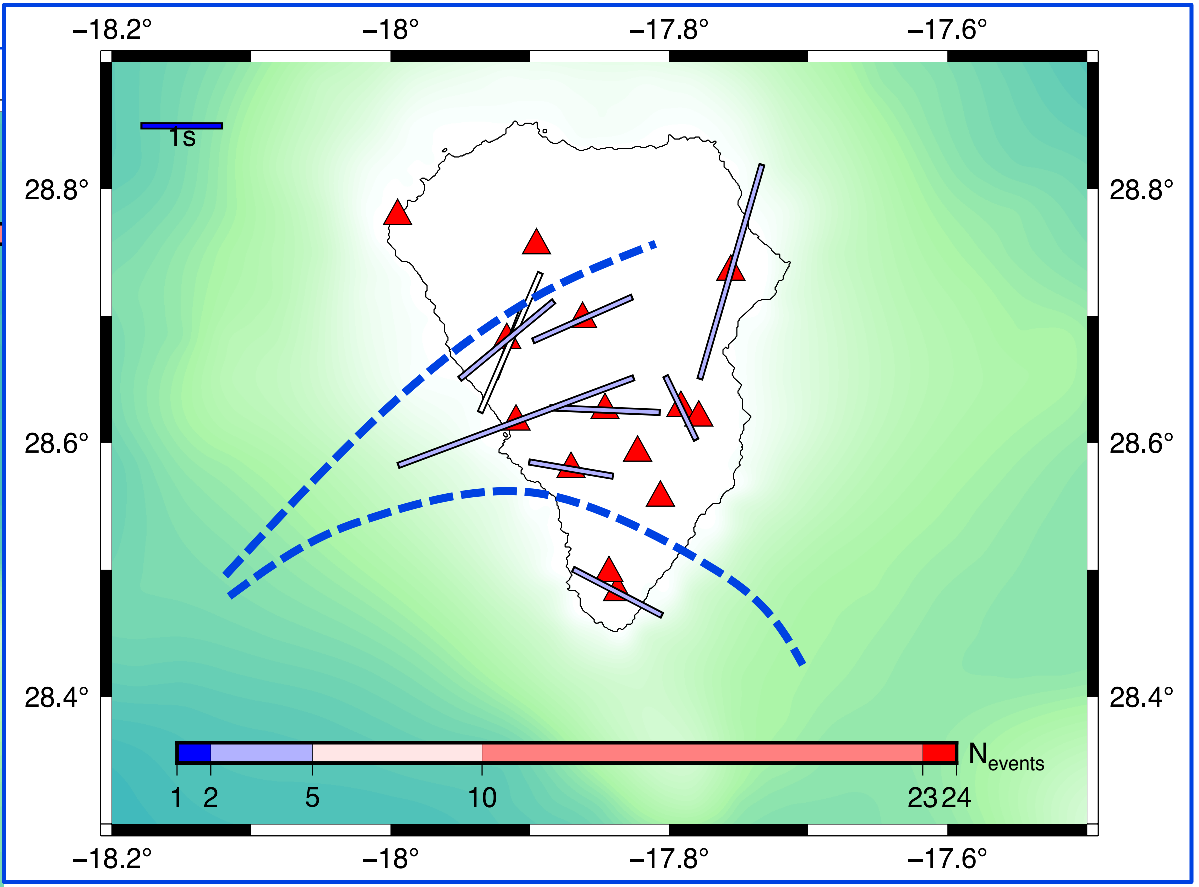


- Station orientation close to general plate motion, slightly rotated clockwise to the east.
- Generally, delay time at slightly above 1s.

Results Canary Islands (La Palma)

What do we observe?

