Contribution of a SMART CAM Ring to earthquake monitoring and tsunami early warning

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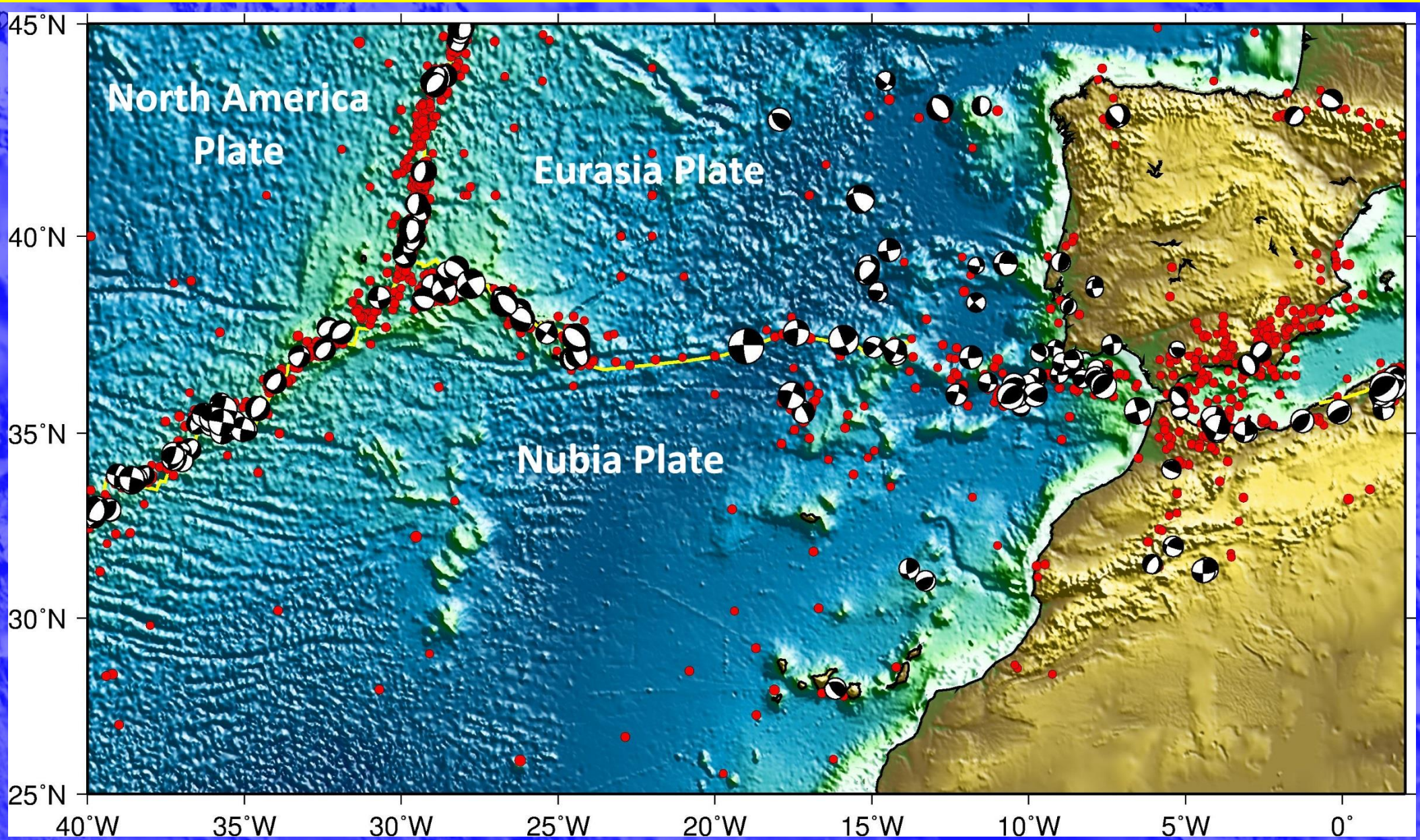
(6) ANACOM - Autoridade Nacional de Comunicações

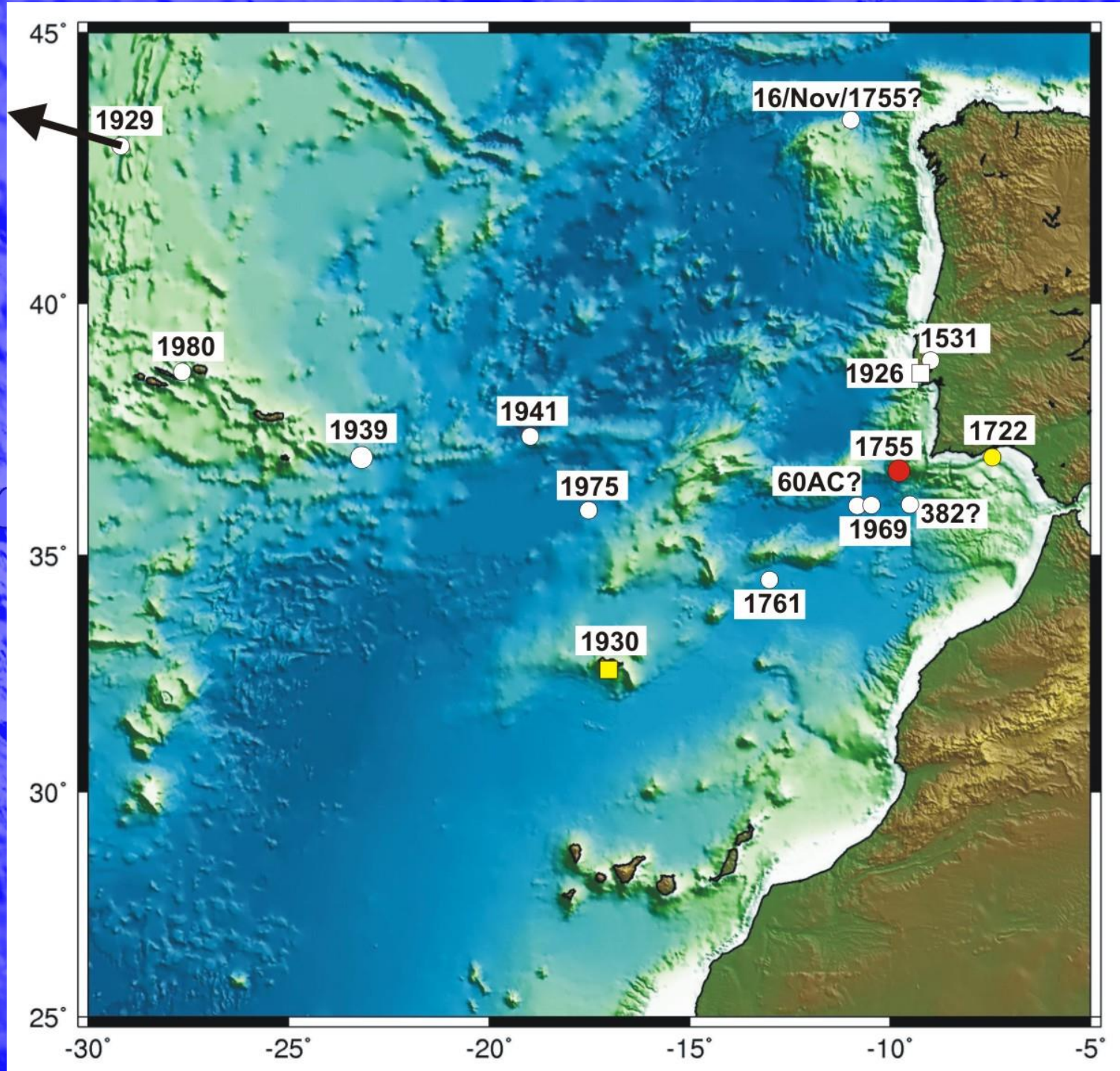
L · E · A
LISTENING TO THE EARTH UNDER THE ATLANTIC

- **Portugal mainland and the Azores are located at or close to a plate boundary that can be the cause of destructive earthquakes and tsunamis**



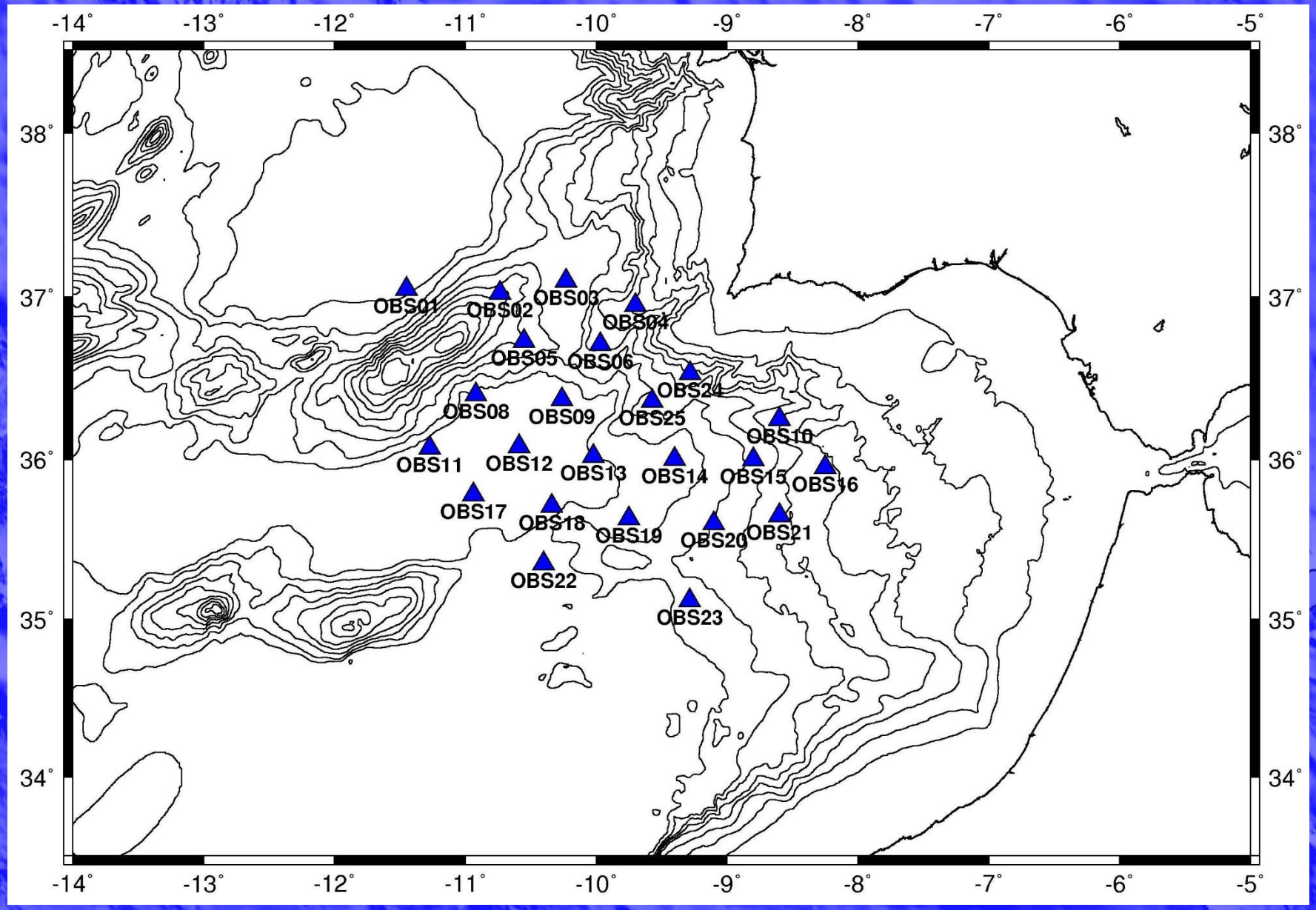
1. MOTIVATION

The 1/11/1755 event was not the only tsunami generated by seismic activity affecting the NE Atlantic coasts *(Portuguese Tsunami Catalogue, Baptista et al., 2009)*



1. MOTIVATION

Tsunamis and offshore earthquakes place considerable challenges to the monitoring systems based on coastal tide-gauges and land seismic stations



