The contribution of the CAM fibre optic submarine cable telecom ring to the early warning of tsunami and earthquakes

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PRESENTATION LAYOUT

1. INTRODUCTION
Earthquake and tsunami hazard along the Nubia-Eurasia Plate Boundary and CAM

2. MITIGATION
Early Warning Systems for earthquakes and tsunami

3. BEING SMART
On the use of commercial submarine optical fiber communication cables for geophysical monitoring

4. EVALUATION OF SMART-CAM: PART-I
The of land observatories and the SMART proposal tested, the CAM ring equipped with 10 geophysical sensor packages

5. EVALUATION OF SMART-CAM: PART-II
The added value to earthquake monitoring and early warning

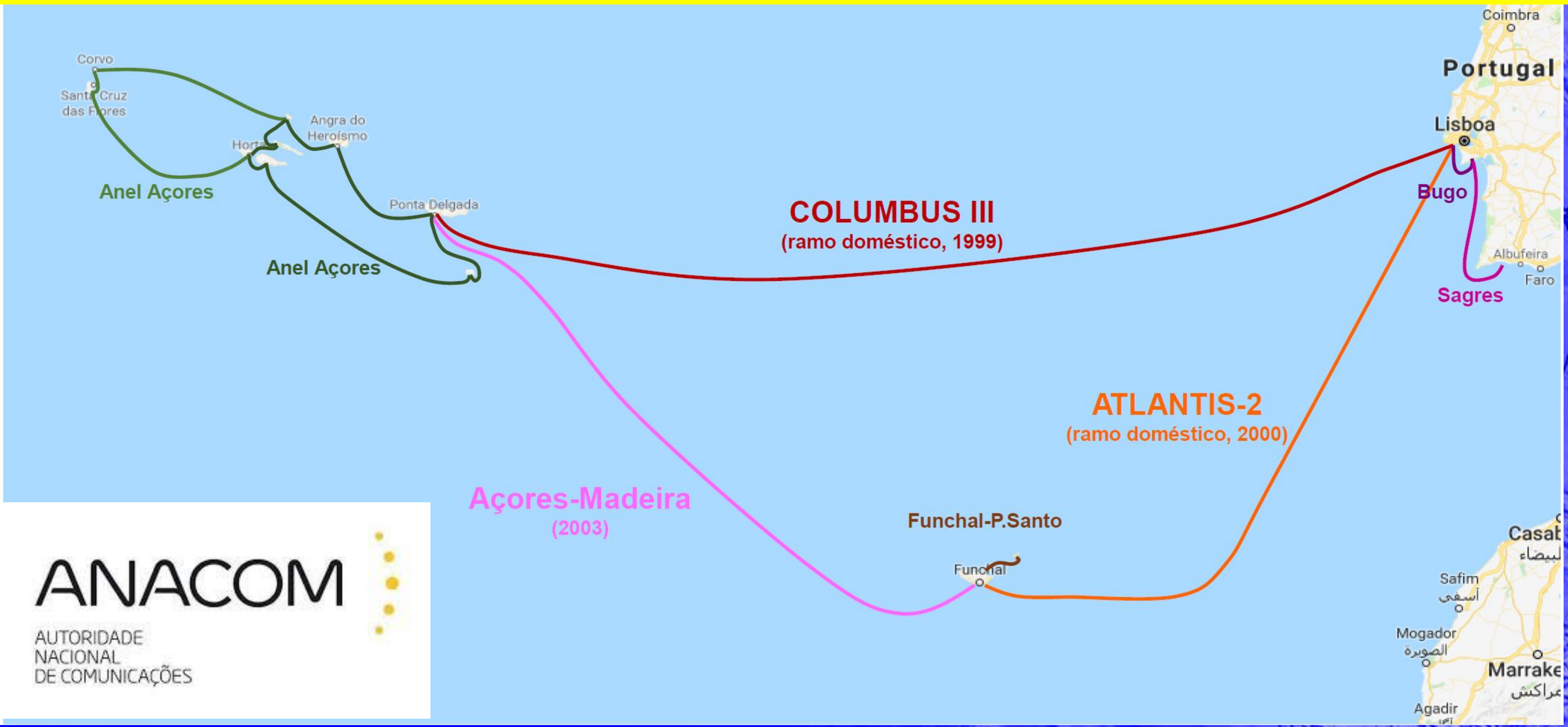
6. EVALUATION OF SMART-CAM: PART-III
The added value to tsunami monitoring and early warning

7. CONCLUSIONS
This is not the end, but only the beginning…

1. INTRODUCTION

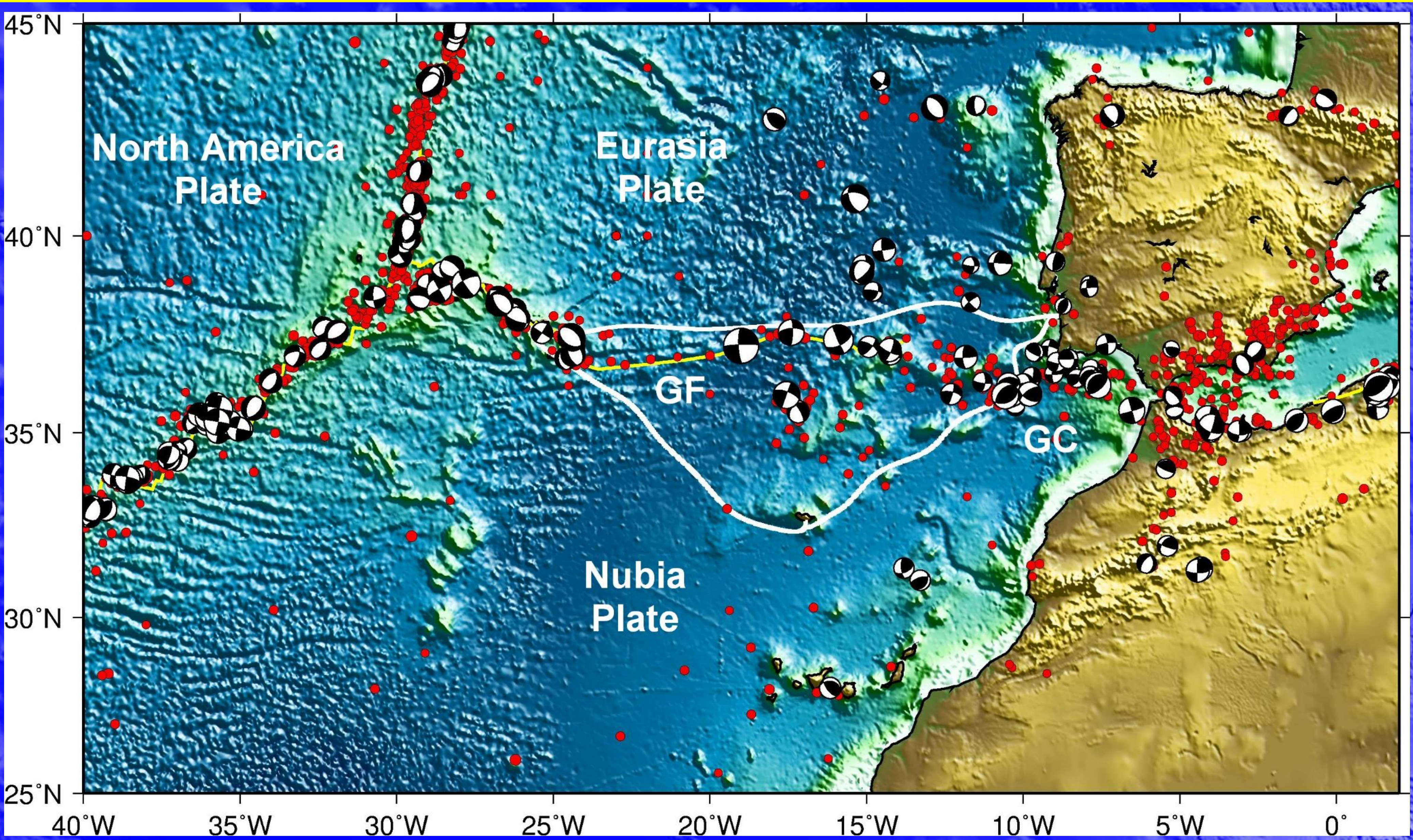
➔ **CAM is the acronym of the submarine telecommunication fibre optic cables that interconnect in a ring Portugal mainland, Azores and Madeira archipelagos**

➔ **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 under consideration by the Portuguese authorities with the technical requirements to be defined until the last quarter of 2020**



1. INTRODUCTION

- The CAM cables span along the plate boundary between Eurasia and Nubia, an offshore domain prone to generate destructive earthquakes and tsunamis.

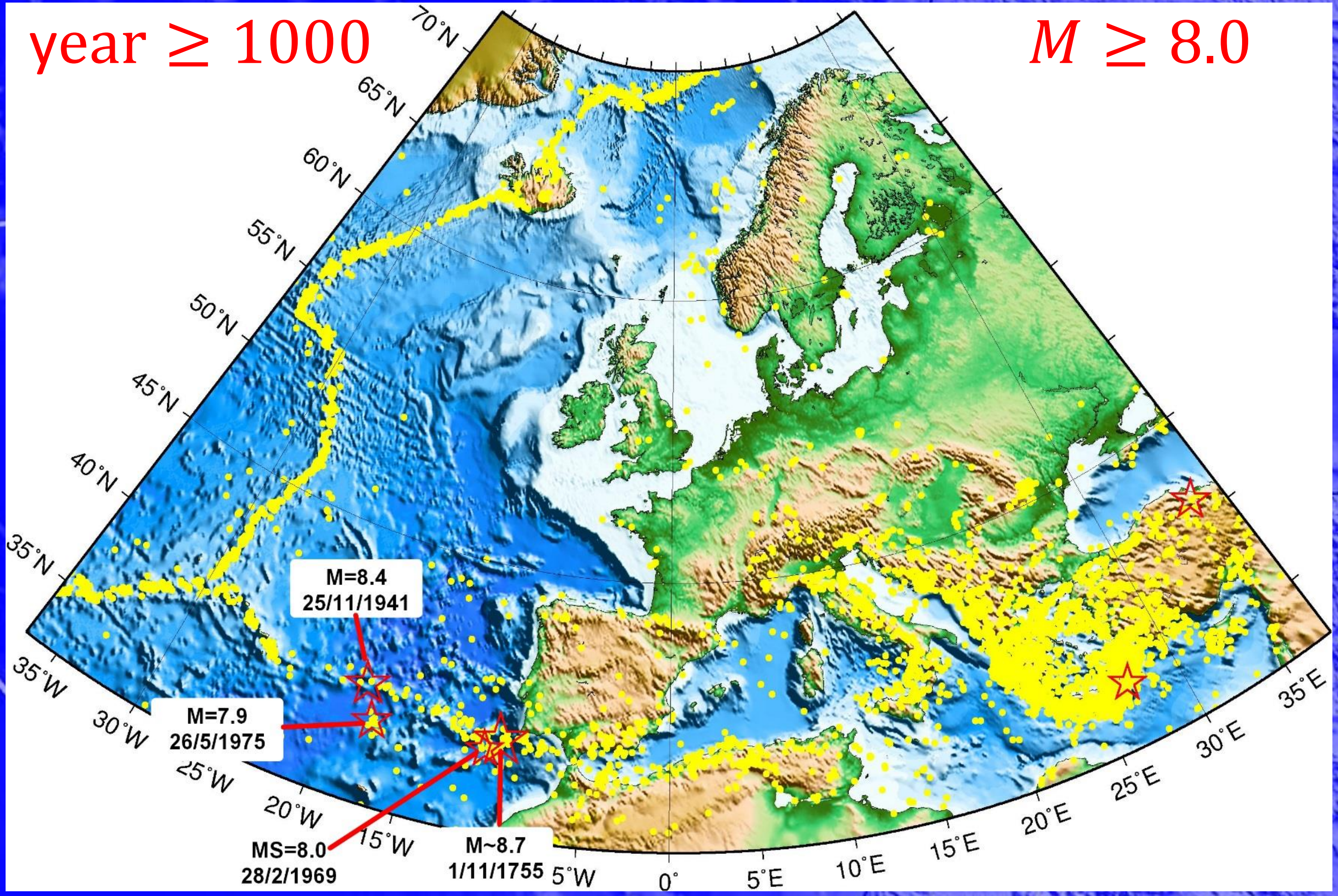


1. INTRODUCTION

- **The Gulf of Cadiz area (GC) SW Iberia generated the largest earthquake in Europe since 1000 in 1/11/1755**
- **In the same domain, the MS=8.0 28/2/1969 was the largest felt earthquake in Europe since 1900.**

➔ The Gloria Fault(GF) generated in 25/11/1941 the 2nd largest ever recorded earthquake on a Fracture Zone