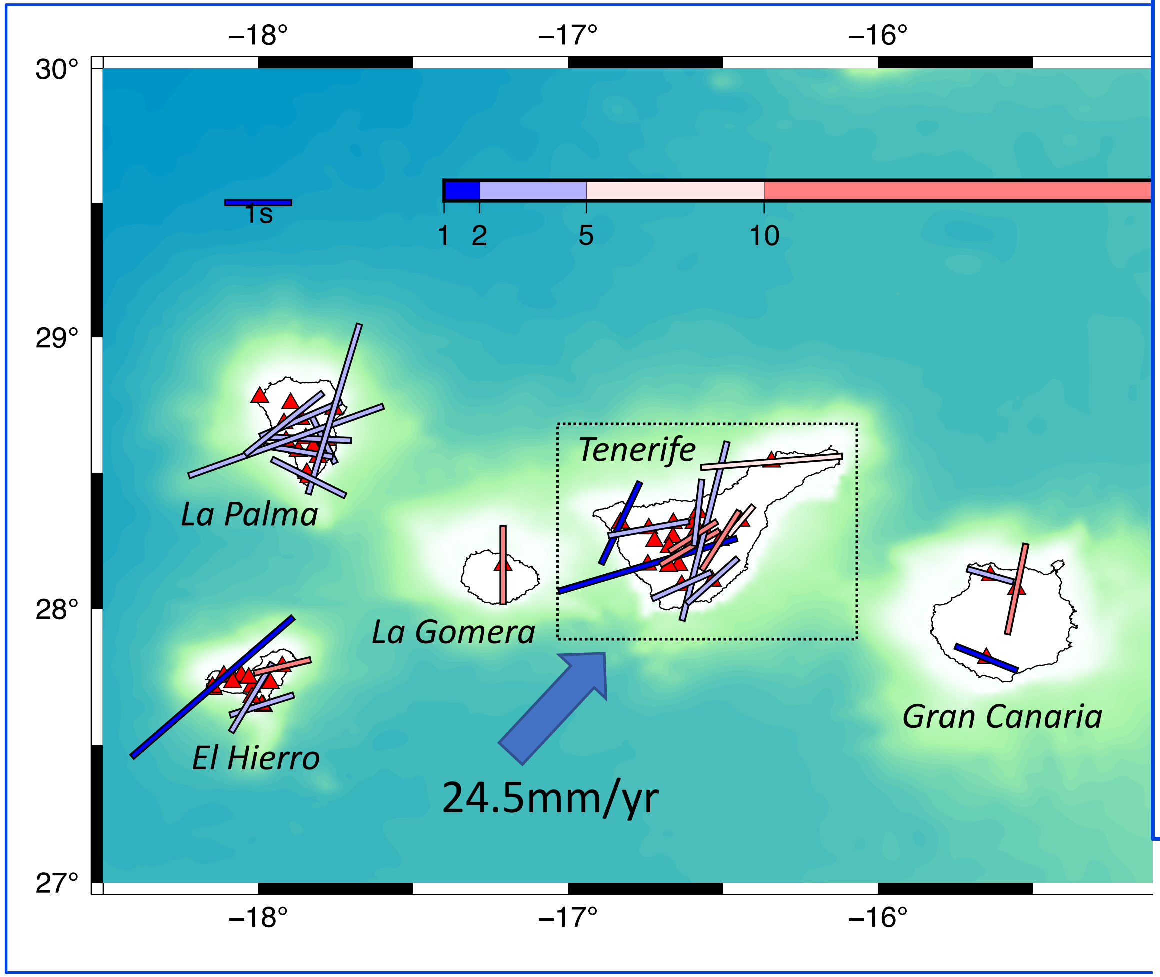


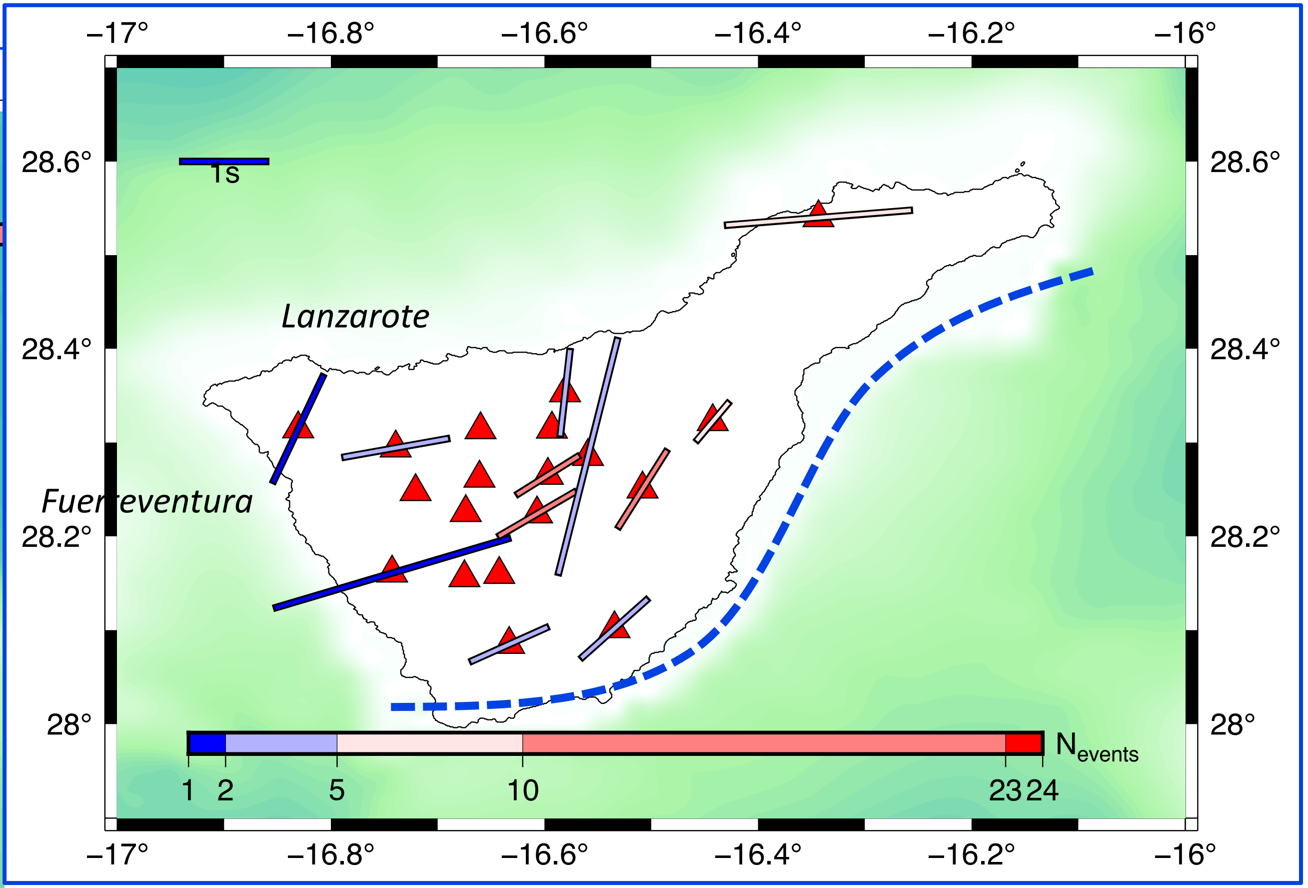


- Station orientation maybe following two general patterns, in the north being close to general plate motion.
- Generally, delay time at about 1s.
- Unofortunately, not many stacked events for any station.

Results Canary Islands (Tenerife)

What do we observe?





- Station orientation following a general pattern, in the centre being close to general plate motion.
- Generally, delay time at about 1s.

Conclusions

What does it all mean?

- Some areas show uniform splitting parameters (e.g., Fuerteventura, Lanzarote).
  - Orientation sometimes close to general plate motion (e.g., parts of Tenerife & Madeira).
  - In other cases matching major geological features (e.g., major rift zone on Madeira).
- In some areas, significant changes in orientation and delay time on short length-scales on the order of tens of kilometres (e.g., central Madeira, Gran Canaria).
- So, in short: “what does it all mean” – we are on that task.
- There is future work we would like to include to refine the conclusions.

What future work?
See next slide.

Conclusions

What does it all mean?

Future work we would like to include:

- Include splitting results from local shear waves.
- Compute apparent splitting parameters due to a combination of two anisotropic layers as a function of backazimuth.
- Combine with previous studies on anisotropy in Iberia and Morocco.