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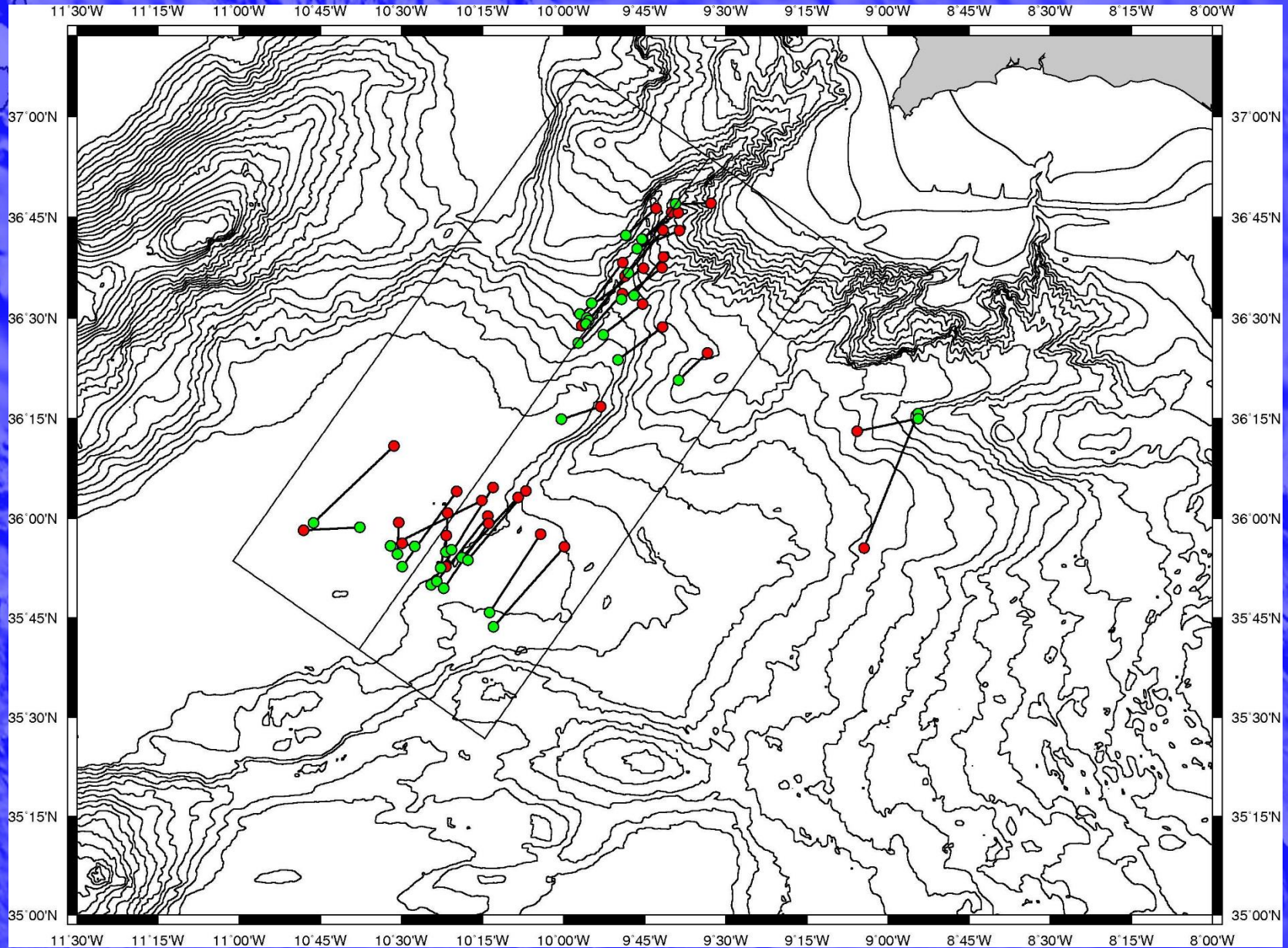
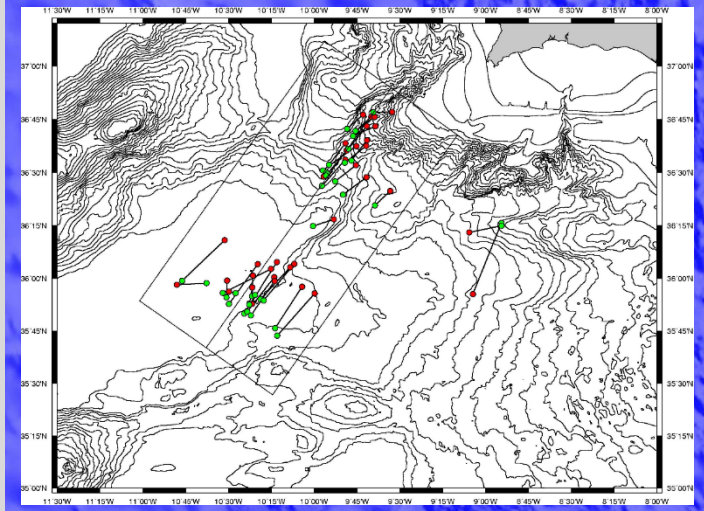


Red – located with land stations only

Green – located with OBS network

Tsunamis and offshore earthquakes place considerable challenges to the monitoring systems based on coastal tide-gauges and land seismic stations



Red – located with land stations only

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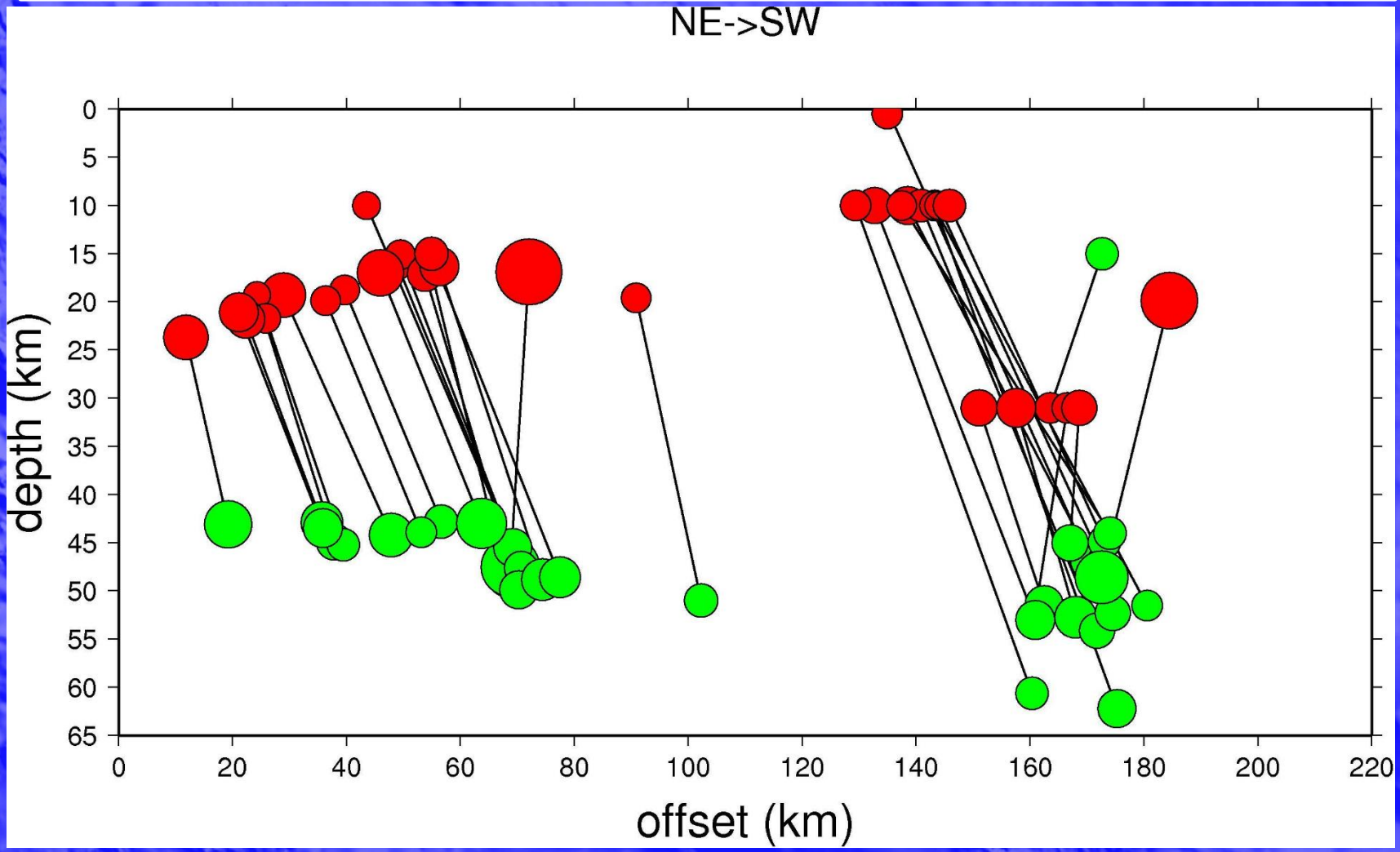
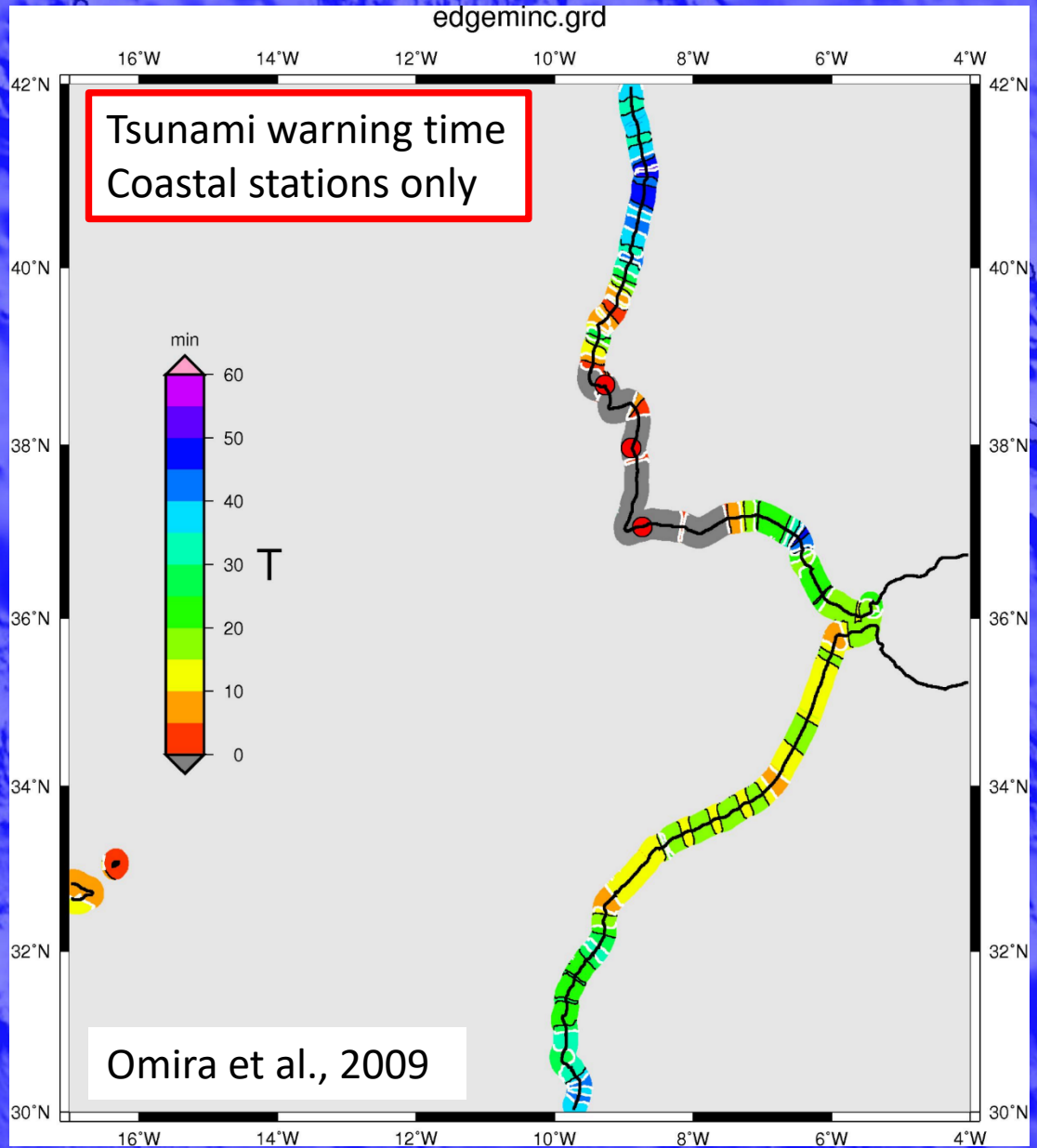
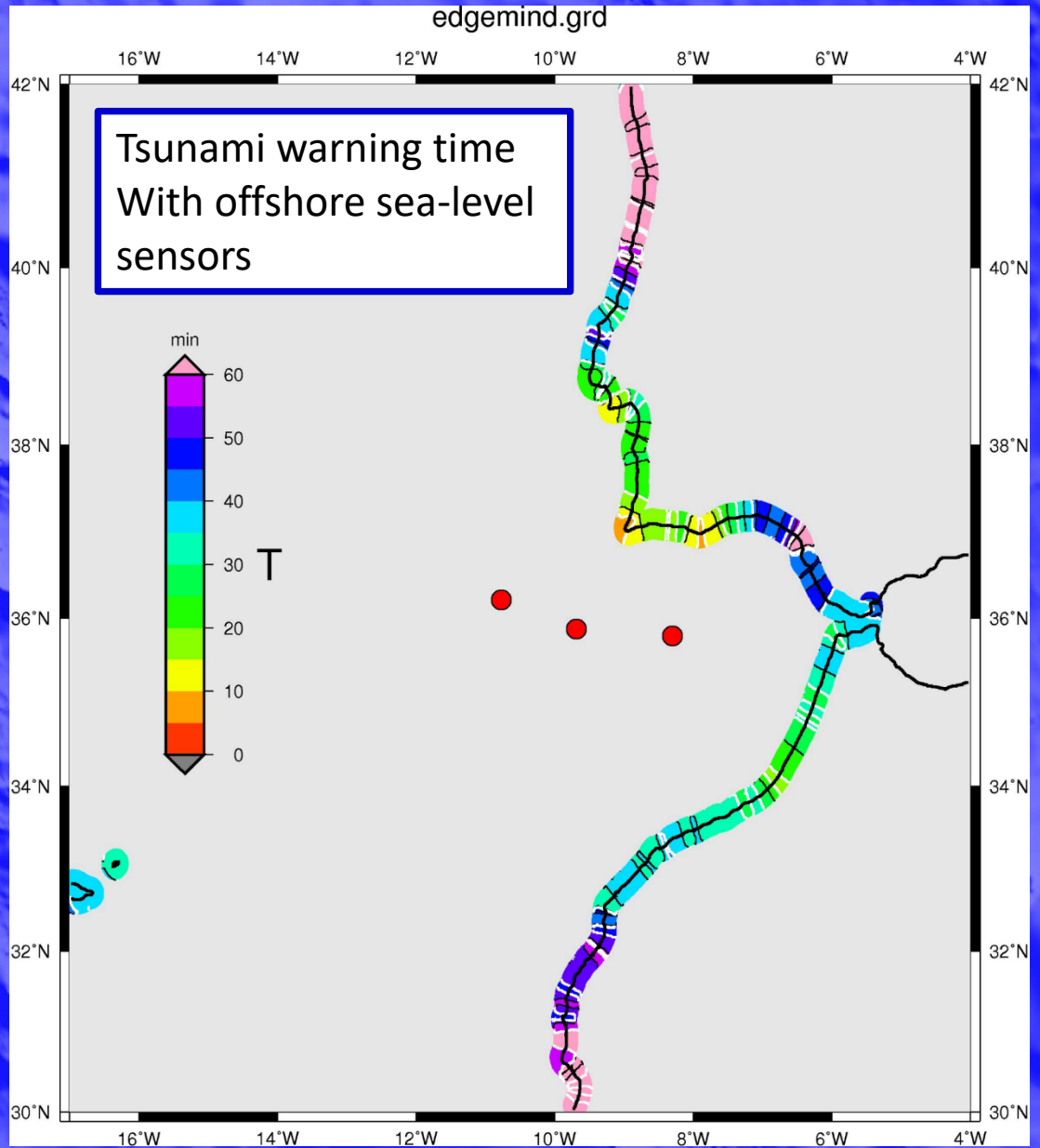
➔ Epicentres and focal depths are strongly biased when land stations only are used