➔ The GF domain was also at the origin of the M=7.9 earthquake in 26/5/1975

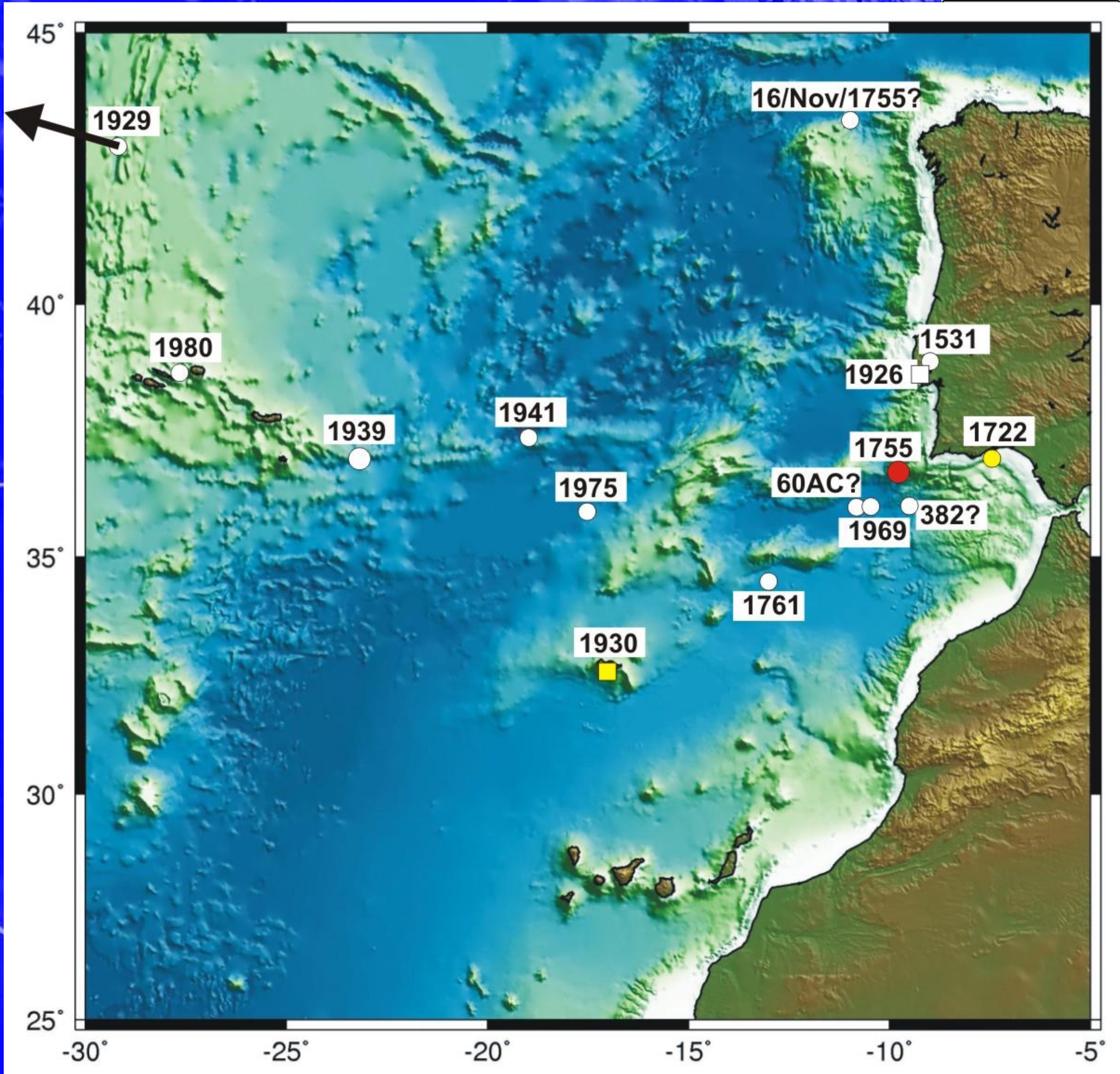


➔ The 1st November 1755 earthquake, devastating Lisbon and causing major destruction in Portugal, Spain and Morocco, also made a strong impact in the whole Europe, political, philosophical, cultural

1. INTRODUCTION

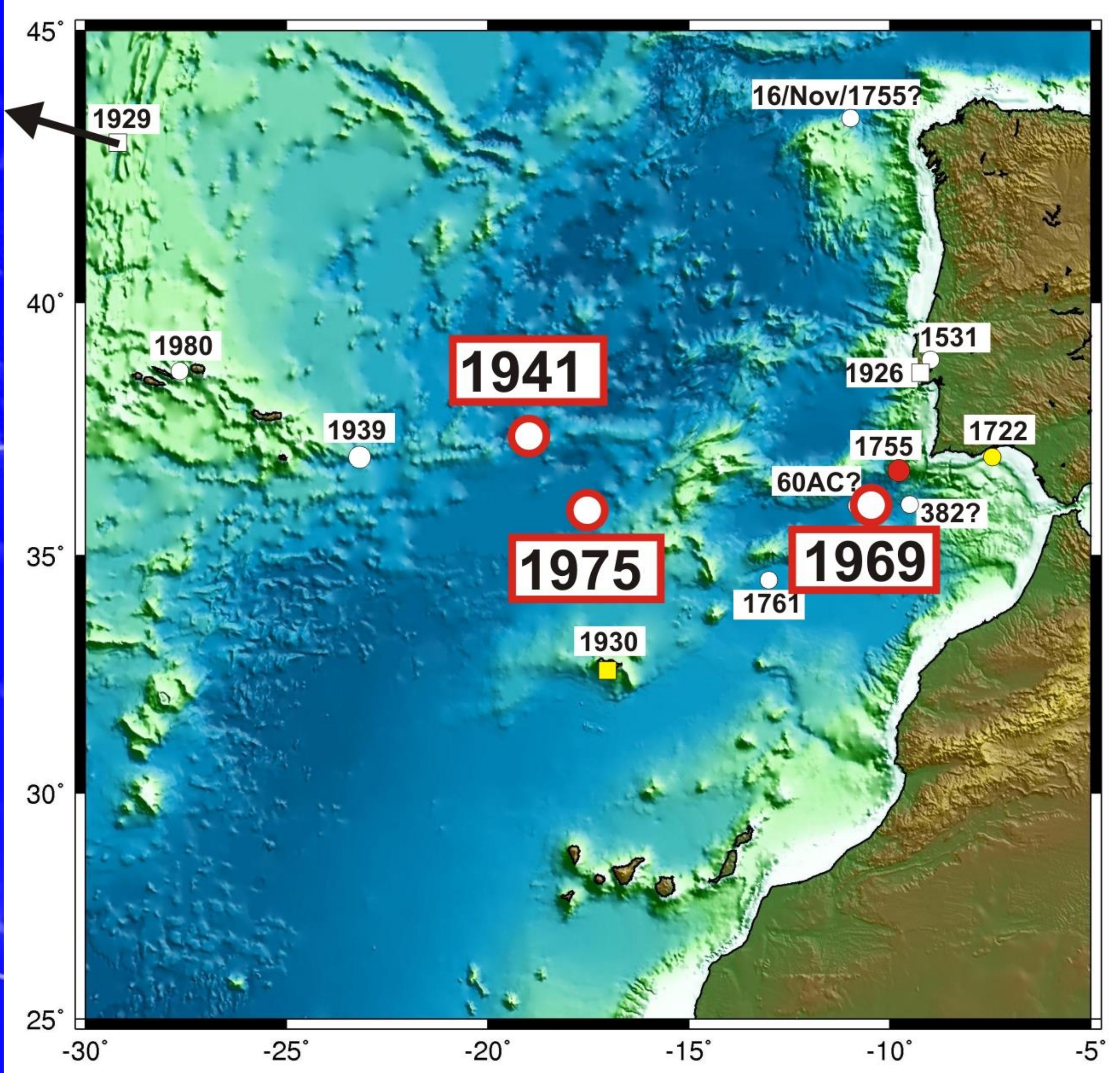
- **The 1st November 1755 earthquake generated also a destructive tsunami devastating to the coasts of Portugal, Spain and Morocco. It was observed in UK and across the Atlantic in the Caribbean**

But 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. INTRODUCTION

➔ The Portuguese Tsunami Catalogue (Baptista et al., 2009) shows that in the XXth century alone 3 tsunamis were generated along the Nubia-Eurasia plate boundary by earthquakes with magnitude larger than 7.7



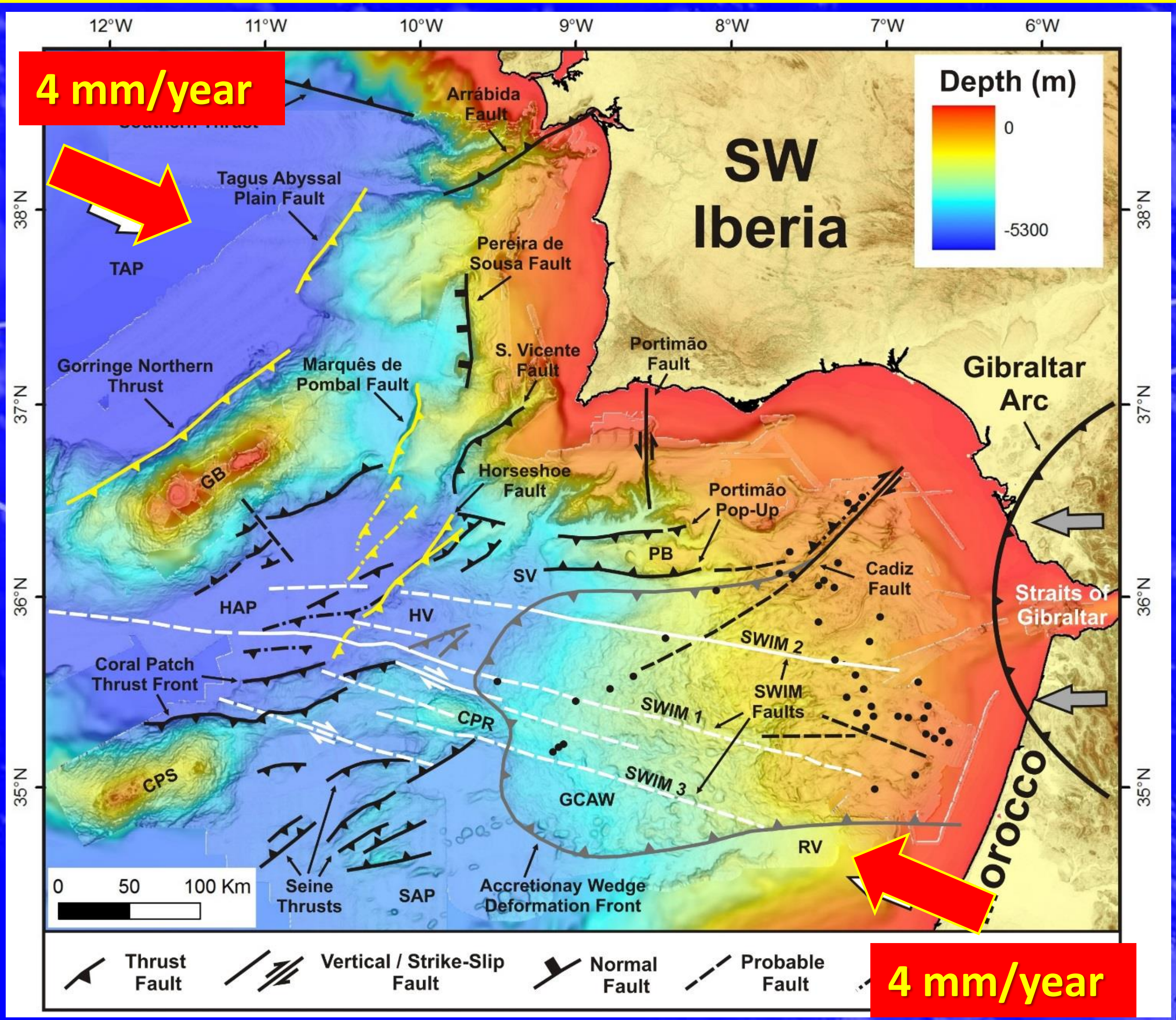
1941 – 45 cm amplitude measured in Casablanca

1969 - 60 cm amplitude measured in Casablanca and recorded in several tide gauges

1975 – 35 cm amplitude measured in Horta (Azores); 30 cm amplitude measured in Lagos (S Portugal mainland)

1. INTRODUCTION

- **The Gulf of Cadiz domain, SW Iberia, is the most dangerous area as regards earthquake and tsunami hazard, being able to generate large magnitude earthquakes and destructive tsunamis**