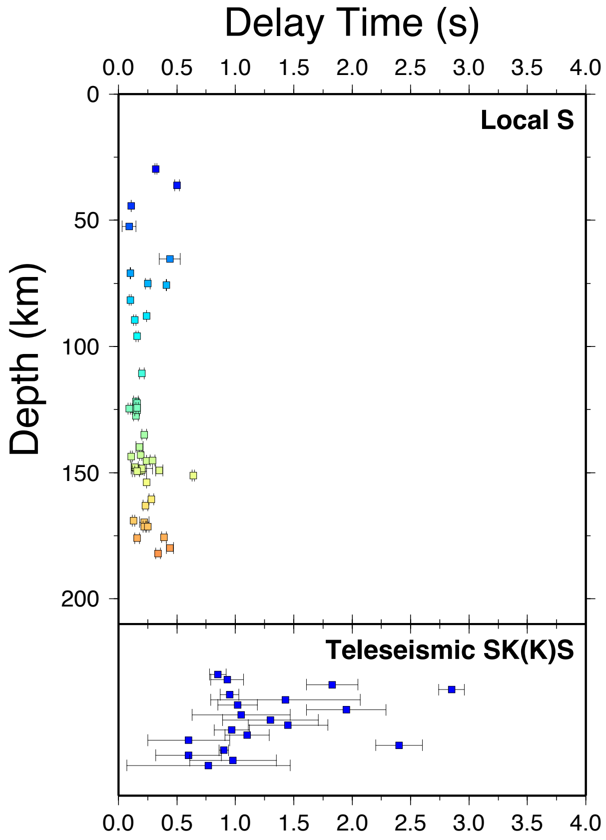
Why would we want to do that and why is it complicated here?
See next slide.

Conclusions

What does it all mean?

Include splitting results from local shear waves.

- Additional results from local events can help distinguish between multiple anisotropic layers (crust, upper mantle).
- BUT: no local events in global seismicity catalogue that are deep enough and close to stations to have steep enough incidence angles.
- NEXT STEP: search local seismicity catalogue.



Schlaphorst et al. (2017)

(Example of differences between local S and teleseismic SKS results: almost no crustal anisotropy and significantly larger delay times hint towards major anisotropic layer in upper mantle, deeper than 200km.)

Conclusions

What does it all mean?

Future work we would like to include:

- Include splitting results from local shear waves.
- Compute apparent splitting parameters due to a combination of two anisotropic layers as a function of backazimuth.
- Combine with previous studies on anisotropy in Iberia and Morocco.

Why would we want to do that and why is it complicated here?
See next slide.

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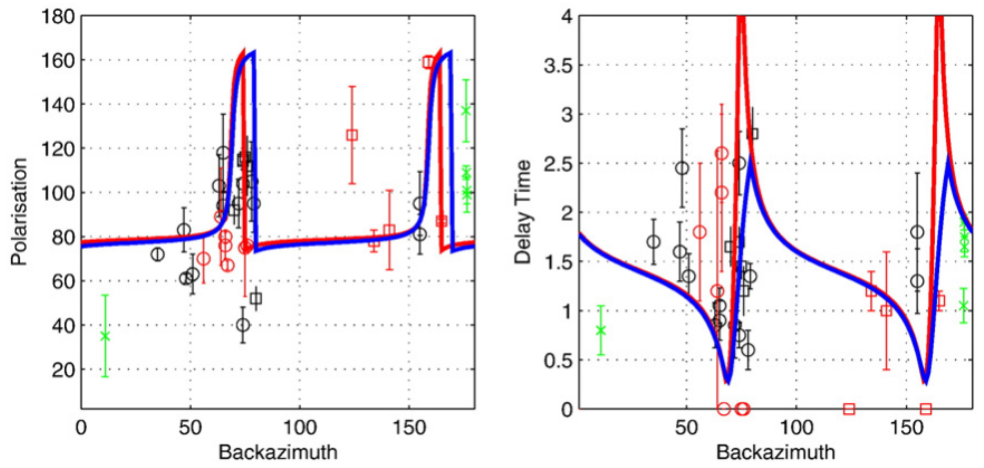
Conclusions

What does it all mean?

Compute apparent splitting parameters due to a combination of two anisotropic layers as a function of backazimuth.

- Apparent splitting parameters can be significantly different from parameters of each individual layer.
- Madeira:
  - General plate motion (≈42˚) might affect upper mantle.
  - Major fault zone orientation (≈108˚) might affect secondary crustal anisotropic layer.
- BUT: backazimuthal coverage not good for most stations → limit to few stations.



Piñero-Feliciangeli & Kendall (2012)
(Example of apparent splitting parameters due to two anisotropic layers.)

Conclusions

What does it all mean?

Future work we would like to include:

- Include splitting results from local shear waves.
- Compute apparent splitting parameters due to a combination of two anisotropic layers as a function of backazimuth.
- Combine with previous studies on anisotropy in Iberia and Morocco.

One first image.
See next slide.