Tsunamis and offshore earthquakes place considerable challenges to the monitoring systems based on coastal tide-gauges and land seismic stations





1. MOTIVATION

- EEWS and TWS systems suffer from a deficient coverage of offshore events due to the absence of sensors on the ocean floor, close to the tectonic sources.

➔ Hence, the earthquake parameters computed fast by the operational centres, epicentre, focal depth, magnitude, are less than optimal

➔ We need sea-level and seismic observations at the deep offshore in real-time!

- **Dedicated cables are too expensive**

➔ **New and current fibre optic telecom cables offer an affordable alternative**

- **Four different technologies are available:**
- **i) SMART, Science Monitoring and Reliable Telecommunications**
- ii) DAS, Distributed Acoustic Sensing;
- iii) PEM, Photonics for Earthquake Monitoring;
- Iv) SoP-OTDR

frontiers in Earth Science

ORIGINAL RESEARCH
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Check for updates

The Contribution of Submarine Optical Fiber Telecom Cables to the Monitoring of Earthquakes and Tsunamis in the NE Atlantic

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2021

frontiers in Earth Science

REVIEW
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Check for updates

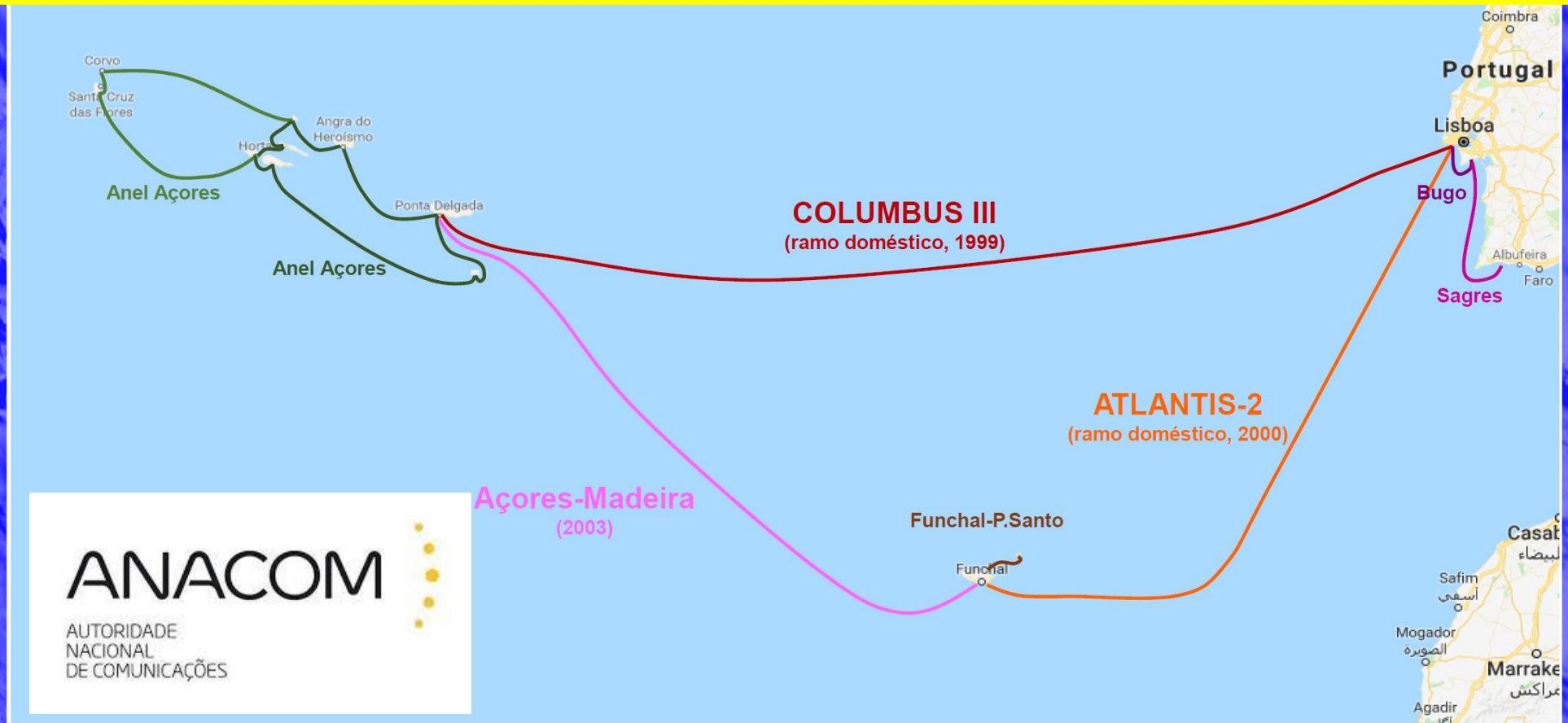
SMART Subsea Cables for Observing the Earth and Ocean, Mitigating Environmental Hazards, and Supporting the Blue Economy

Bruce M. Howe[1]*, *Michael Angove*[2], *Jérome Aucan*[3], *Christopher R. Barnes*[4], *José S. Barros*[5], *Nigel Bayliff*[6], *Nathan C. Becker*[7], *Fernando Carrilho*[8], *Matthew J. Fouch*[9], *Bill Fry*[10], *Anthony Jamelot*[11], *Helen Janiszewski*[12], *Laura S. L. Kong*[13], *Stephen Lentz*[14], *Douglas S. Luther*[15], *Giuditta Marinaro*[16], *Luís Manuel Matias*[17], *Charlotte A. Rowe*[18], *Andi E. Sakya*[19,20], *Amir Salaree*[21], *Torsten Thiele*[22], *Frederik J. Tilmann*[23], *Christa von Hillebrandt-Andrade*[24], *Laura Wallace*[10,25], *Stuart Weinstein*[7] and *William Wilcock*[26]

2022 OPEN ACCESS

➔ **CAM** is the acronym of the submarine telecommunication fibre optic cables that interconnect in a ring Portugal mainland, Azores and Madeira archipelagos

➔ The current cables will cease their operation by 2024 (due to the end of cable lifetime), and the process of their replacement by a new set of cables is now waiting for a political decision, delayed by the fall of the Government. **LEA helped IP-Telecom to define the SMART technical requirements for the new CAM.** RFT expected mid 2022.



Evaluation of the contribution of fibre optic submarine cables to earthquake and tsunami monitoring

1) Define the area and sources to be investigated

2) Define the rules for fast evaluation of earthquake/tsunami parameters

3) Define the background scenario based on land stations only

4) Compute relevant parameters

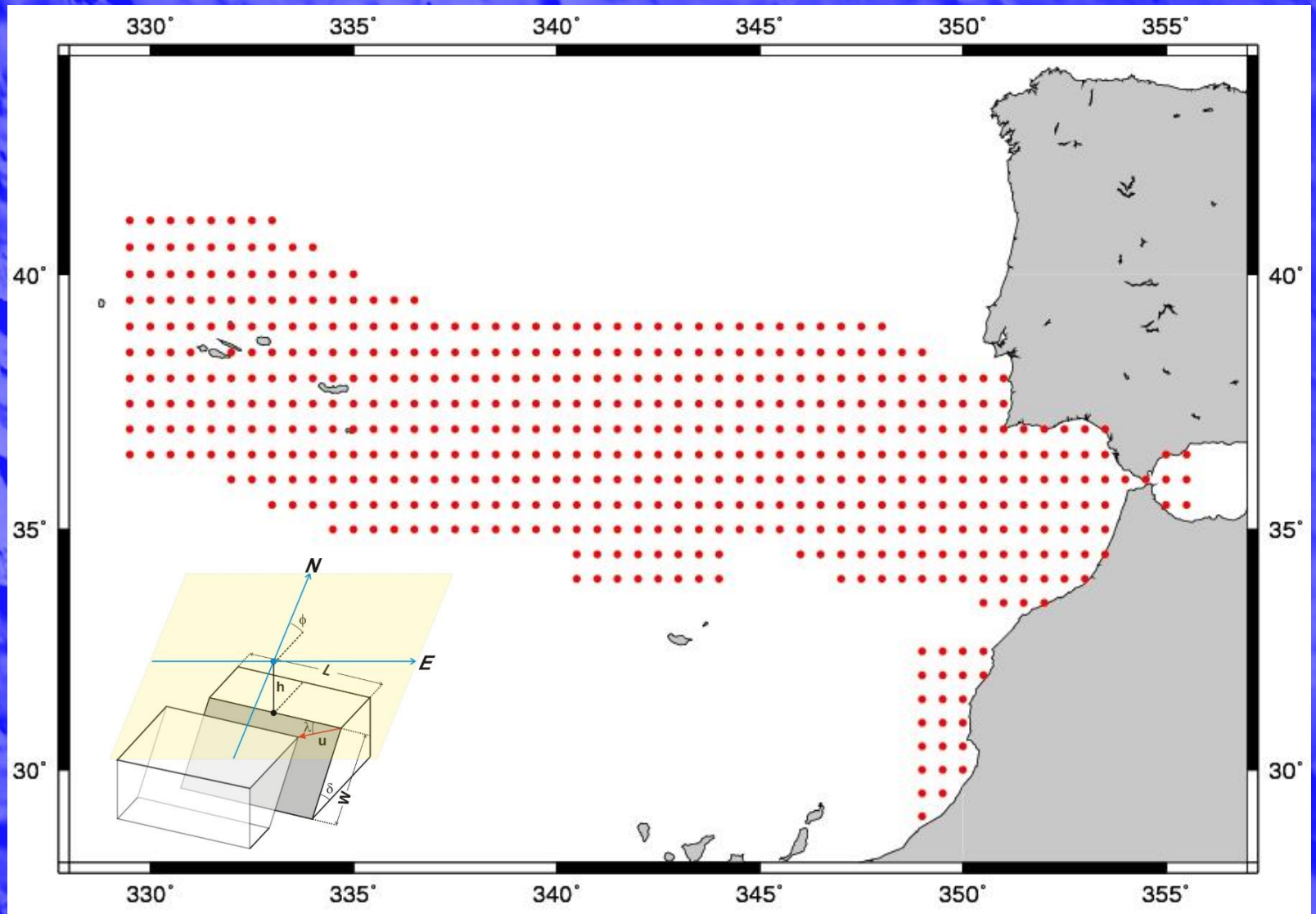
5) Define the scenario with cable observations and compute the same parameters