1. INTRODUCTION

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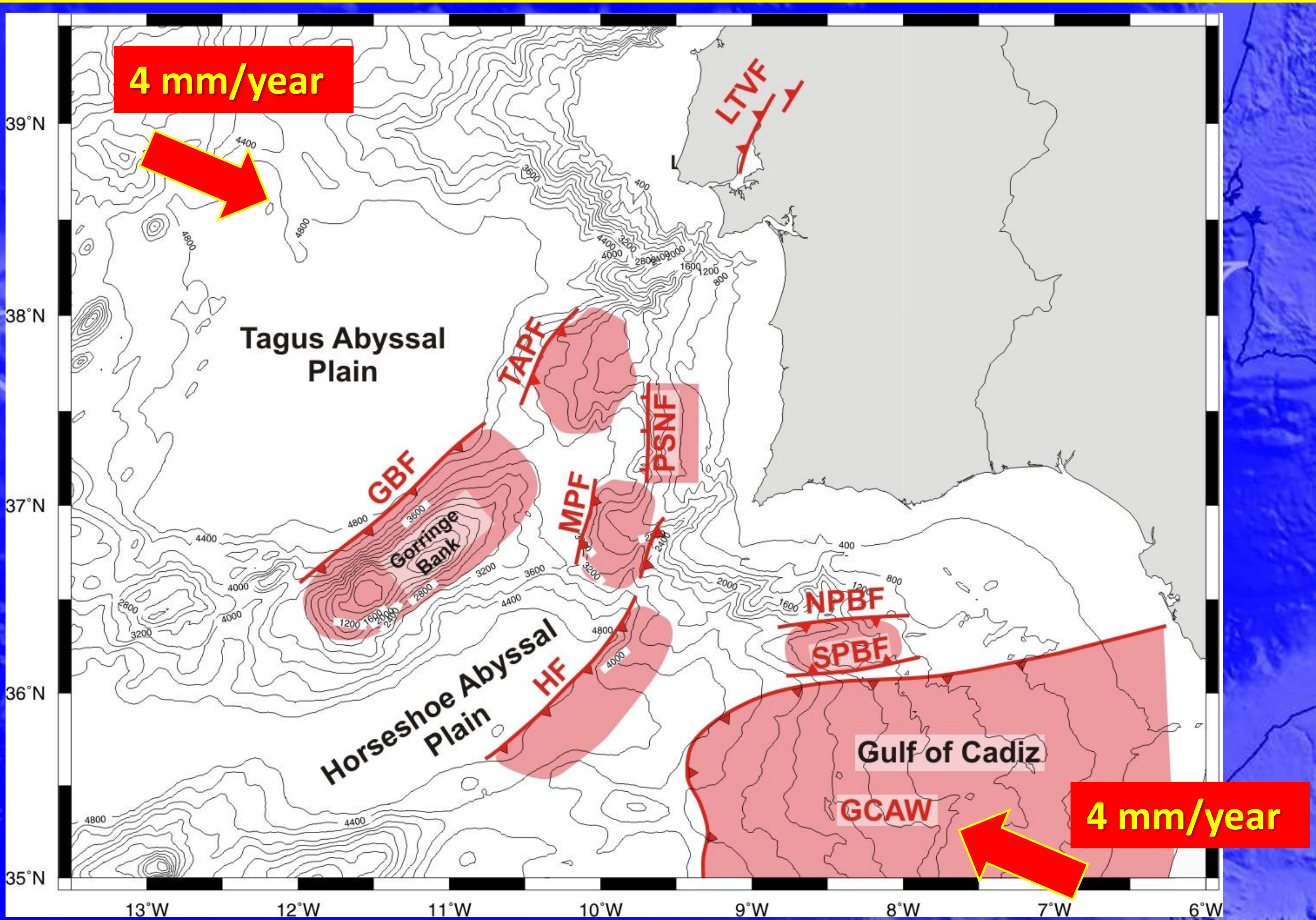
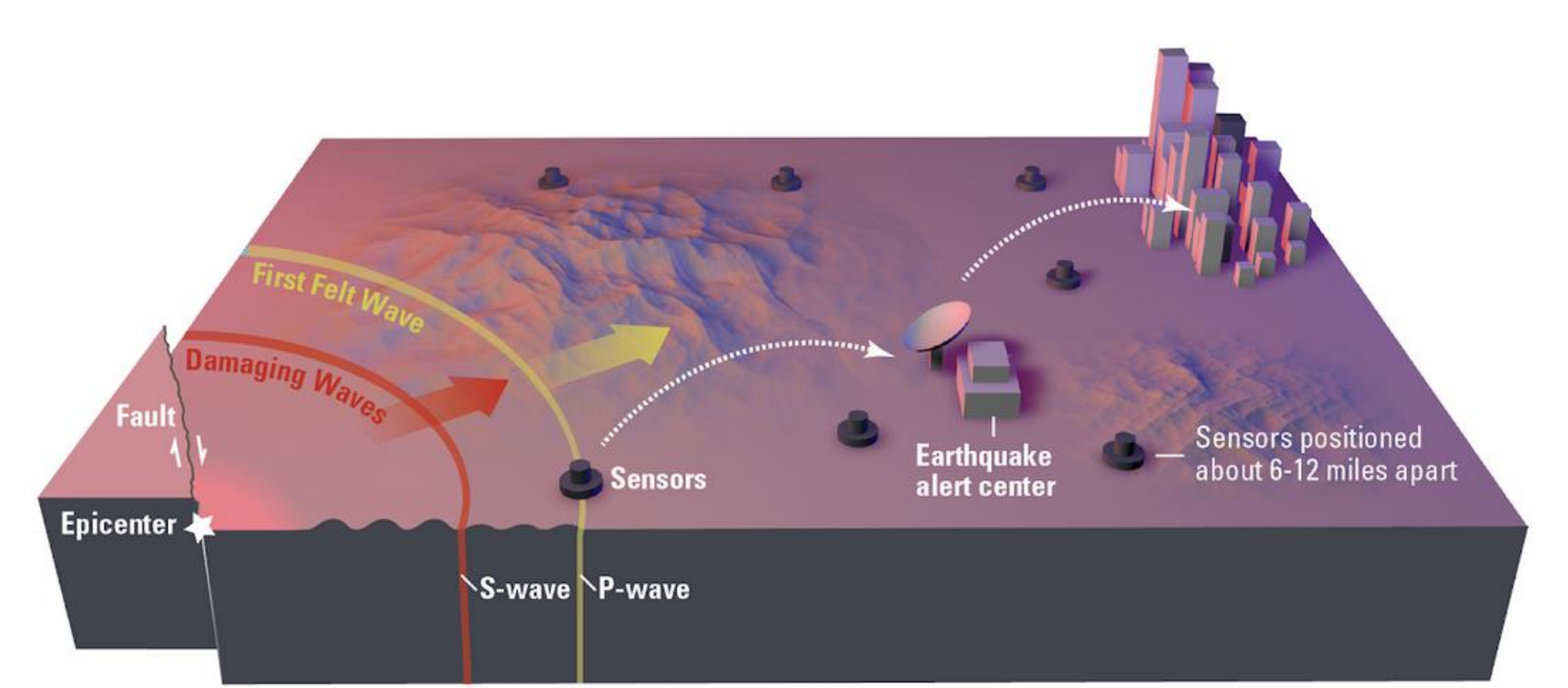


- **The impacts caused by destructive earthquakes originated in the offshore area along the Nubia-Eurasia plate boundary can be mitigated by effective earthquake early warning system (EEWS) that would benefit (but not only) Portugal, Spain and Morocco. The Portuguese EEWS is currently under testing at IPMA.**



https://www.caloes.ca.gov/SiteCollectionImages/eew-basics.png

- **The effectiveness of an earthquake early warning system (EEWS) depends on the time between the detection by the seismic network of a large earthquake, using only P-waves, and the arrival time of the most damaging waves, the S-waves.**
- **EEWS that rely on land station observations of strong motion will not profit the regions closest to the epicentre.**

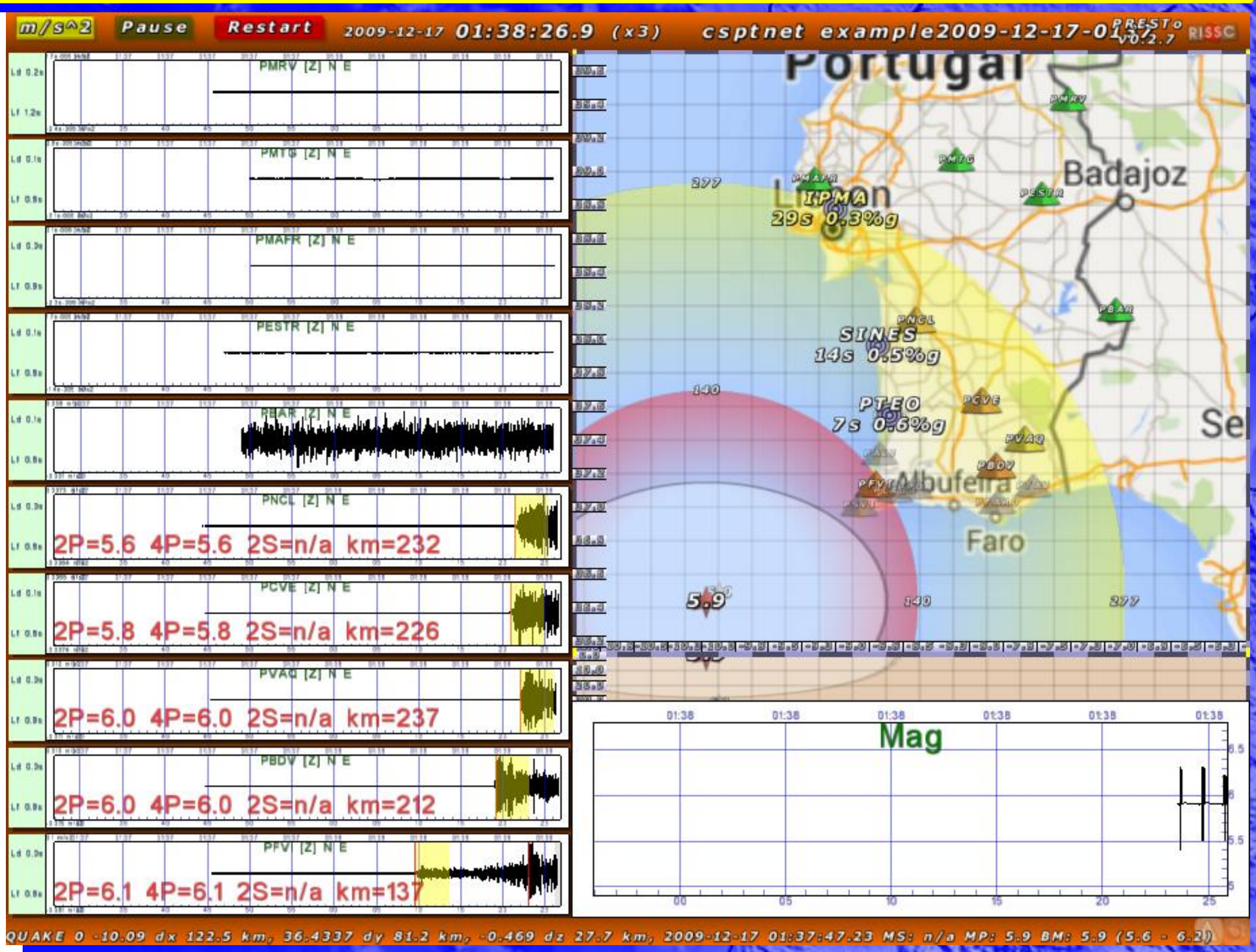
2009-12-17 01:35

SW San Vincent Cape MW5.6 (CMT)

The current land based network EEWS allows, for this offshore event, 14 s advance time at Sines (a major industrial site) and 29 s lead time for Lisbon