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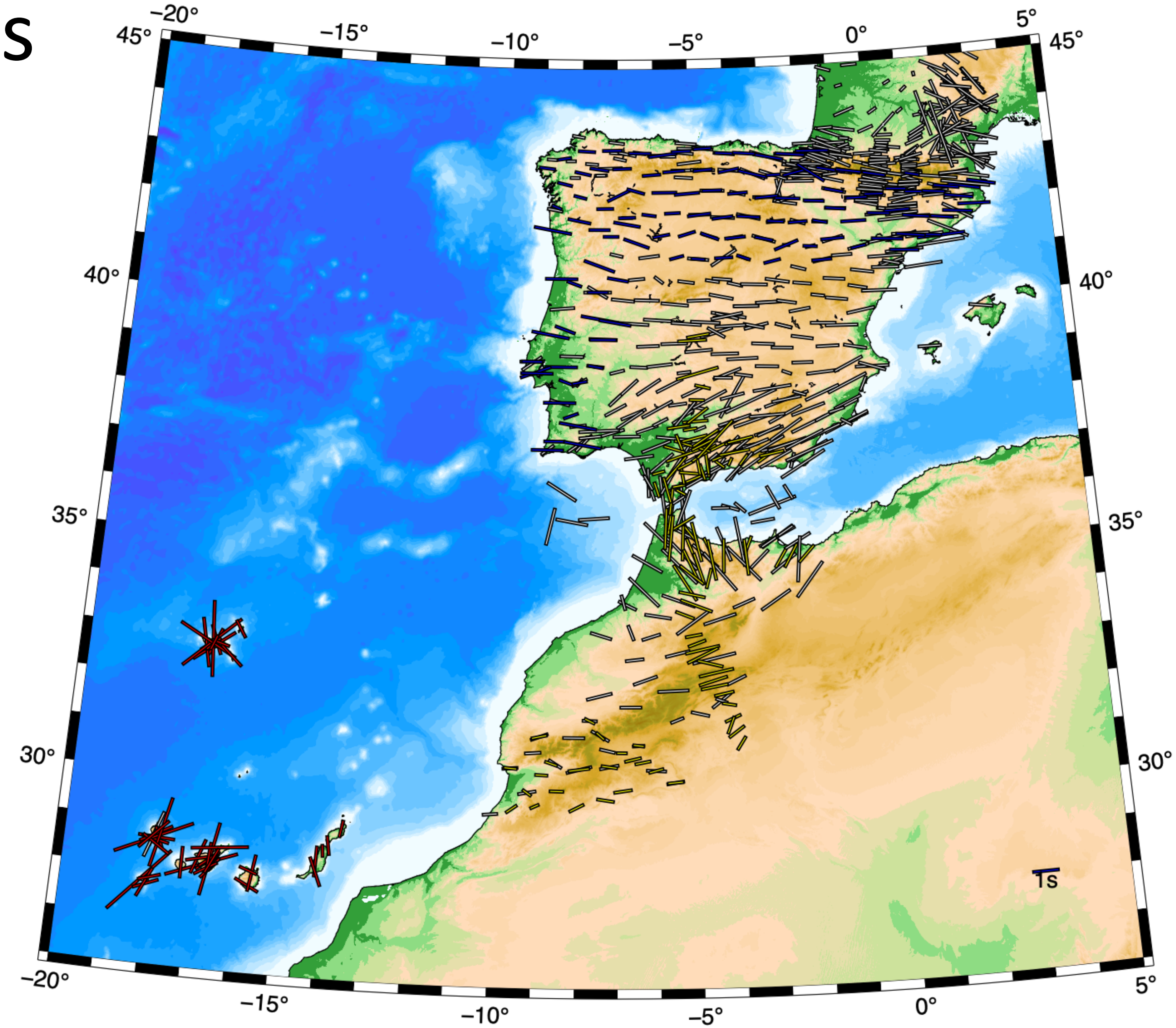
Conclusions

What does it all mean?



Results:

- This study (red).
- Díaz et al., 2015 (blue).
- Miller et al., 2013 (yellow).
- Wüstefeld et al., 2009 (white).

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Contact Information

Who am I?

David Schlaphorst

Postdoctoral Researcher in Seismology
Instituto Dom Luiz IDL
Edif. C8, FCUL, Campo Grande
1749-016 Lisboa
Portugal
Web: http://idl.campus.ciencias.ulisboa.pt/idlmember/david-schlaphorst/
Email: dschlaphorst@fc.ul.pt
Tel.: +351 217 500 881*

(*well, not at the moment, since we are not in the office)

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