6) Evaluate the difference

The earthquake and tsunami generation scenario

- It consists of the 518 locations present in the IPMA database for tsunami scenarios, regularly spaced every 0.5º

Focal depth is fixed to 5 km

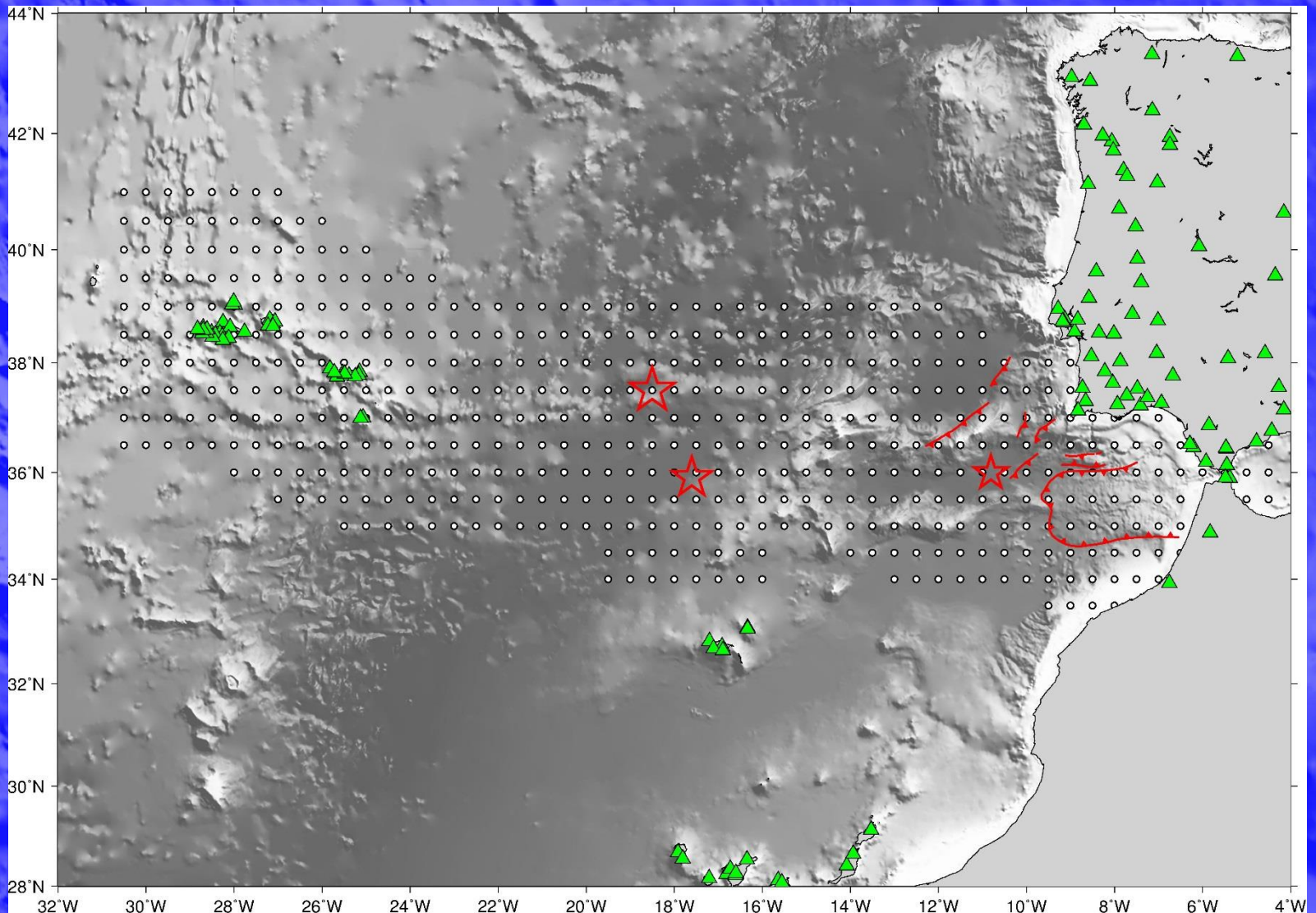


Scenario 0 – Land stations only

- The SMART-CAM will be compared to the current performance of the seismic and tide gauge networks operated by IPMA

Location of seismic stations (green triangles) monitored by IPMA and used for the fast determination of earthquake parameters

The fast determination of earthquake parameters is obtained with the first 10 stations detecting the P arrival

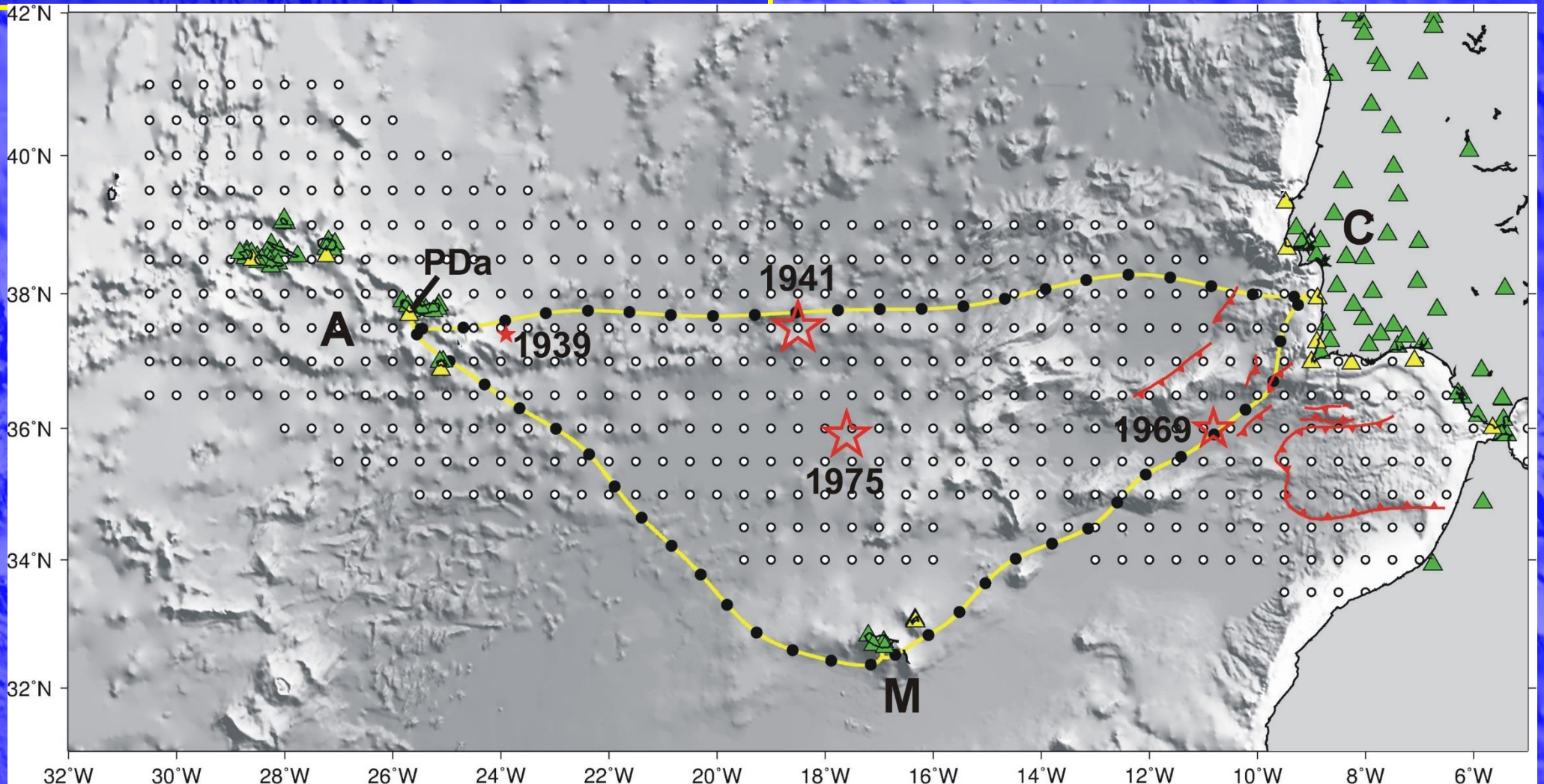


The SMART-CAM scenario to be investigated

- It comprises 47 UCOs placed along the CAM ring with ~70 km interval

UCO = Universal Cable Observatory

Each UCO is considered to be equipped with 3C ground motion sensors and 1 absolute pressure gauge



Added value to earthquake monitoring

- We may select several parameters relevant to earthquake early warning and to the quality of fast and real-time earthquake parameter computation

1. travel-time10: the time that it takes for the seismic waves to reach the 10 closest stations with P waves
2. GAP: It is defined as the maximum azimuthal gap between any pair of stations belonging to the set of the 10 first stations to detect the event
3. dU: The quality parameter defined by Bondar & McLaughlin (2009)
4. Emaj: the major semi-axis of the horizontal error ellipse estimated by the location code
5. Zerr: the estimated error on focal depth

$$\Delta U = \frac{4\sum \left| esaz_i - (unif_i + b) \right|}{360N}, \quad 0 \le \Delta U \le 1$$

Added value to earthquake monitoring

- In real-time the seismologist at the operational room has access to several parameters that estimate the quality of the hypocentre location automatically computed. Any decision on issuing appropriate information or alert messages consider this estimated uncertainty. The smaller these uncertainty parameters, the more reliable are the messages issued

➔ travel-time10, dU and GAP are only a function of the geometry of the network

The other parameters are a function of the velocity model and the quality of the phase picks

➔ To have a more reliable estimate of the contribution of the cabled sensors to the fast determination of earthquake parameters we use a Monte-Carlo simulation

Added value to earthquake monitoring

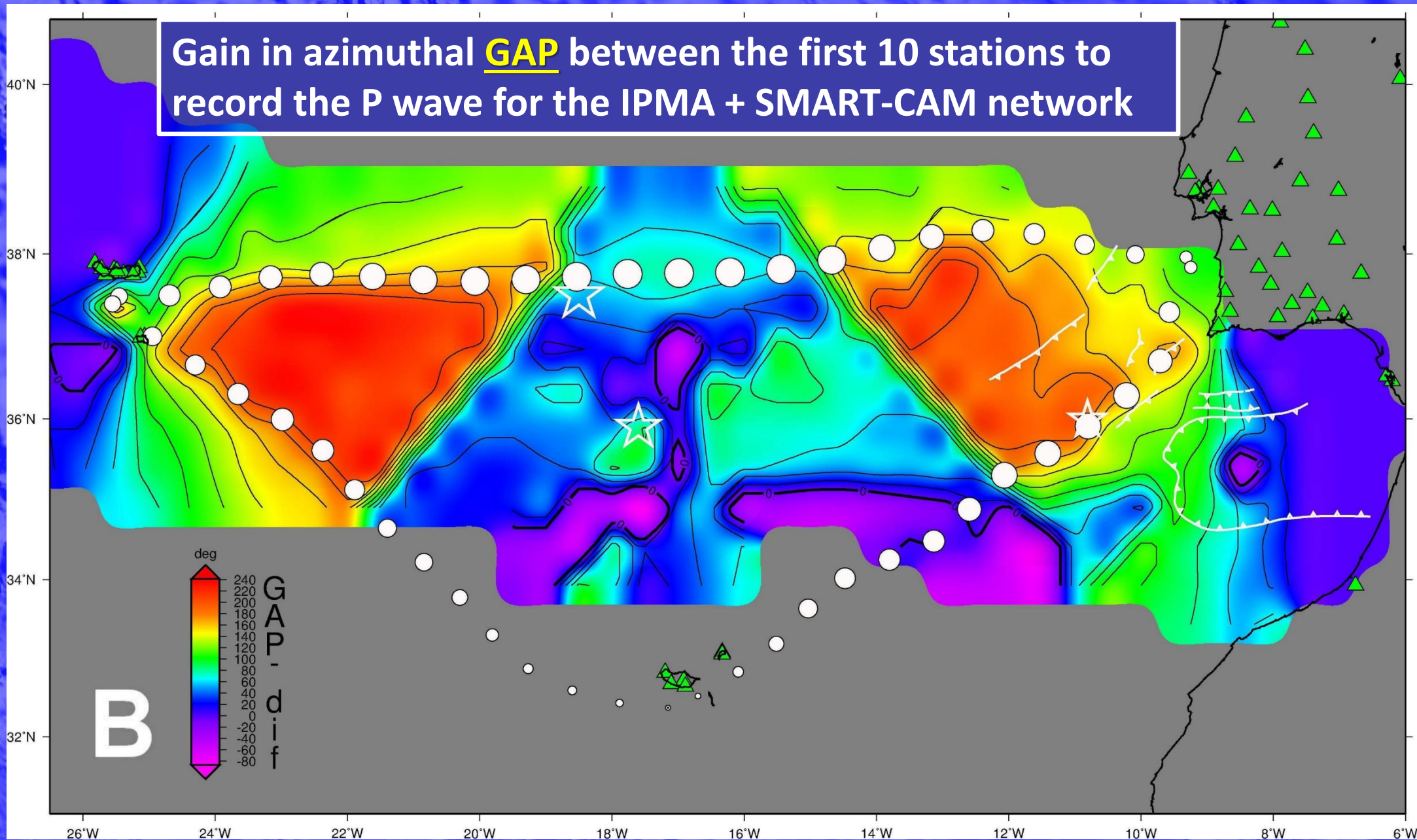
Monte-Carlo simulation

- 100 different models are investigated
- Phase picks are disturbed by a random error $\pm$ 0.2 s
- Velocity model is disturbed by random perturbations
- Monte-Carlo (MC) best location is the centroid
- The epicenter covariance matrix defines an error ellipse