First solution

based only on P waves for Mw determination



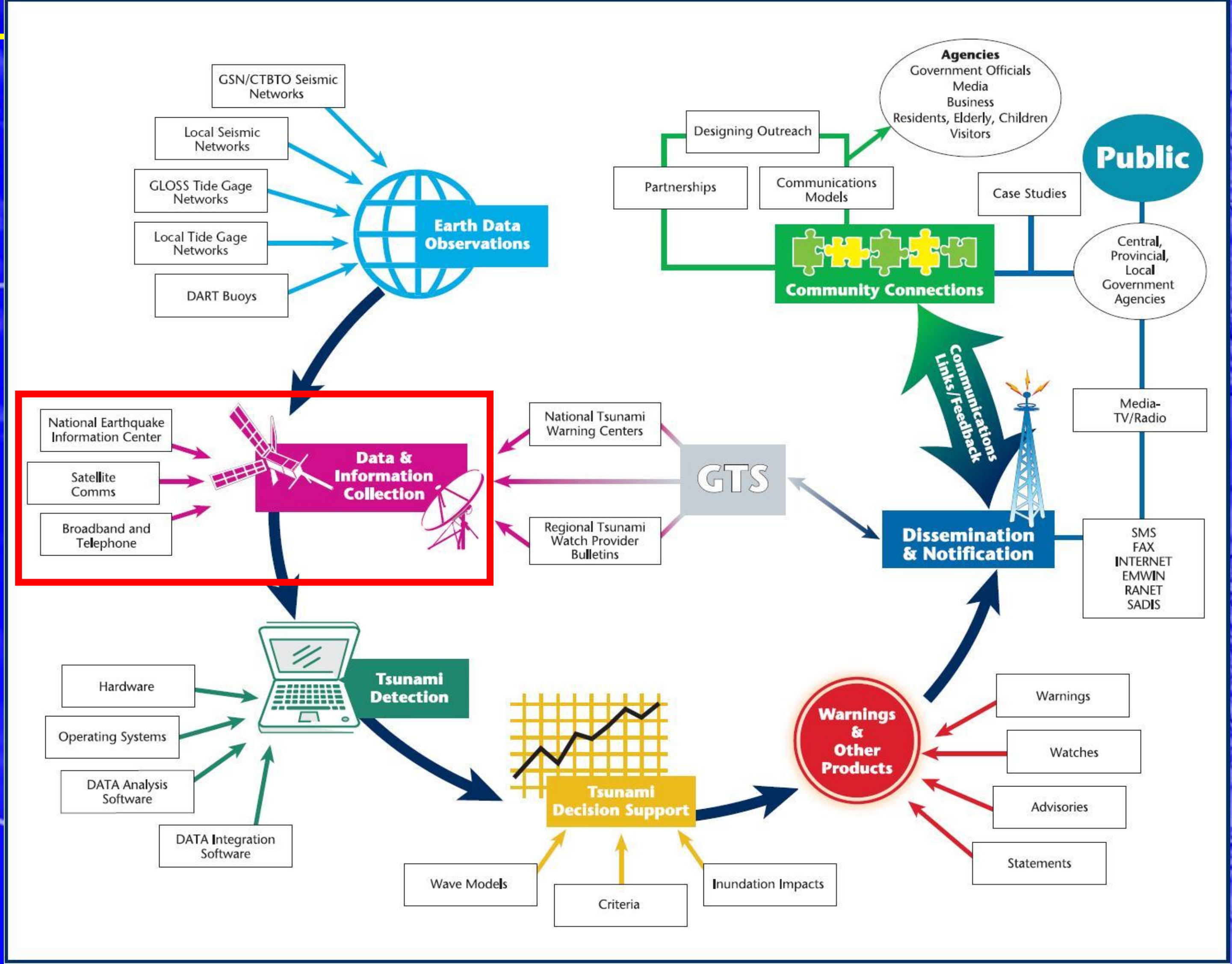
2. MITIGATION

- **The impacts caused by destructive tsunamis originated in the offshore area along the Nubia-Eurasia plate boundary can be mitigated by an effective tsunami early warning system (TWS) that would benefit Portugal, Spain and Morocco and the whole North Atlantic coast.**

TSUNAMI WARNING CENTER REFERENCE GUIDE
U.S. Indian Ocean Tsunami Warning System Program
2007
Printed in Bangkok, Thailand

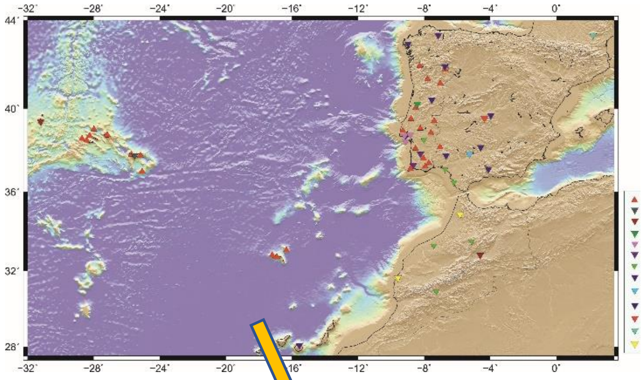
This the 2007 vision of an <u>end-to-end Tsunami Warning System</u>, from the Earth observation to the coastal communities

The red box needs to be updated if cabled sensors and communications are considered as part of the TWS

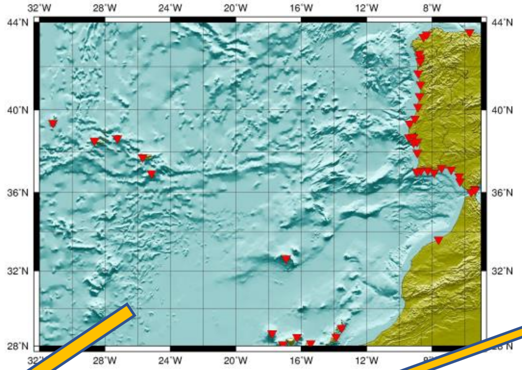


- **IPMA is currently operating the Pt-TWS. It provides to each forecast point, or to each stretch of the coast, information on the estimated arrival time (ETA) of the tsunami and its severity.**

Seismic network



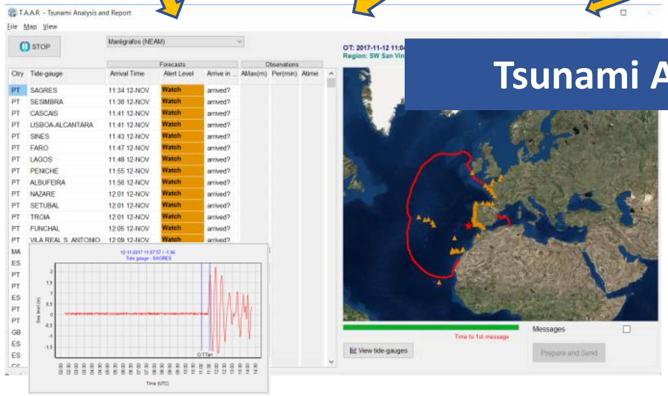
Tide-gauge network



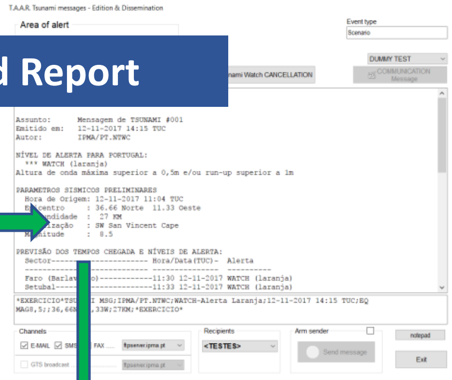
Decision Matrix

Decision Matrix for the NE Atlantic

Depth (km)	Epicentre Location	Earthquake Magnitude (Mw)	Tsunami Potential	Type of tsunami message: Local	Regional	Ocean-wide
<100Km	Offshore or close to the coast (<=40Km inland)	≥5.5 and <6.5	Weak potential for a destructive local Tsunami	Advisory	Information	Information
		≥6.5 and <7.0	Potential for a destructive local Tsunami	Advisory	Information	Information
	Offshore or close to the coast (<=100km inland)	≥7.0 and <7.5	Potential for a destructive local Tsunami	Watch	Advisory	Information
		≥7.5 and <7.9	Potential for a destructive regional tsunami	Watch	Watch	Advisory
		≥7.9	Potential for a destructive ocean-wide tsunami	Watch	Watch	Watch
[illegible]Km	Offshore or inland (<=100Km inland)	≥5.5	No tsunami potential	Information	Information	Information



Tsunami Analysis and Report

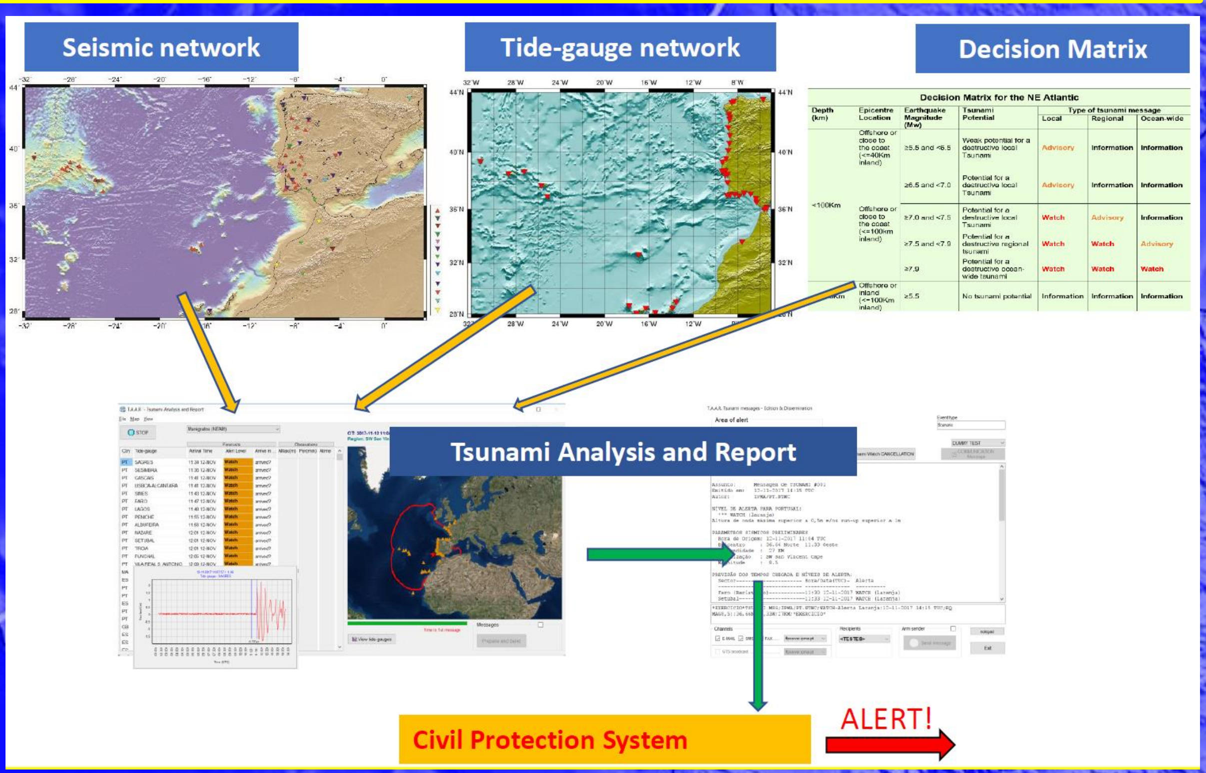


Civil Protection System

ALERT!

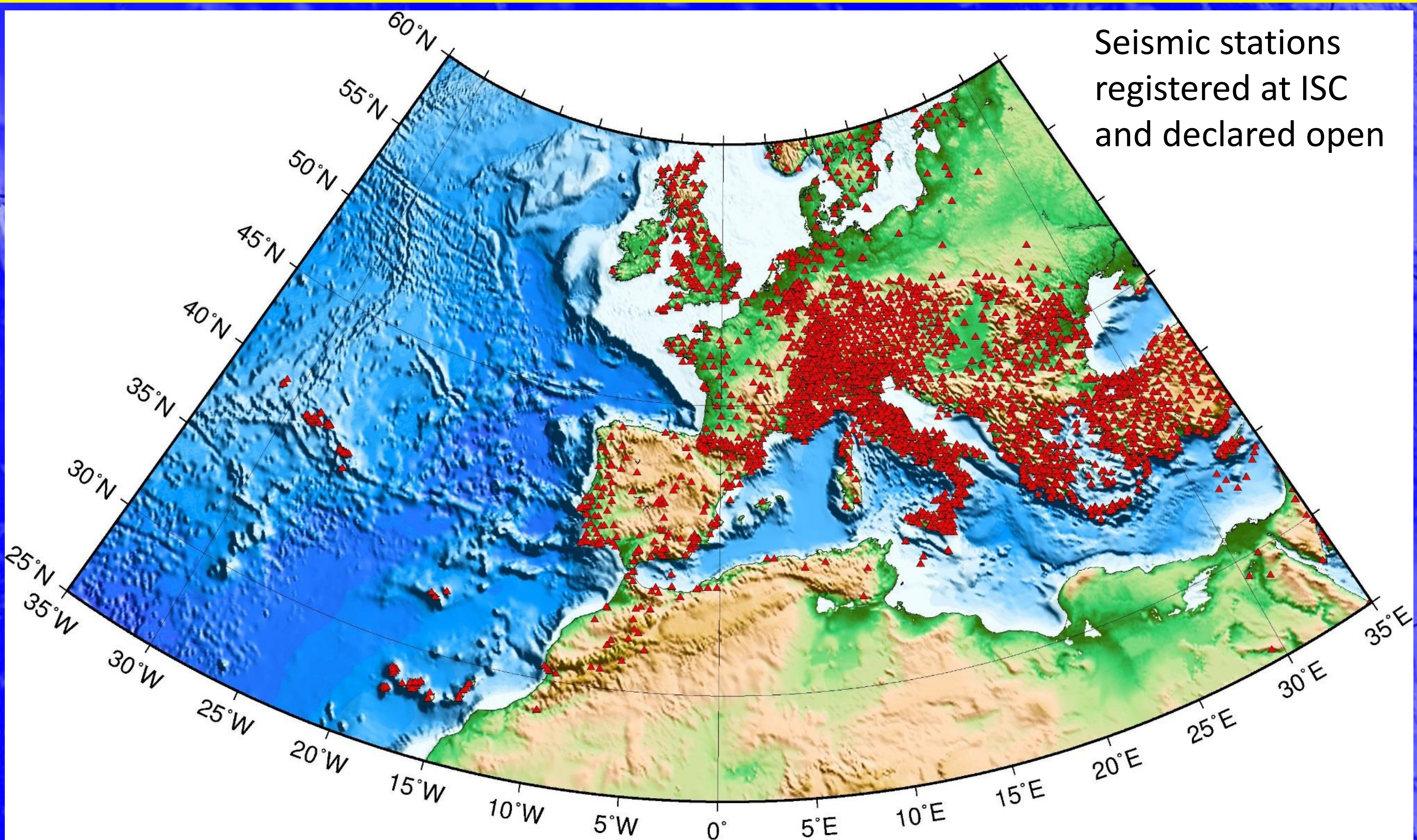
2. MITIGATION

- At the Pt-TWS, a confirmation that a tsunami was generated, and an evaluation of its amplitude, are only obtained after the recordings from the closest coastal tide-gauge are analysed. Hence, this information will not benefit large stretches of coastline
- The effectiveness of this confirmation message can be evaluated by the time it takes for the tsunami to reach the closest tide gauge
- TWS that rely on coastal tide gauges only will not benefit the regions that are hit first by the tsunami