Quality parameters are:

- DD - Distance between centroid and true location
- SS - The area of the uncertainty ellipse defined by the covariance $\sqrt{s_1 s_2}$

Gain with SMART-CAM



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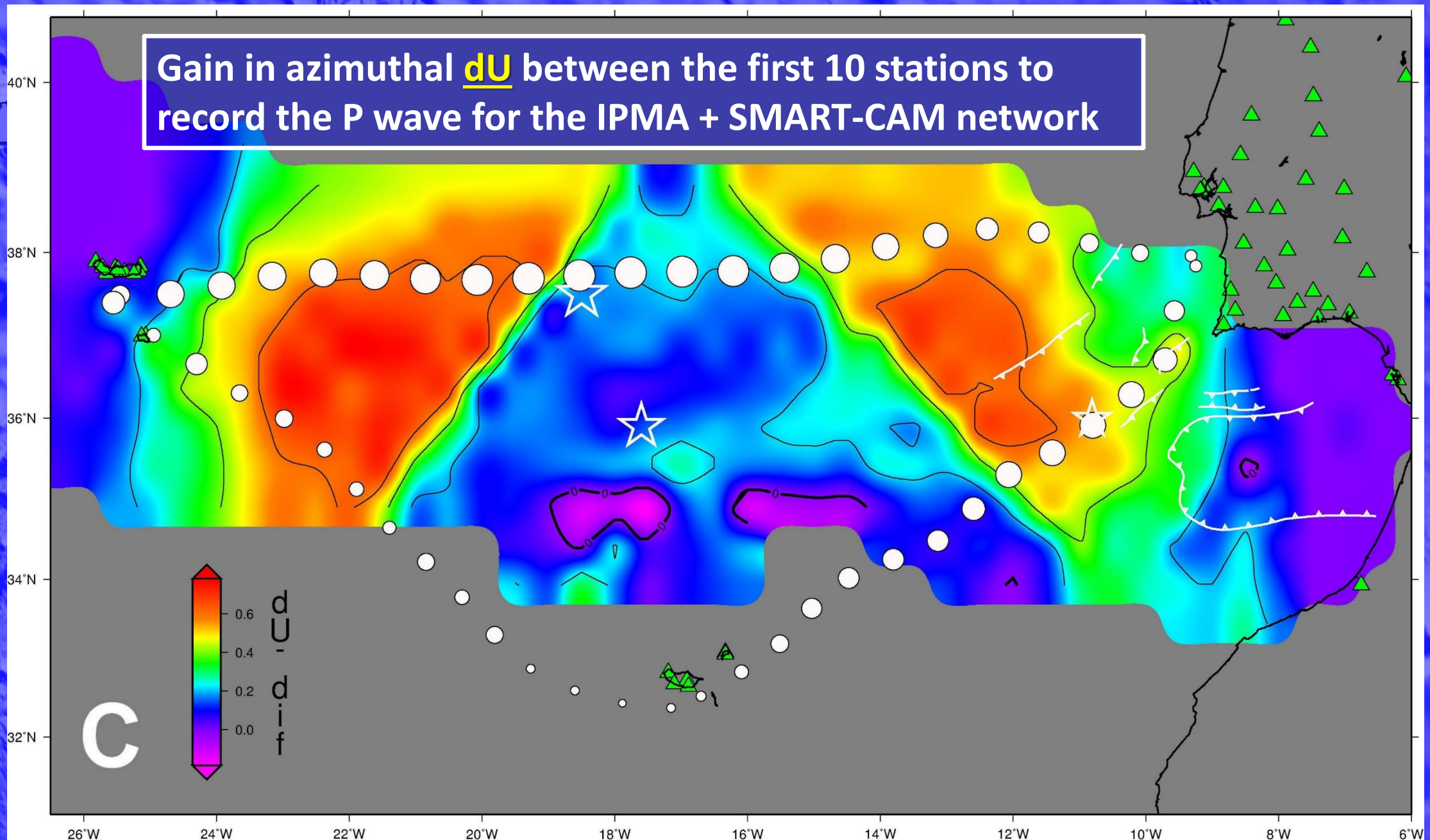
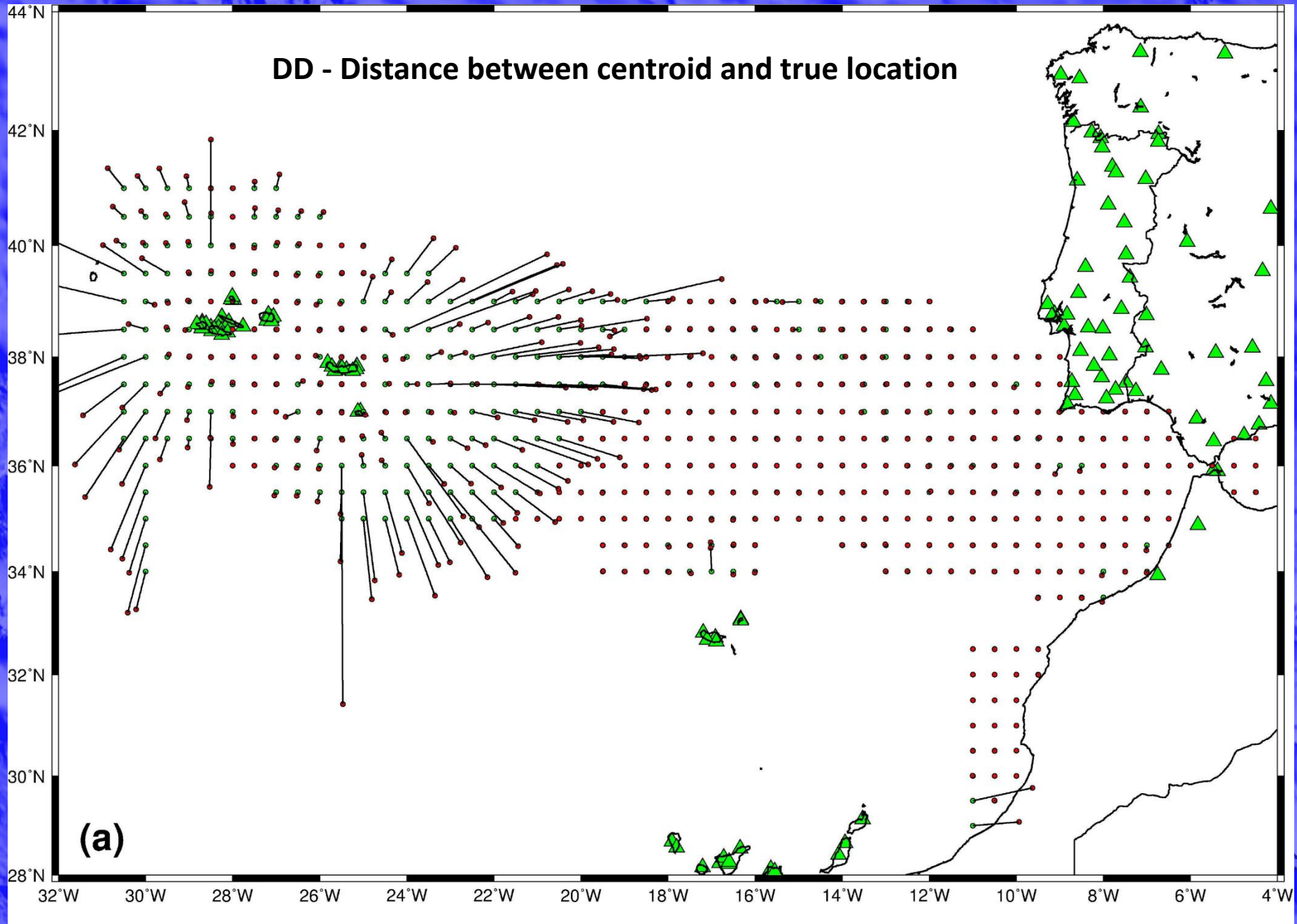
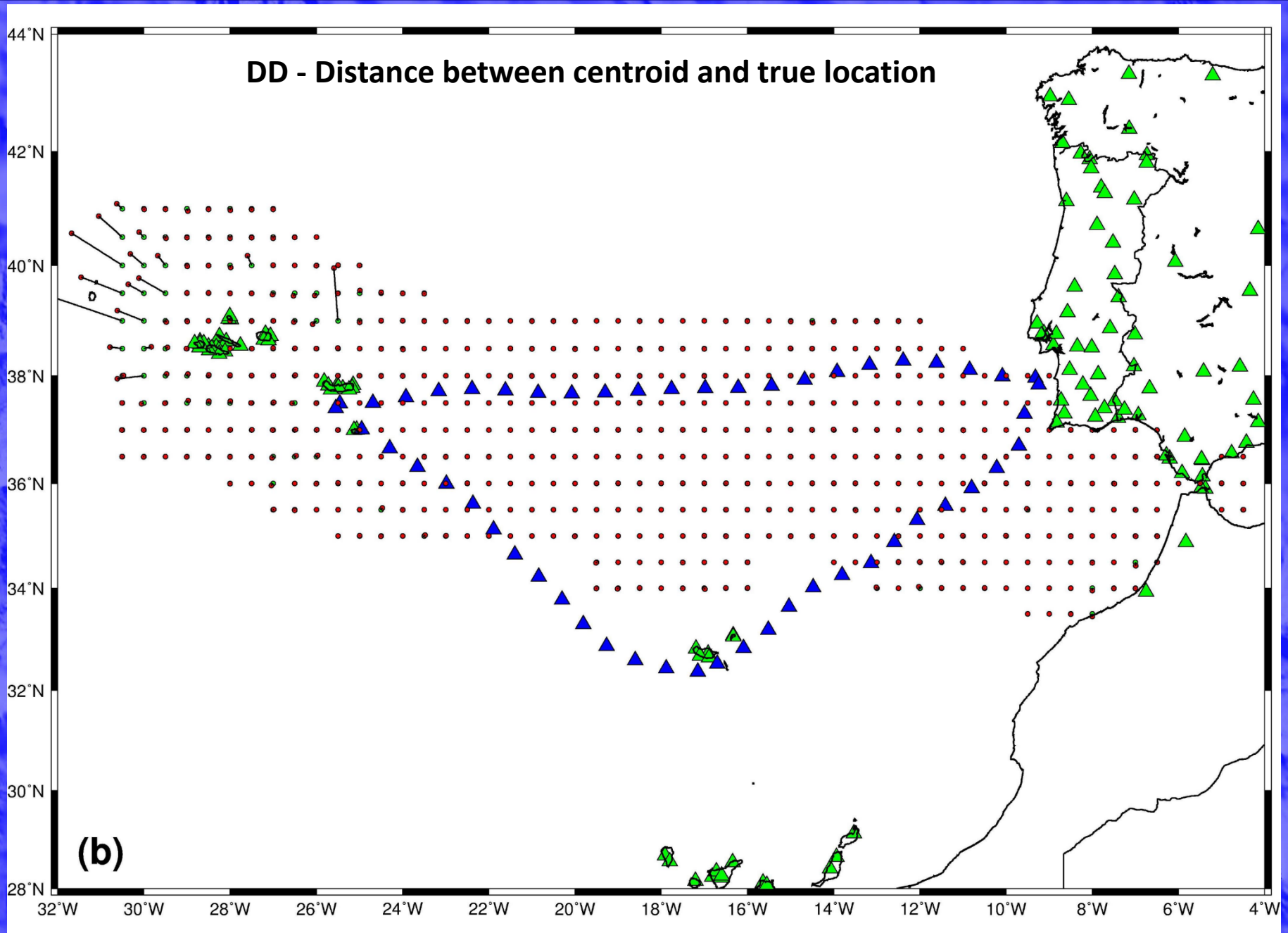


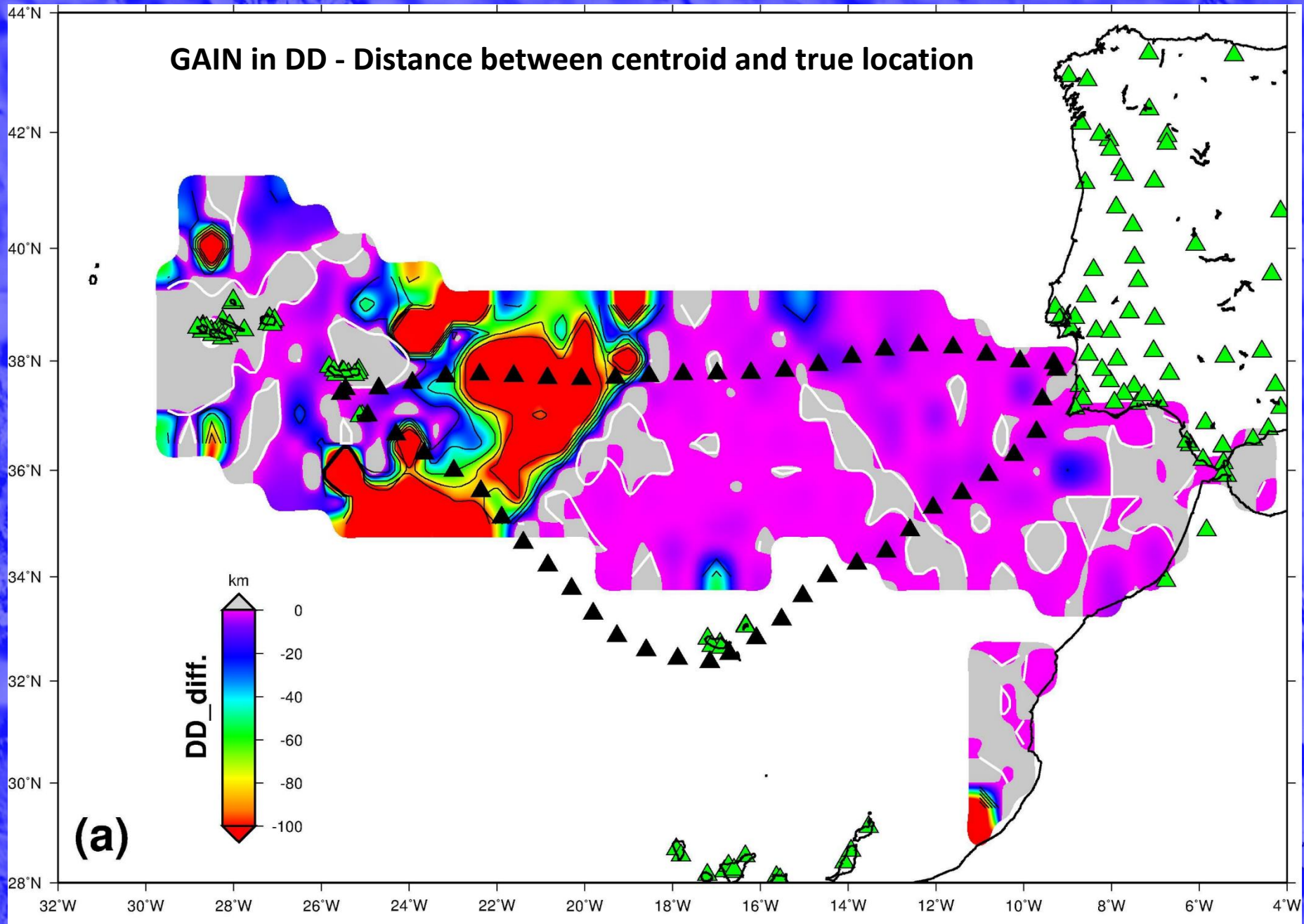
Monte-Carlo: Scenario 0, land stations only



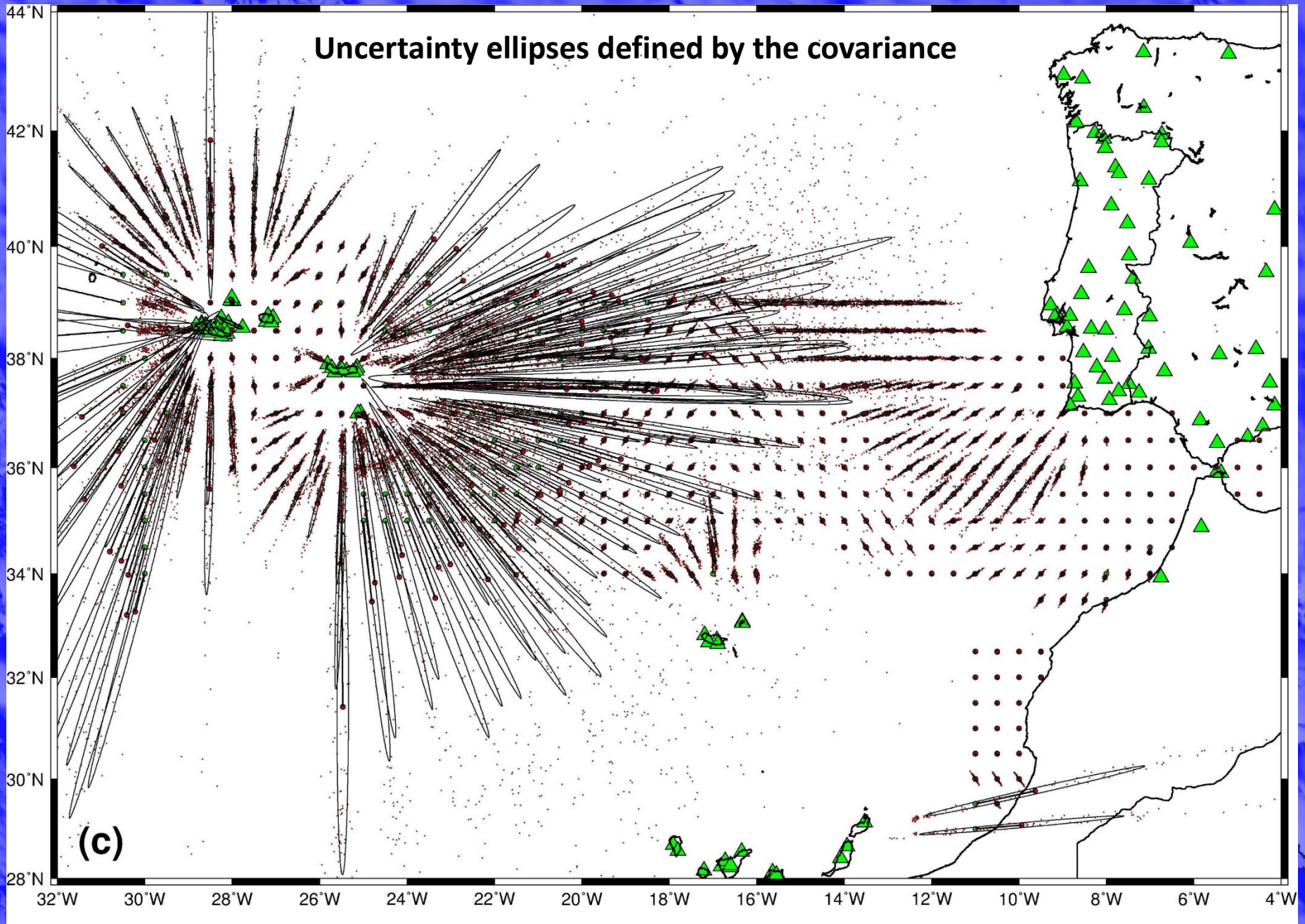
Monte-Carlo: Scenario 1, with cabled sensors