- **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.**

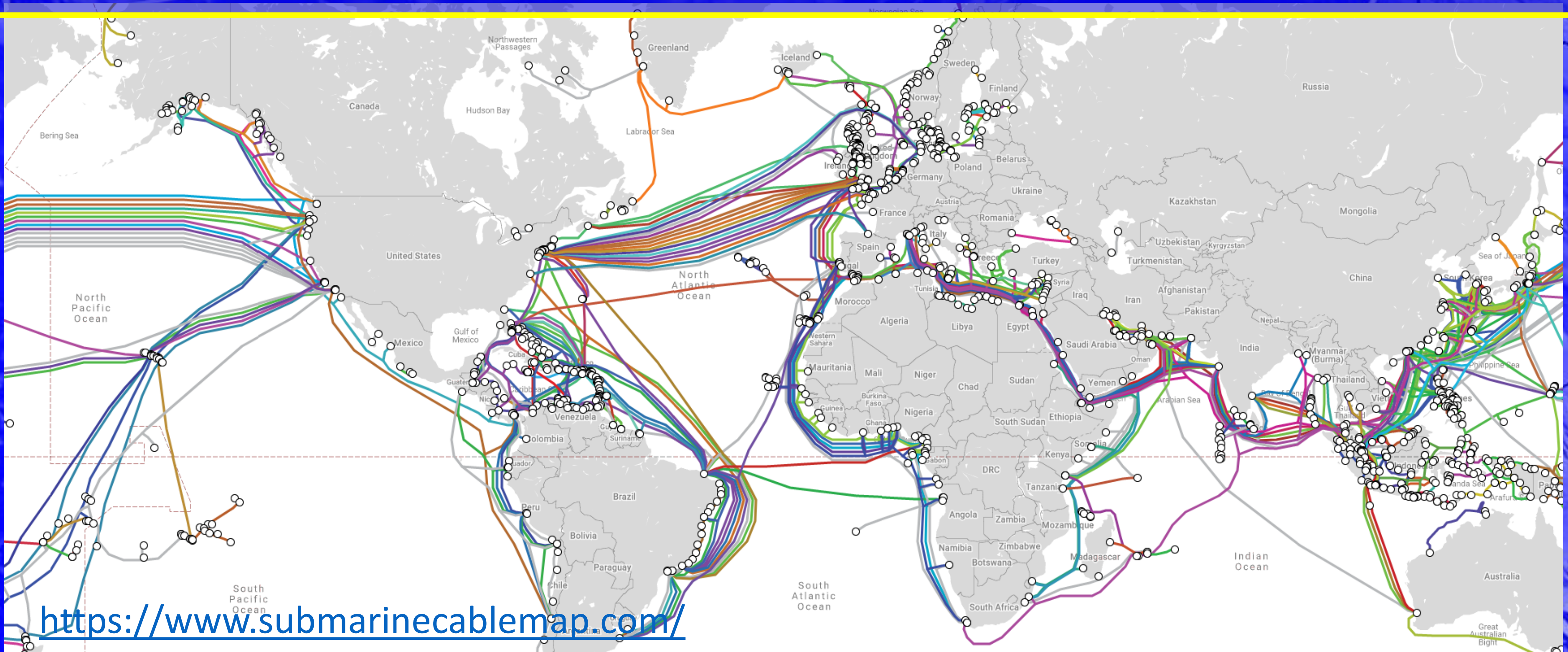
➔ Hence, the earthquake parameters computed fast by the operational centres, epicentre, focal depth, magnitude, are less than optimal



Seismic stations registered at ISC and declared open

2. MITIGATION

- **All the shortcomings and difficulties that EEWS and TWS suffer when monitoring offshore events can be mitigated by deploying sensors integrated in the commercial telecom submarine cables to be installed in the future, without causing any reduction of the reliability, lifetime, operational and functional requirements demanded by telecom operators for the telecom system**
- **Being closer to the tectonic sources, such sensors (and the cable itself) will record the geophysical parameters and transmit them to land much faster than the speed of destructive waves, providing the processing centres with critical lead time**



https://www.submarinecablemap.com/

- **SMART stands for Science Monitoring and Reliable Telecommunications**
- **The SMART approach to the geophysical monitoring of the oceans has been proposed and defended for more 10 years by JTF, a Joint Task Force led by three U.N. agencies (ITU, WMO and UNESCO-IOC), Howe et al., 2019.**

frontiers in Marine Science

REVIEW
published: 02 August 2019
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Check for updates

SMART Cables for Observing the Global Ocean: Science and Implementation

Bruce M. Howe[1], Brian K. Arbic[2], Jérome Aucan[3], Christopher R. Barnes[4], Nigel Bayliff[5], Nathan Becker[6], Rhett Butler[7], Laurie Doyle[8], Shane Elipot[9], Gregory C. Johnson[10], Felix Landerer[11], Stephen Lentz[12], Douglas S. Luther[13], Malte Müller[14], John Mariano[15], Kate Panayotou[16], Charlotte Rowe[17], Hiroshi Ota[18], Y. Tony Song[11], Maik Thomas[19,20], Preston N. Thomas[21], Philip Thompson[22], Frederik Tilmann[19,20], Tobias Weber[19] and Stuart Weinstein[6] on behalf of the Joint Task Force for SMART Cables*

➔ Technology exists and has been used in dedicated cables in Japan, Canada and the US

Fig. 5 A photograph of the cabled seismometers for deployment in the Japan Sea. The cabled seismometers have already connected to single armored optical fiber submarine cables. The size of the pressure vessels is 13 cm in diameter and 50 cm in length

Shinohara et al., Mar. Geophys. Res., 2014

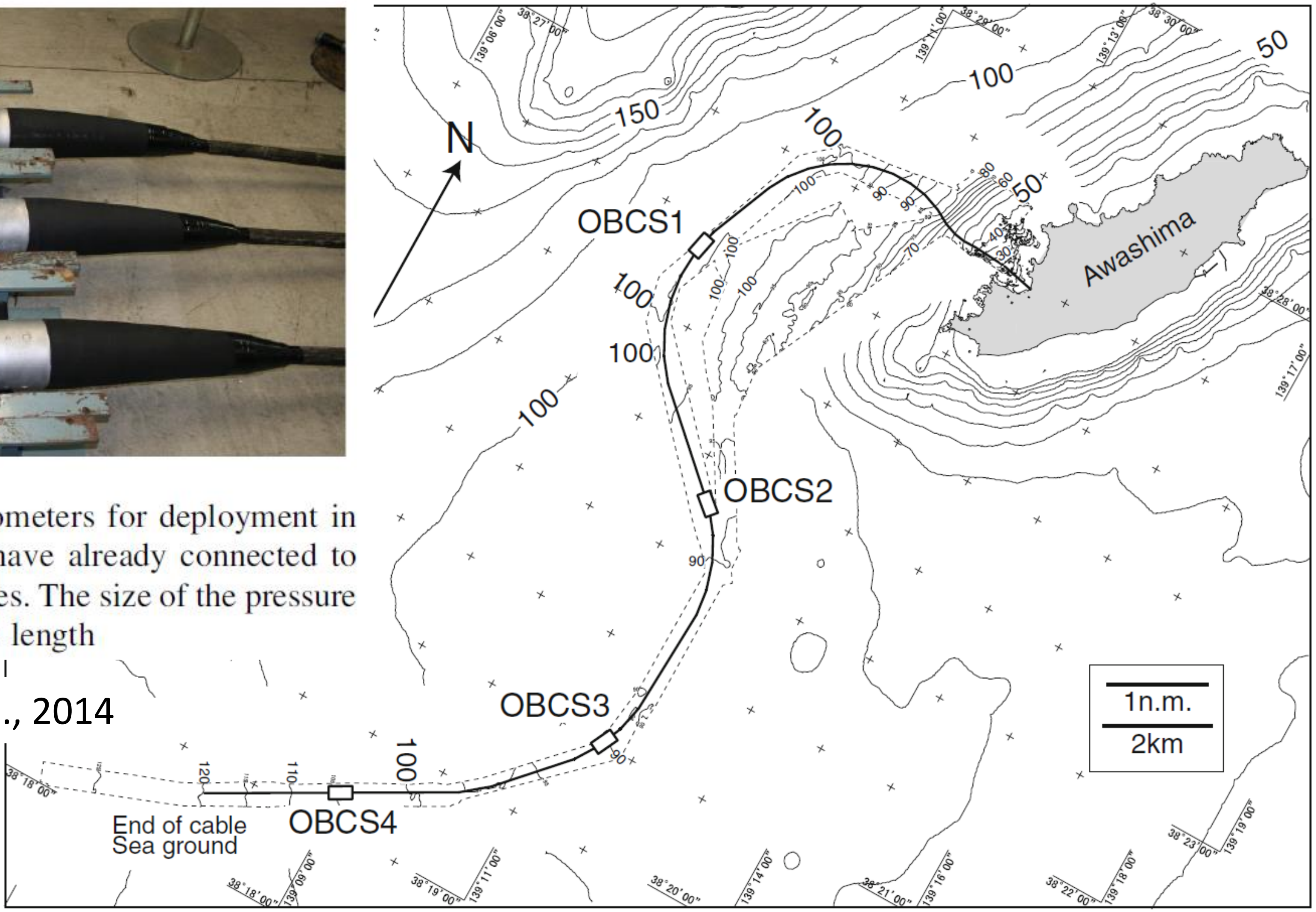

Fig. 9 Position of the cabled seismometers and the cable route with seafloor topography. Numerals indicate water depth. Marine surveys before the deployment were carried out in the region surrounded by dotted line. The system is landed on the west coast of the Awashima, and has a total length of 25 km. Sea ground is installed at the offshore end of the cable. The landing station is supplying power with minus voltage compared to that of sea water. A part of the system which lies at water depths greater than 30 m is completely buried 1 m below the seafloor