Monte-Carlo: gain with cabled sensors



Monte-Carlo: Scenario 0, land stations only



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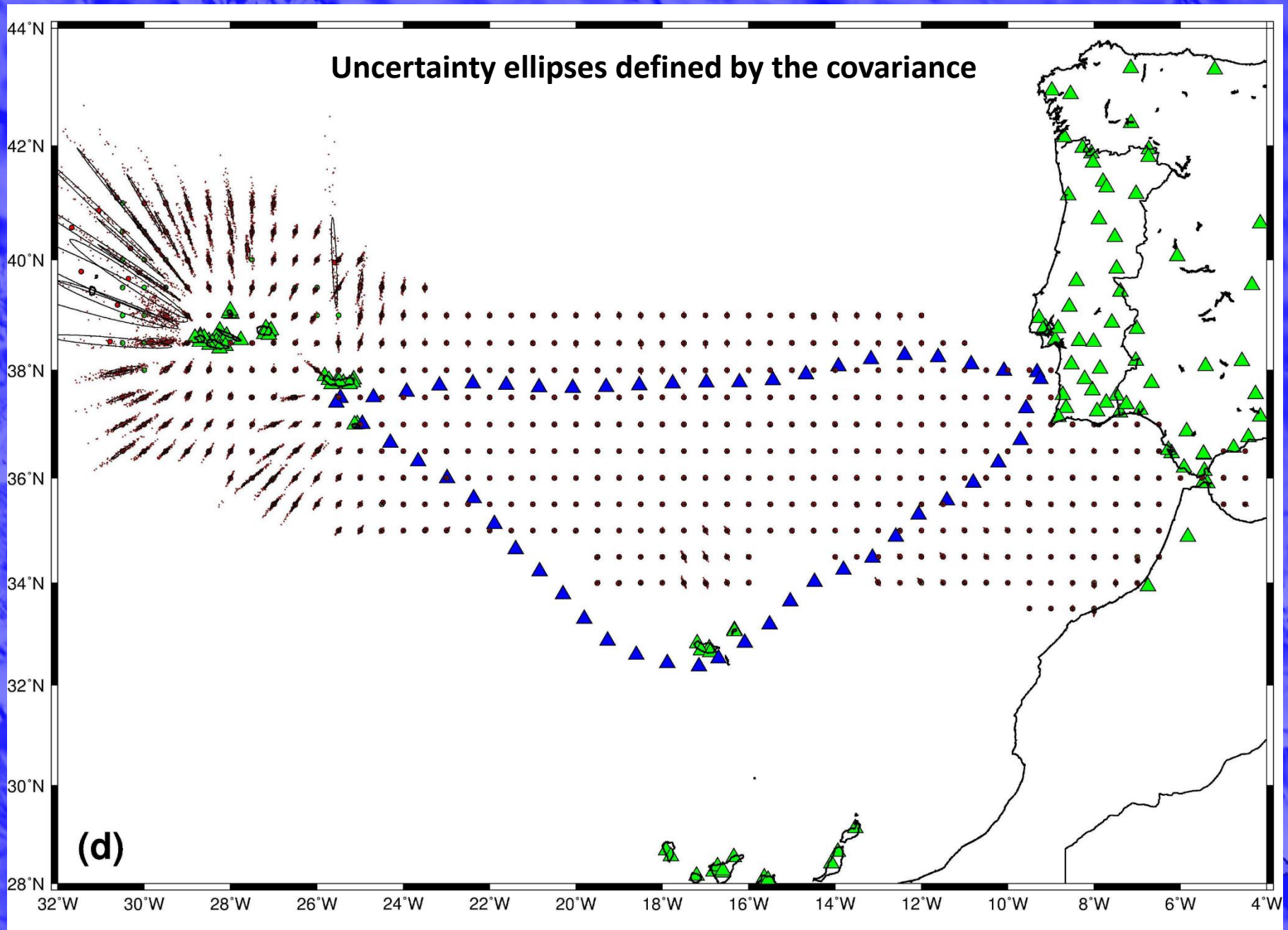
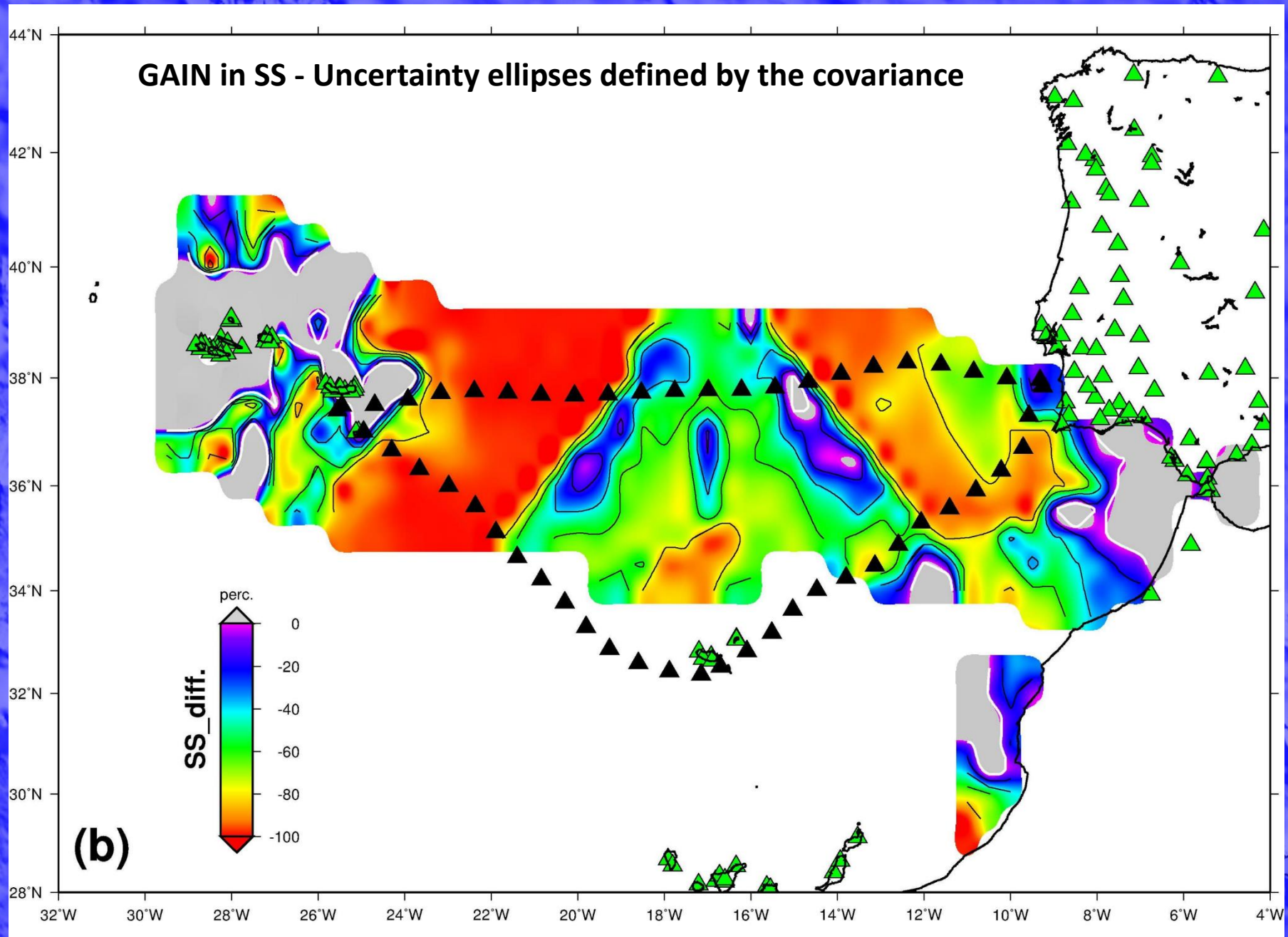
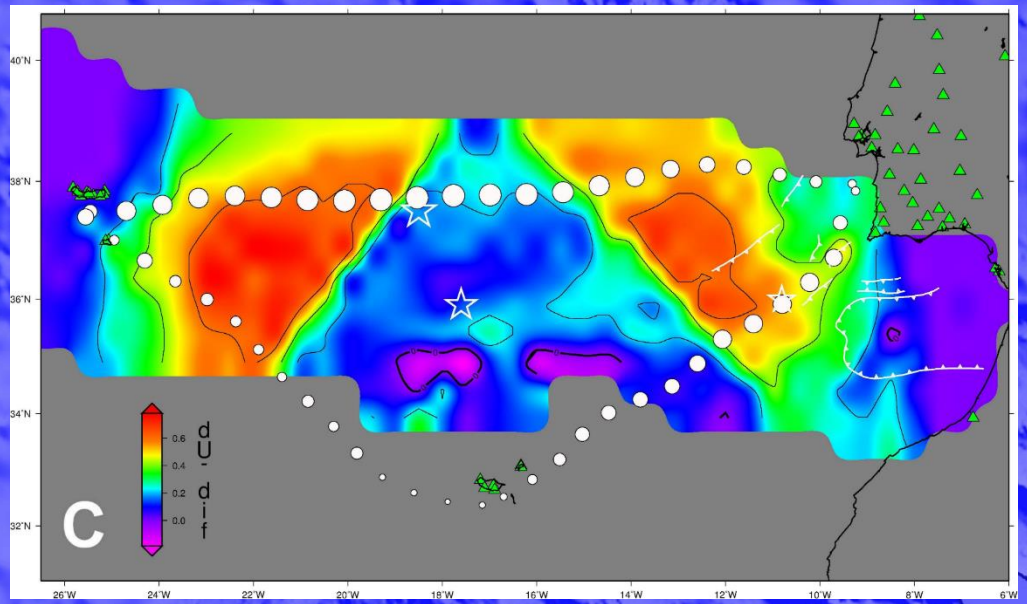
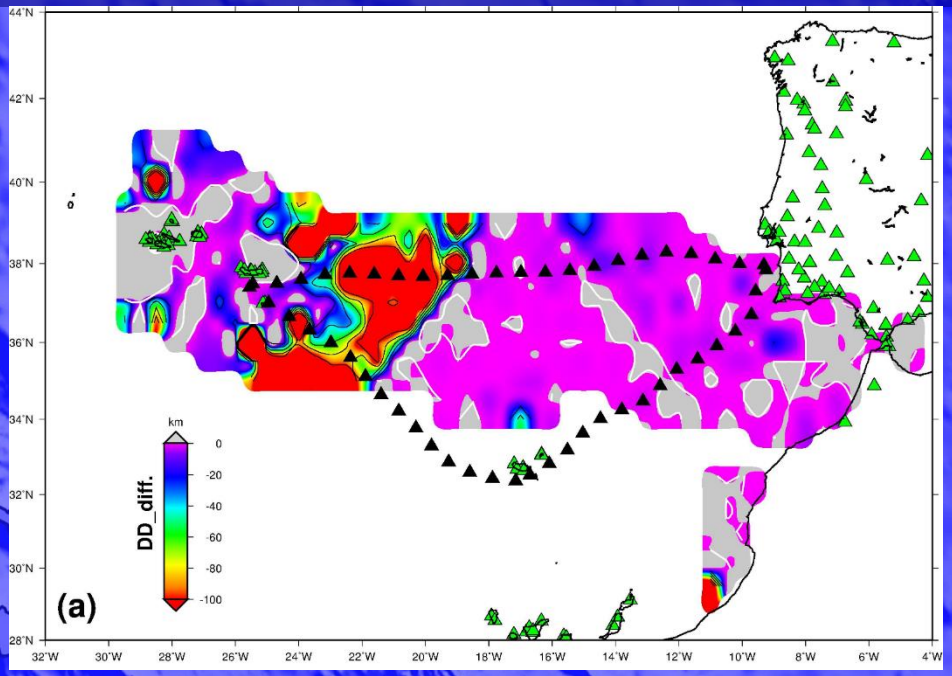


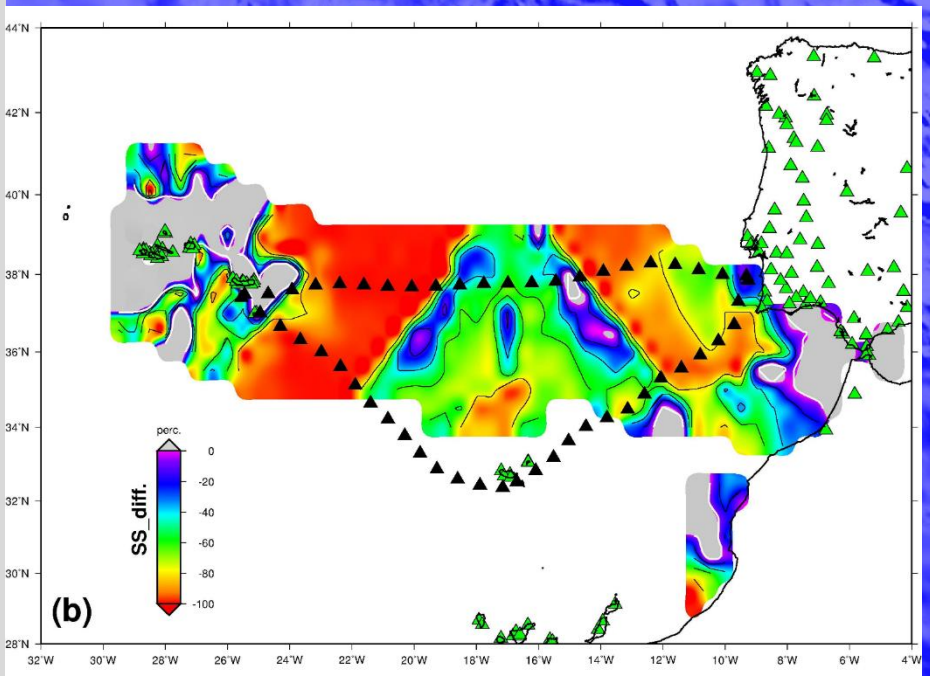
Monte-Carlo: gain with cabled sensors



Gain with SMART-CAM: summary

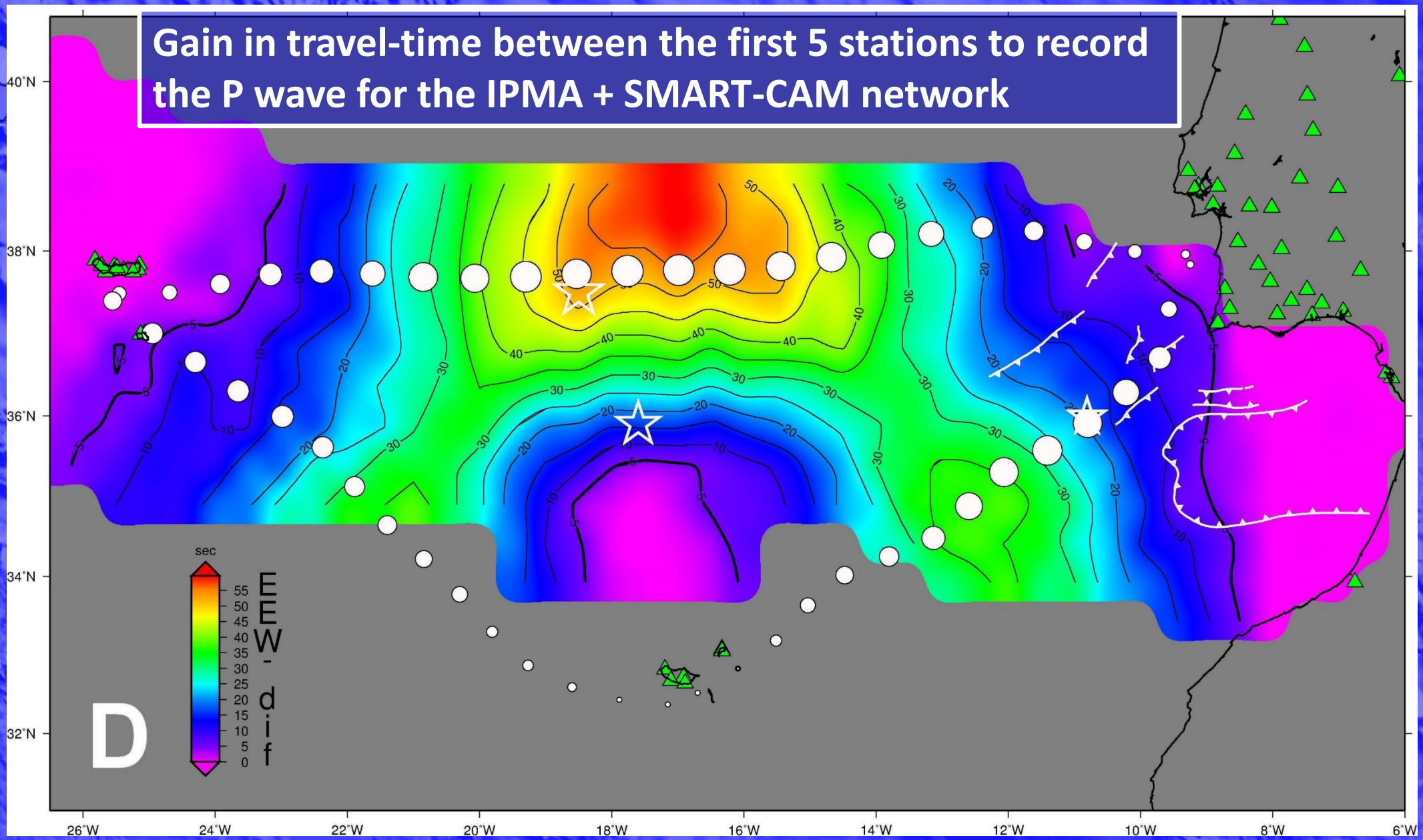






- Considerable gain in GAP, dU, DD and SS for a domain East of Santa Maria and West of Faro
- Gain in DD limited to the Western Gloria Fault