3. BEING SMART

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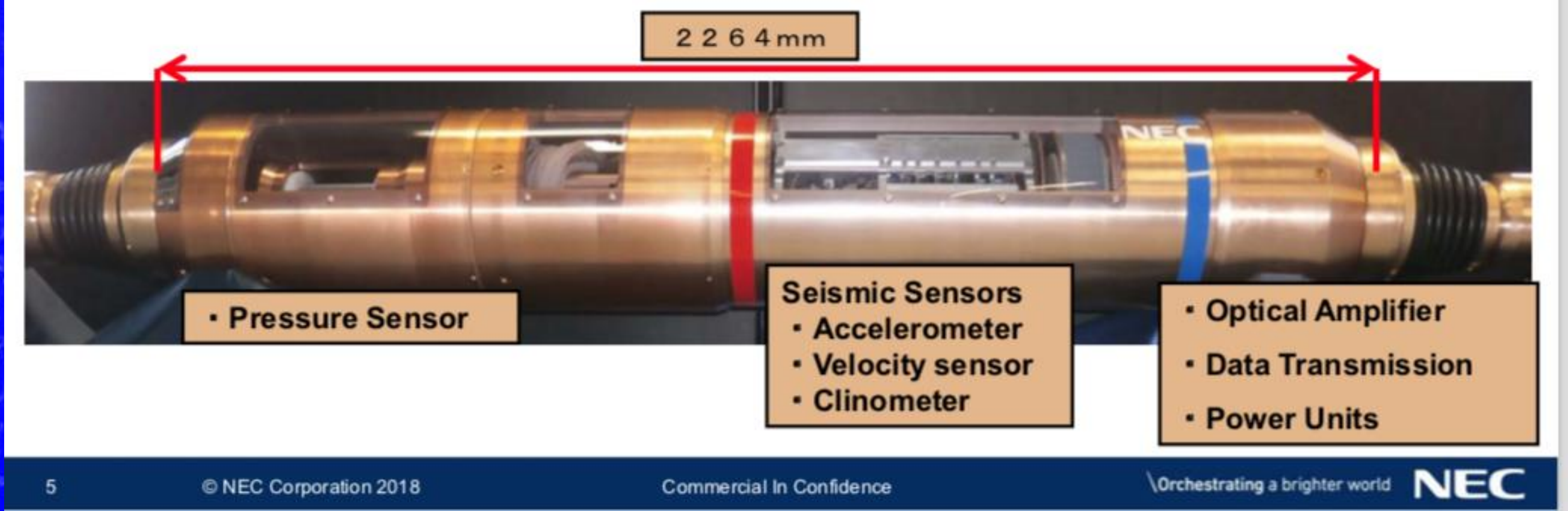
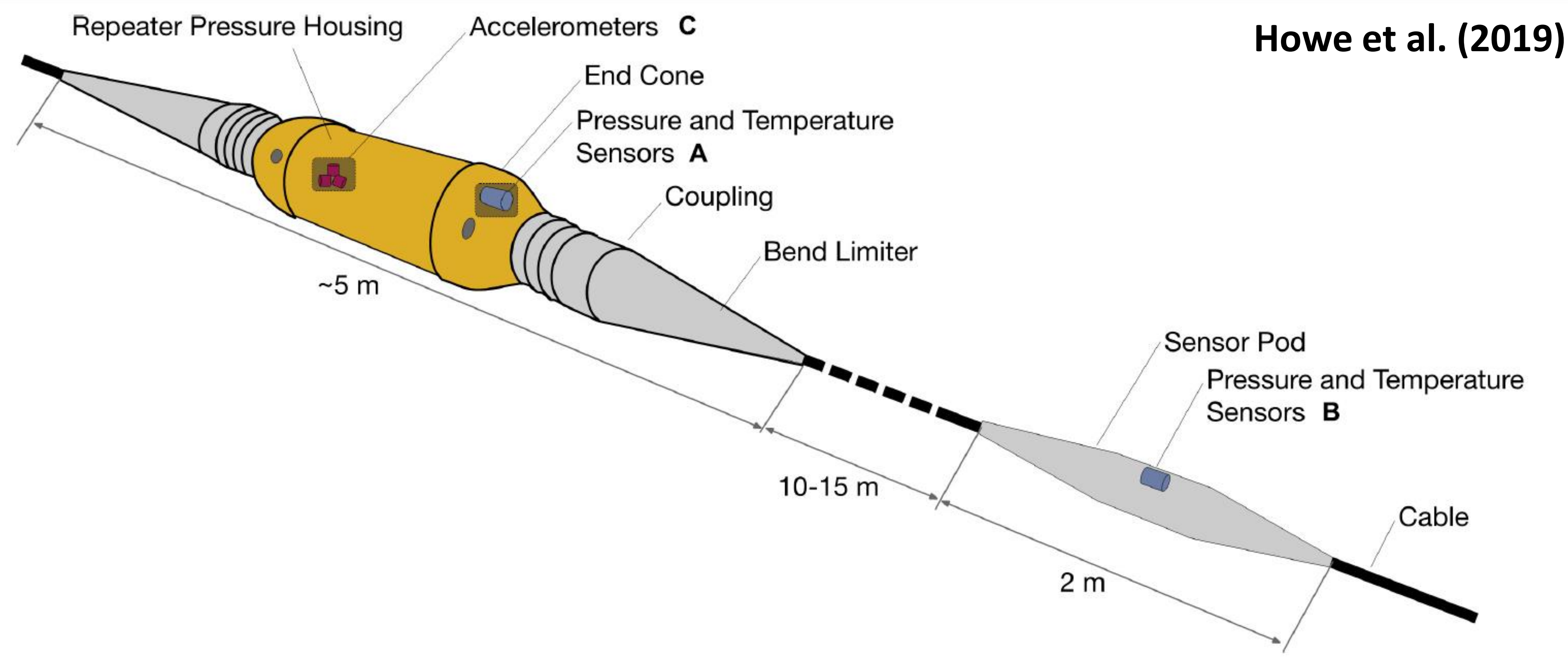


➔ Basic sensor payload of one UCO (Universal Cable Observatory) should include:

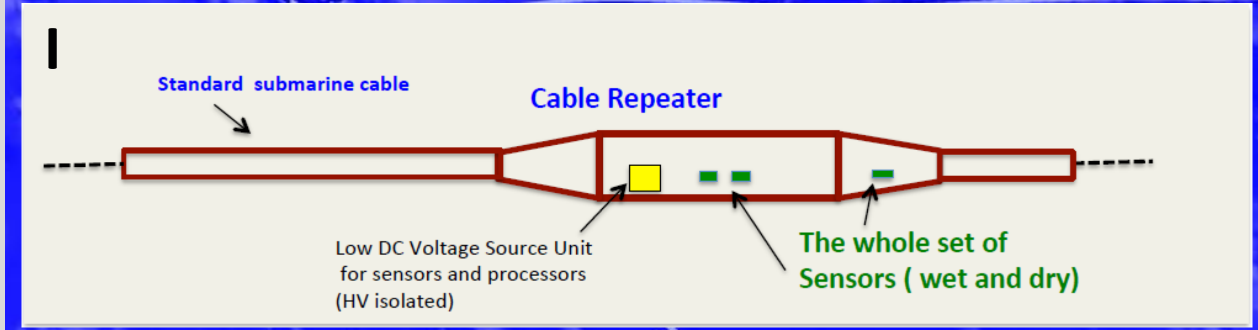
- **3/6 component ground motion sensors**
- **Absolute pressure gauge**
- **Temperature**

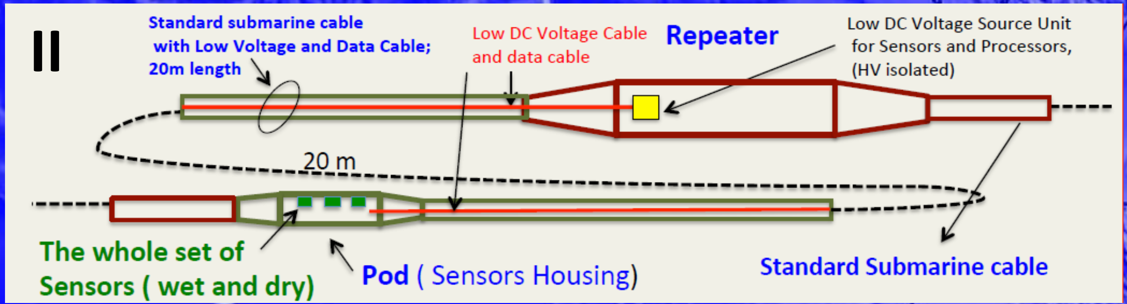


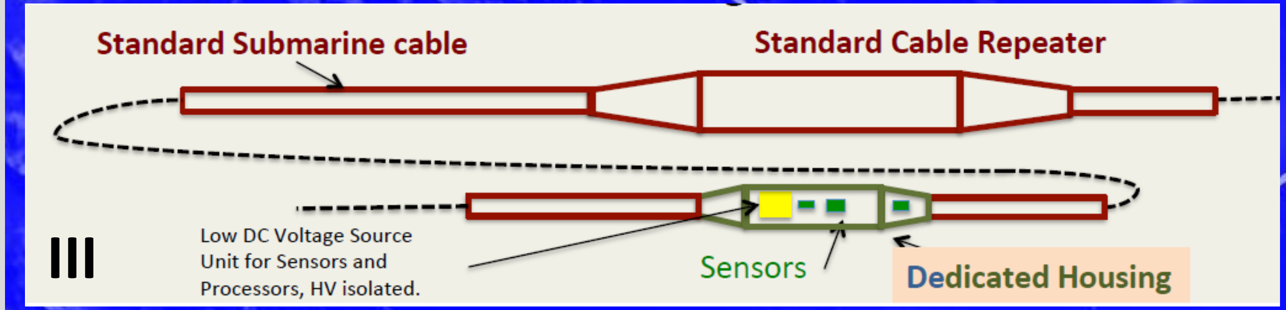
Howe et al. (2019)

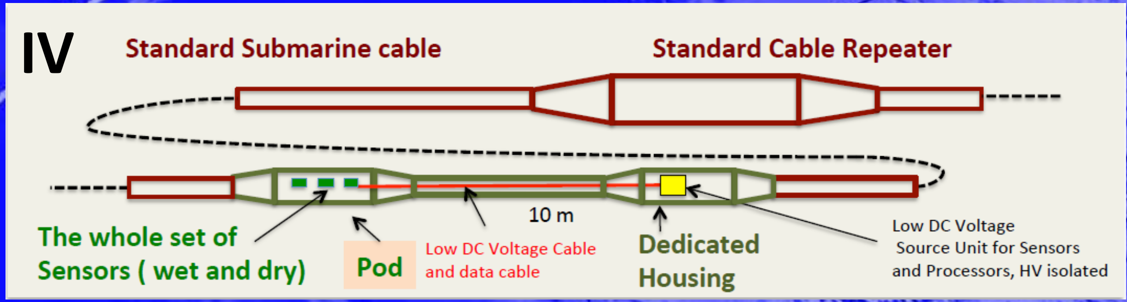
FIGURE 14 | Illustration of a repeater housing showing two possible sensor mounting locations: **(A)** on the end of repeater housing under the bell housing or **(B)** in an external pod. Accelerometers are mounted inside the pressure housing **(C)**. Permission obtained for use of figure.

- **The SMART sensors, to be accepted by operators to be installed in future submarine cables, cannot compromise the commercial traffic. They must be reliable, have long lifetime and interfere with telecom hardware the least possible. They must <u>not cause any reduction of reliability, lifetime and functional requirements</u> demanded by telecom operators for the telecom system**
- **For this purpose, several system configurations can be suggested to telecom operators**

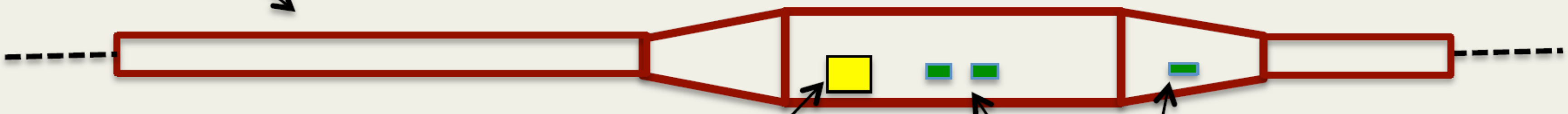








Configuration I – Submarine Cable Repeater with Sensors



Notes:

1 All **Wet Sensors** (with external contact with sea water) and **Dry Sensors** (without external contact) are inside the Standard Repeater. The Sensors, inside the standard Repeater, are fed from Low Voltage DC Source (isolated from HV).

2 Data from Sensors, after being processed, is permanently transmitted in real time, for example, via a dedicated smart WL, inside one telecom fibre pair, using **O**ptical **A**dd **D**rop **M**ultiplex and TDMA or Ethernet long distance facilities. An alternative solution may consider a dedicated fibre pair, using one WL per Smart Repeater (telecom repeater with Sensors). This solution has the advantage of having a dedicated fibre pair, separated from the other telecom fibre pairs. The use of existing auxiliary data transmission facilities to control the telecom repeater parameters, could also be evaluated as another alternative.

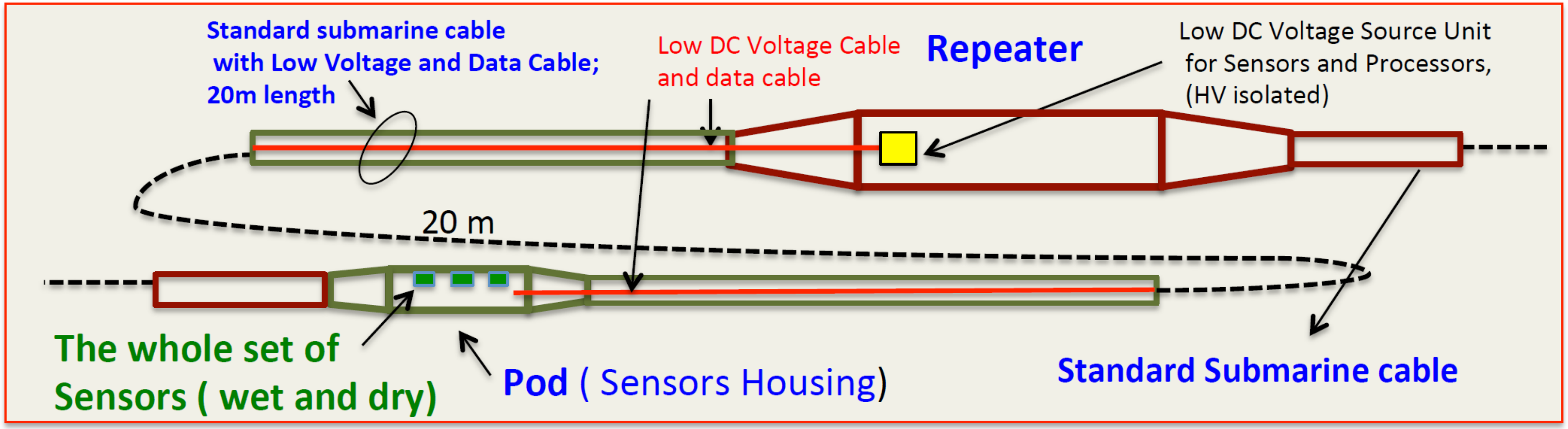
POSITIVE:

No need of additional undersea Housing. The Housing of the standard repeater is used.