Added value to earthquake early warning

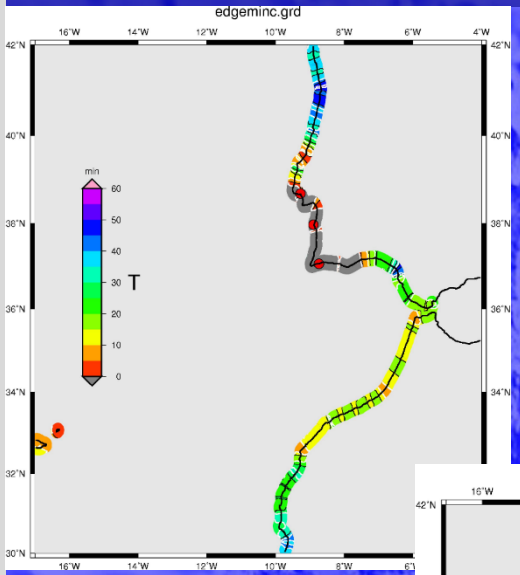


Added value to tsunami monitoring

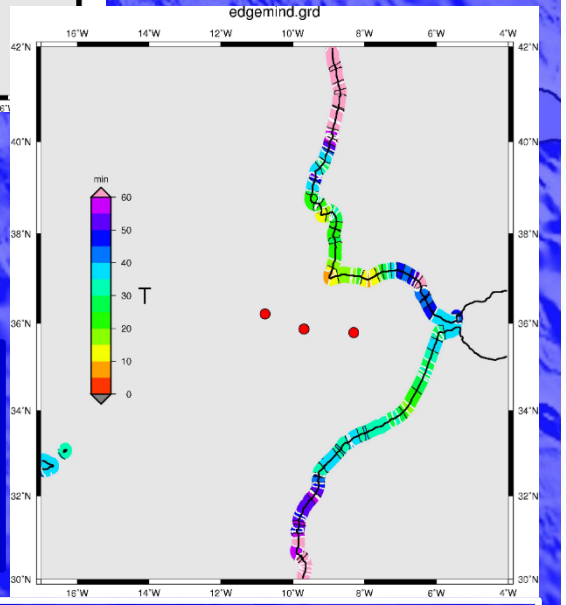
In case a large magnitude earthquake occurs offshore or close to the shore, the Portuguese Tsunami Warning System (PtTWS) operated by IPMA sends the tsunami alert (or information) message a few minutes after the event (typically 6 to 10 minutes) with seismic information only (magnitude, location, focal depth, typical or assessed source mechanism). At this time there is no knowledge if a tsunami has been generated or not. A confirmation message (or alert cancellation message) is issued by the PtTWS only after the first tsunami wave is recorded (or not) by tide gauges. The time for the broadcast of this second message, the one where observations of sea level are included, is a function of the tsunami travel time (TTT) to the closest tide gauge to the earthquake and tsunami source. We identify the time of this message as the minimum-TTT. Any reduction of the minimum-TTT has an enormous impact on the performance of the tsunami early warning system.

➔ The only quality parameter evaluated here is the Minimum-TTT: the time it takes for a tsunami wave to reach the closest tide-gauge

Scenario 0 – Coastal tide gauges only



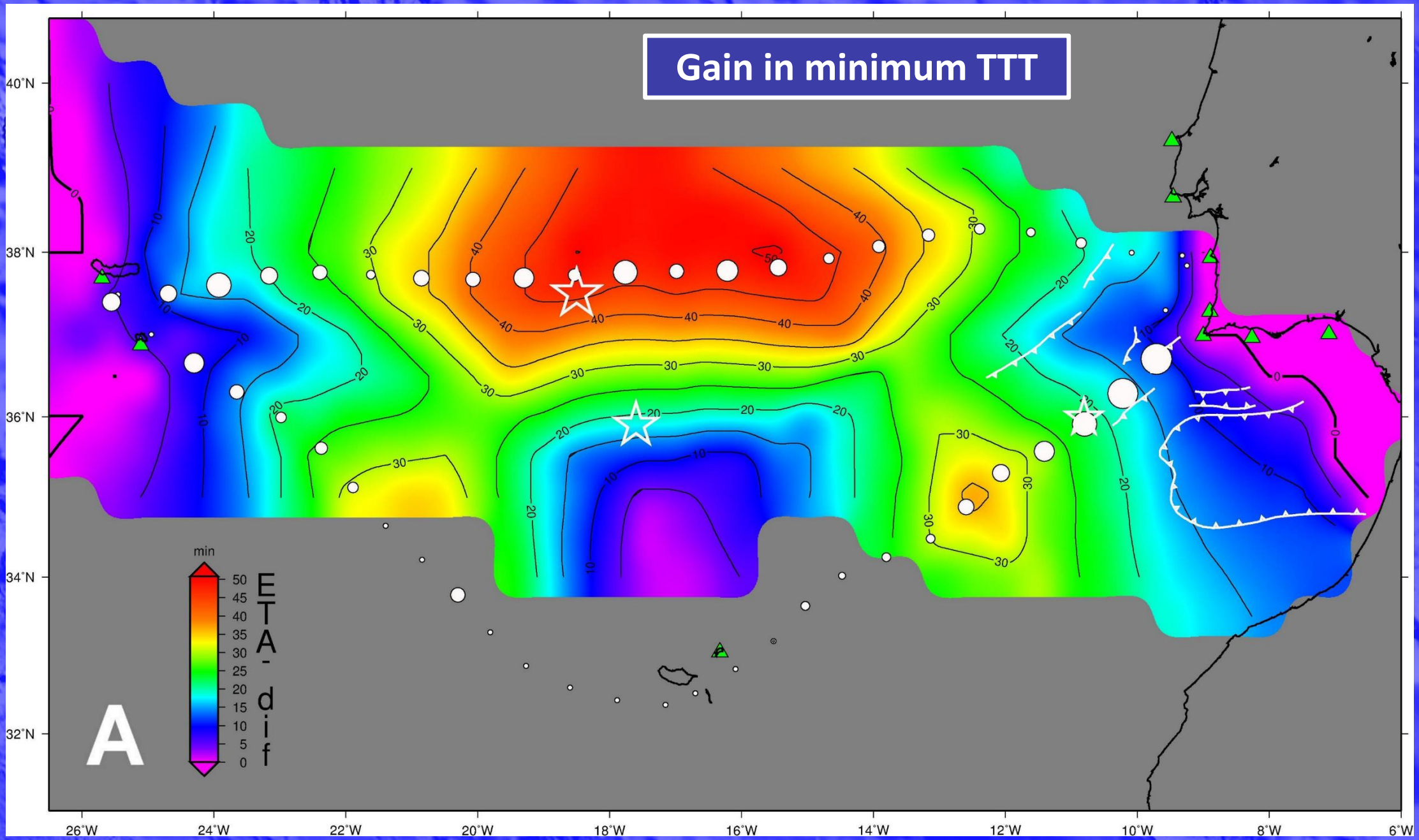
Tsunami warning time
Coastal stations only



Tsunami warning time
With offshore sea-level sensors

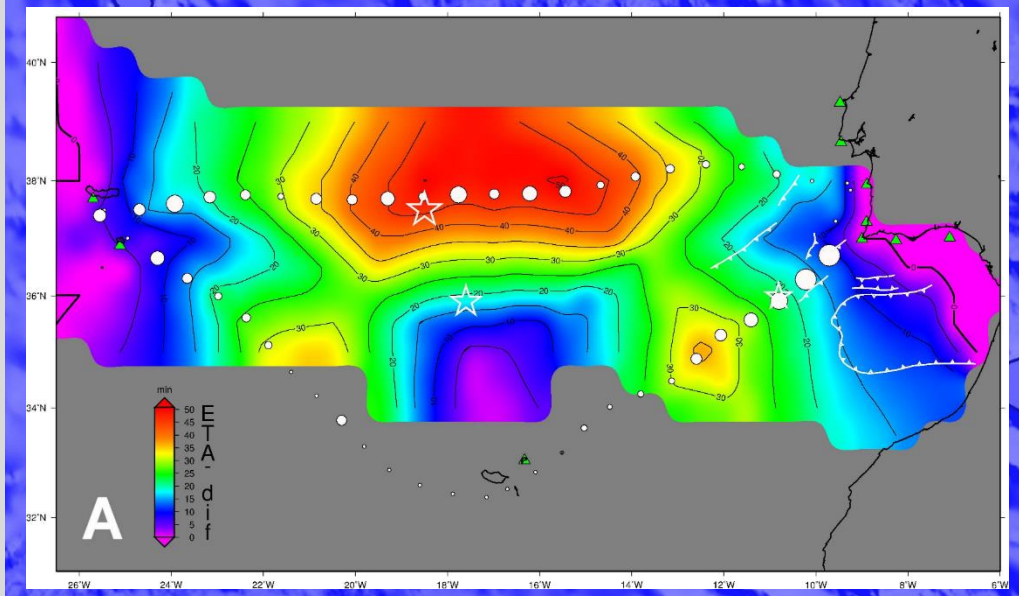
Location of coastal tide-gauges monitored by IPMA for sea-level changes related to tsunamis

Added value to tsunami monitoring



Added value to tsunami monitoring

Gain in minimum TTT

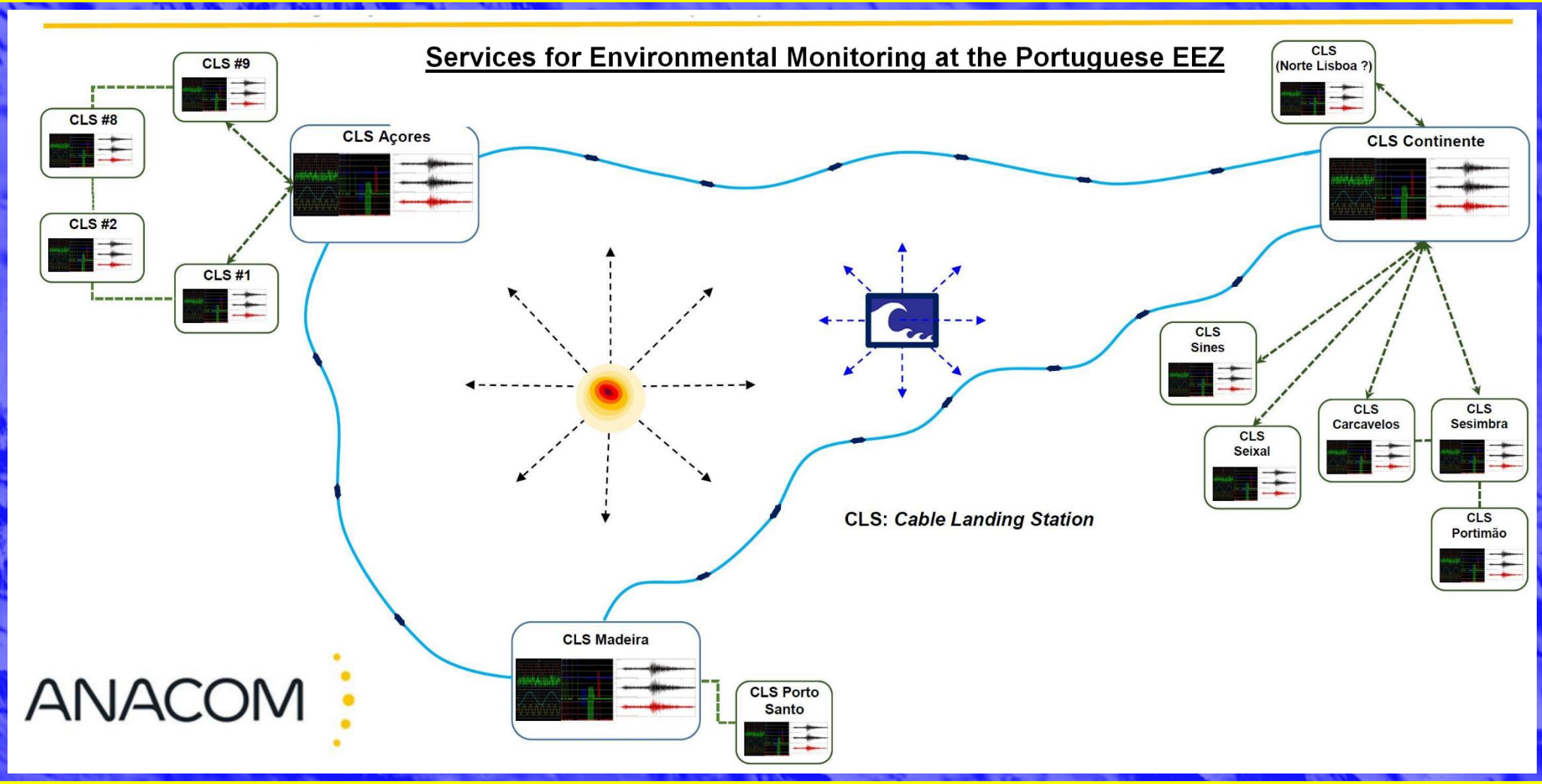


The improvement on the tsunami early warning time is significant (greater than 10 minutes) in a wide area between 23ºW and Portugal mainland and Morocco coastal areas. The area of improvement includes all zones that have generated tsunamis, as presented in the Portuguese tsunami catalogue (Baptista and Miranda 2009), the whole Gloria Fault East of the Azores and the Gulf of Cadiz. **For a large domain in the Gloria Fault and SW Gulf of Cadiz the gain on the tsunami early warning time is larger than 30 minutes.**

Conclusion

- The SMART-CAM cables provide significant improvement on earthquake monitoring on the two most hazardous source areas, SW Portugal mainland and the western Gloria Fault with activity affecting the Azores
- The SMART-CAM cables provide significant gain in the Tsunami Warning time for the most active offshore source areas

The SMART-CAM approach was originally suggested in 2019 by the ANACOM CEO (the Portuguese regulator for telecommunications advising the national authorities) for the cables that were planned to be operational in early 2024



Acknowledgements to ANACOM for fruitful discussions and encouragement

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