NEGATIVE:

A. Power feeding scheme inside the cable repeater is adjusted and used to feed the sensors and its auxiliary equipment.
B. Standard telecom cable repeaters need to be adjusted/modified for powering the Sensors and Transmit its data.
C. Limitation for some type of sensors, for ex. temperature.
D. Positioning of Sensors in the standard Repeater may be conditioned by space and mechanical repeater design.

Configuration II – Repeater + Pod with Sensors



Notes:

1 All **Wet Sensors** (with external contact with sea water) and Dry Sensors (without external contact) are inside the **Pod**. This may facilitate the mechanical installation of Wet Sensors and the use of Temperature Sensors (heat dissipation). **The standard submarine cable passes through the Pod.** Sensors, inside the **Pod (housing for sensors),** are fed by Low Voltage DC Source (isolated from HV) positioned inside the telecom Repeater, using a dedicated cable positioned along the standard submarine cable (about 20m long).

2 Data from Sensors, after being processed by a dedicated unit, inside the **Pod**, is connected to the Repeater via a Data cable and from there transmitted via a dedicated WL, used for all Smart Repeaters, using **O**ptical **A**dd **Drop M**ultiplex and TDMA or Ethernet long distance facilities. An alternative solution could consider a dedicated fibre pair, using one WL for each smart Repeater. This solution has the advantage of having a dedicated fibre pair separated from telecom traffic. The use of existing auxiliary data transmission facilities to control the telecom repeater parameters, could also be evaluated, as another alternative.

POSITIVE:

A. Only the Low DC Voltage Source Unit (HV isolated) and Data Processing and Transmission unit are inside the Cable Repeater.

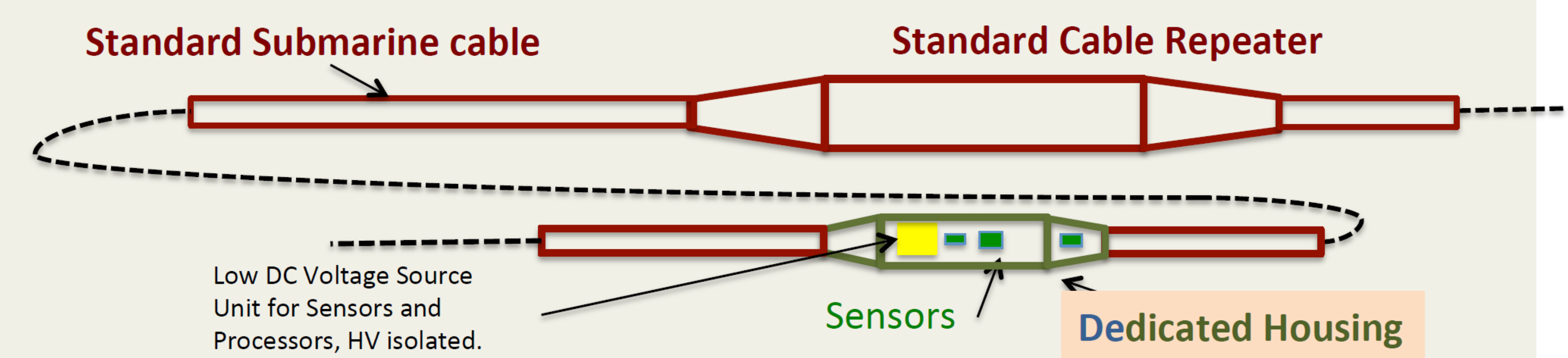
B. All Sensors are in the Pod and fed with Low Voltage from the Telecom Repeater.

NEGATIVE:

A. Power feeding facilities and Data Transmission schemes for Sensors need modification or additional units positioned inside the Telecom Repeater.

B. Additional undersea housing, for Smart application, is required: the Pod.

Configuration III – Dedicated Housing for Sensors



Notes:

1 All **Wet Sensors** (with external contact with sea water) and **Dry Sensors** (without external contact) are inside the **Dedicated Housing.** Sensors are fed by Low Voltage DC Source (isolated from HV), positioned inside the Dedicated Housing. The power is extracted from inside the **Dedicated Housing**, as in a standard repeater, from cable DC current.

2 Data from Sensors, after being processed in the **Dedicated Housing**, is transmitted **via a dedicated fibre pair**, shared by all **Dedicated Housings**. Each **Dedicated Housing** (making use of a Wavelength **O**ptical **A**dd **D**rop **M**ultiplex facility unit, inserted inside the respective **Dedicated Housing**, would access its dedicated WL. An alternative solution could use only one WL (inside one telecom fibre pair), shared for sensors data transmission by all **Dedicated Housings**, using, for example, TDMA or Ethernet long distance facilities. Whenever using a **dedicated fibre pair**, fibre pair optical amplification could be done inside the telecom repeater, as for the telecom fibre pairs, or alternatively, **only** inside the **Dedicated Housings**, if they have a maximum acceptable span separation, allowing to achieve the OSNR necessary for Sensors data transmission. A mix solution may be used, depending of Dedicated Housings layout.

POSITIVE:

A. No modification inside the standard cable repeater

B. There is a potential to insert Dedicated Housings in existing submarine systems, using an available/unused telecom fibre pair as dedicated fibre pair, but requiring a marine intervention to insert the Dedicated Housing.

C. The position of Dedicated Housings is not dependent of Cable Repeater location. Is only dependent from cable route. More than one Dedicated Housing could be potentially used inside a Cable Segment (portion of cable between two cable Repeaters).

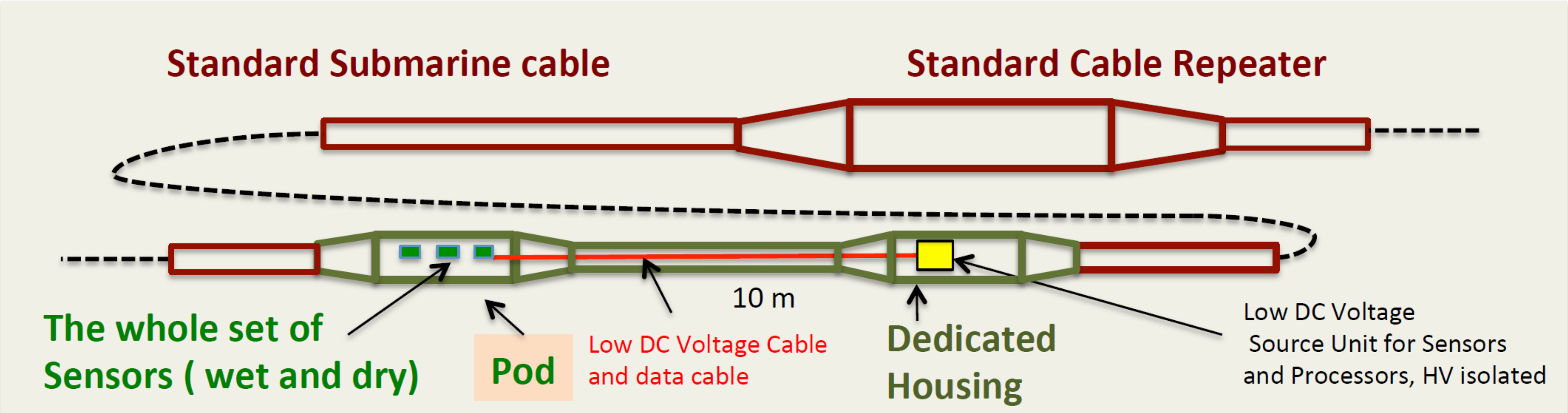
NEGATIVE:

A. An additional undersea housing is required: the Dedicated Housing. Additional overall costs may be involved.

B. Possible limitations for Wet sensors Insertion inside Dedicated Housing (ex. temperature), due to internal heat dissipation.

3. BEING SMART

Configuration IV – Dedicated Housing + Pod with Sensors



Notes:

1 All **Wet Sensors** (with external contact with sea water) and **Dry Sensors** (without external contact) are in the **Pod.** This may facilitate the mechanical installation of Wet Sensors and the use of Temperature Sensors or others (heat dissipation) . **The standard submarine cable passes through the Pod, without any modification.**

2 Sensors, in the **Pod** are fed by DC low Voltage, HV isolated, from **Dedicated Housing** using a low voltage and Data cable positioned along the standard submarine cable (about 10m length).

3 Sensors data transmission, using a **dedicated fibre pair**, or a single WL would be achieved as mentioned for configuration III. The same, as in configuration III, applies for optical amplification, whenever a dedicated fibre pair is used.

POSITIVE:

A. **No modification inside the standard cable repeater** (also applies to Configuration III).

B. **All Sensors are in the POD. Limitations for Wet sensors positioning inside Dedicated Housing** (heat dissipation), **are avoided.**

C. **Dedicated Housing and Pod, could potentially be inserted in existing submarine systems, subject to a marine operation** (also applies to configuration III).

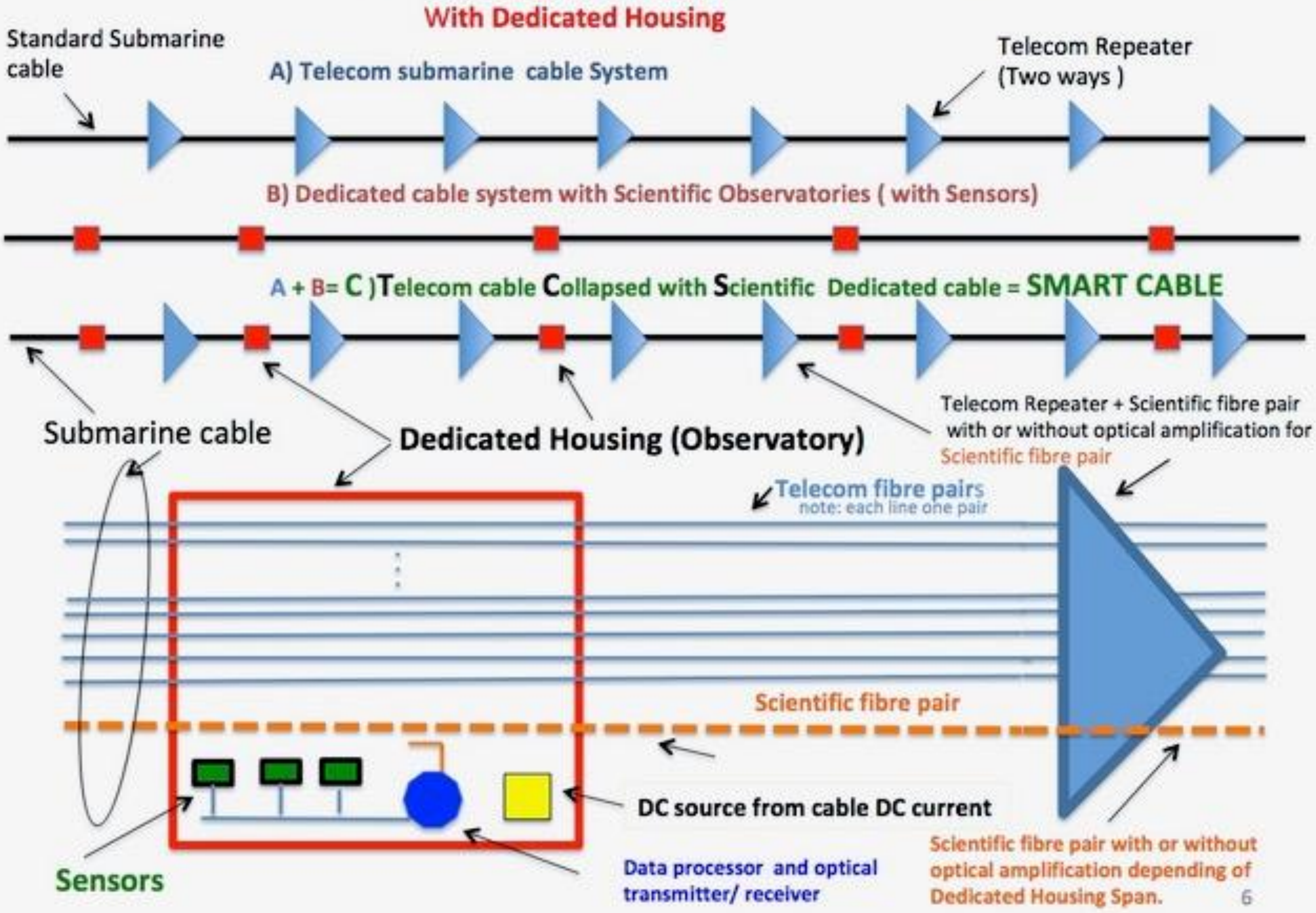
D. **The position of Dedicated Housings is not dependent of Telecom Cable Repeater location, it is only dependent from cable route. More than one Dedicated Housing could be potentially positioned inside a Cable Segment** (portion of cable between two cable Repeaters). Also applies to Configuration III.

NEGATIVE:

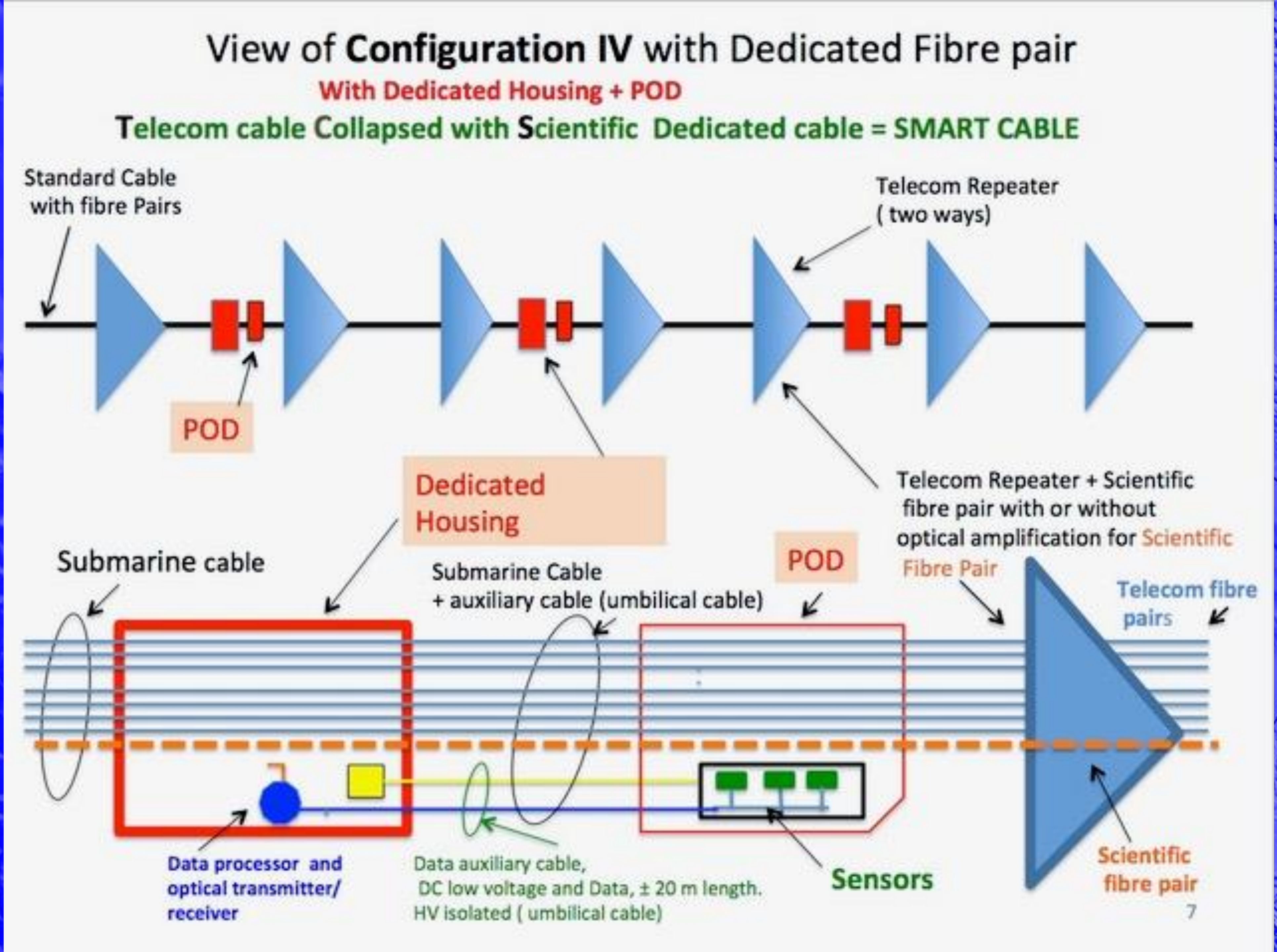
Additional housings, for smart application, are required: Dedicated Housing and Pod. Additional overall costs may be involved.

3. BEING SMART

View of Configuration III with Dedicated Fibre pair



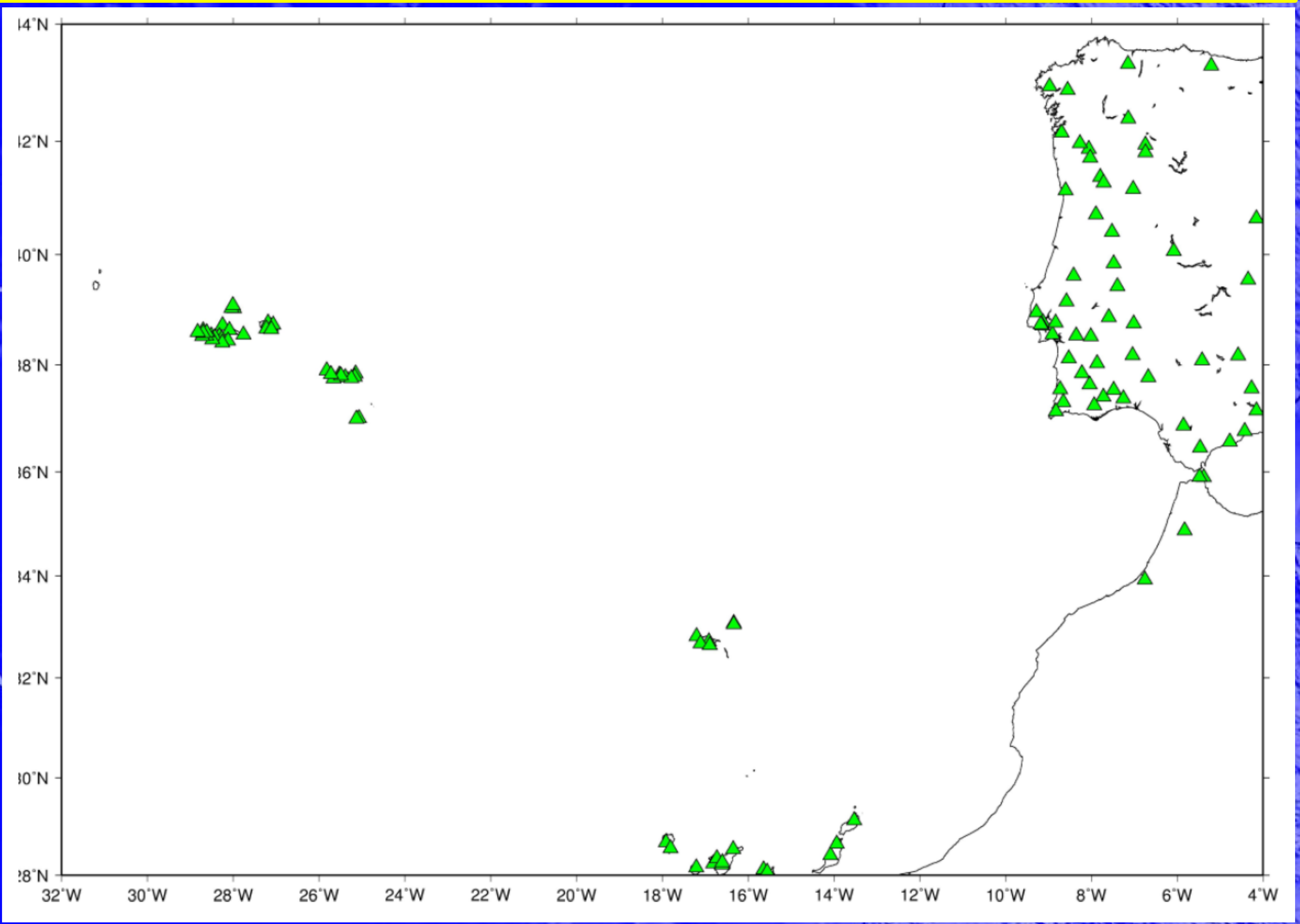
3. BEING SMART



View of Configuration IV with Dedicated Fibre pair
With Dedicated Housing + POD
Telecom cable Collapsed with Scientific Dedicated cable = SMART CABLE
Standard Cable with fibre Pairs
Telecom Repeater (two ways)
POD
Dedicated Housing
Telecom Repeater + Scientific fibre pair with or without optical amplification for Scientific Fibre Pair
Submarine cable
Submarine Cable + auxiliary cable (umbilical cable)
POD
Telecom fibre pairs
Data processor and optical transmitter/ receiver
Data auxiliary cable, DC low voltage and Data, ± 20 m length. HV isolated (umbilical cable)
Sensors
Scientific fibre pair
7

Background

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



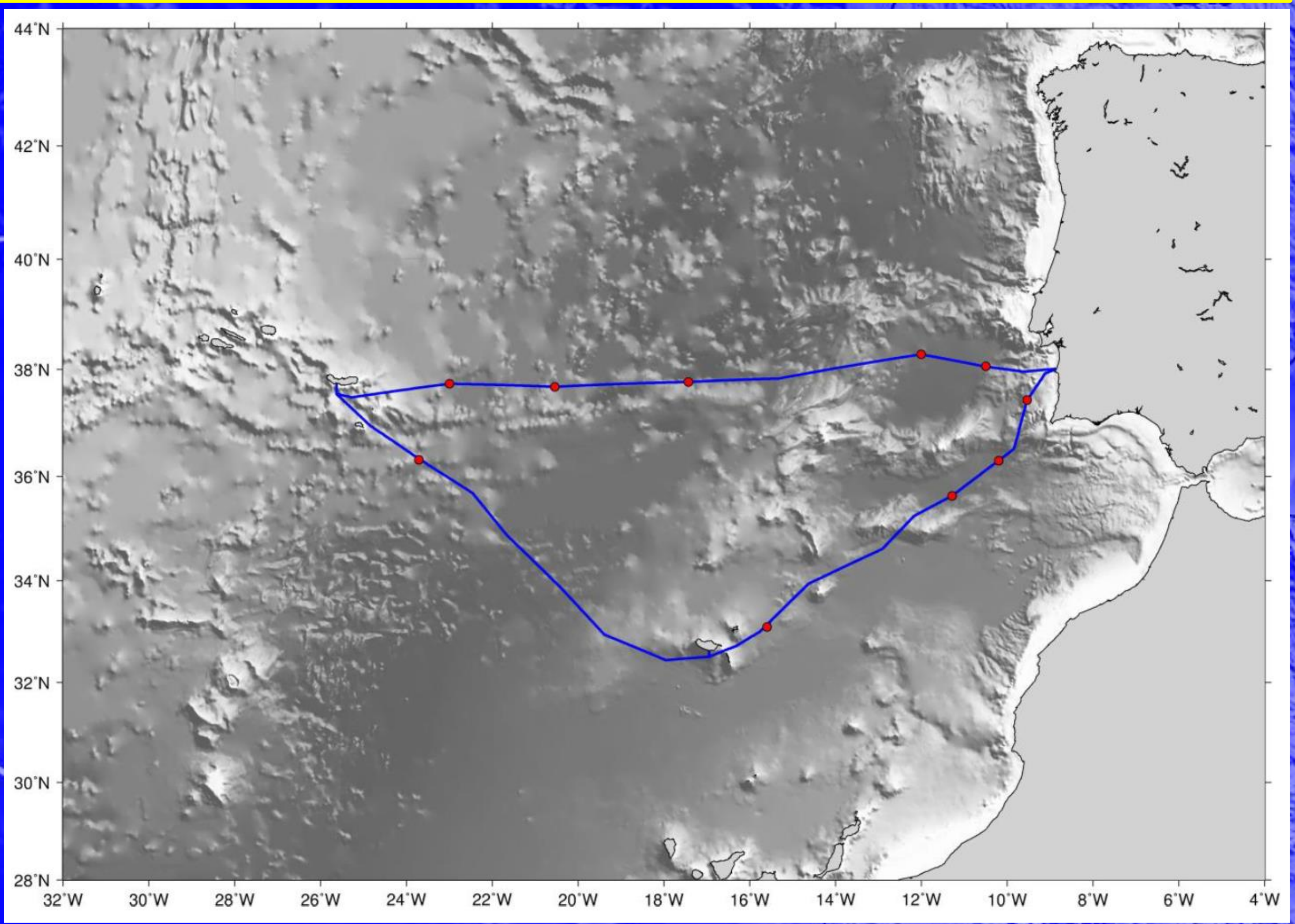
Location of seismic stations monitored by IPMA and used for the fast determination of earthquake parameters

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

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

The SMART-CAM scenario to be investigated

- It comprises 10 UCOs placed along the CAM ring with a distribution controlled by the location of large earthquake and tsunami sources. This scenario was considered as the <u>minimum</u> proposal, not the optimal.

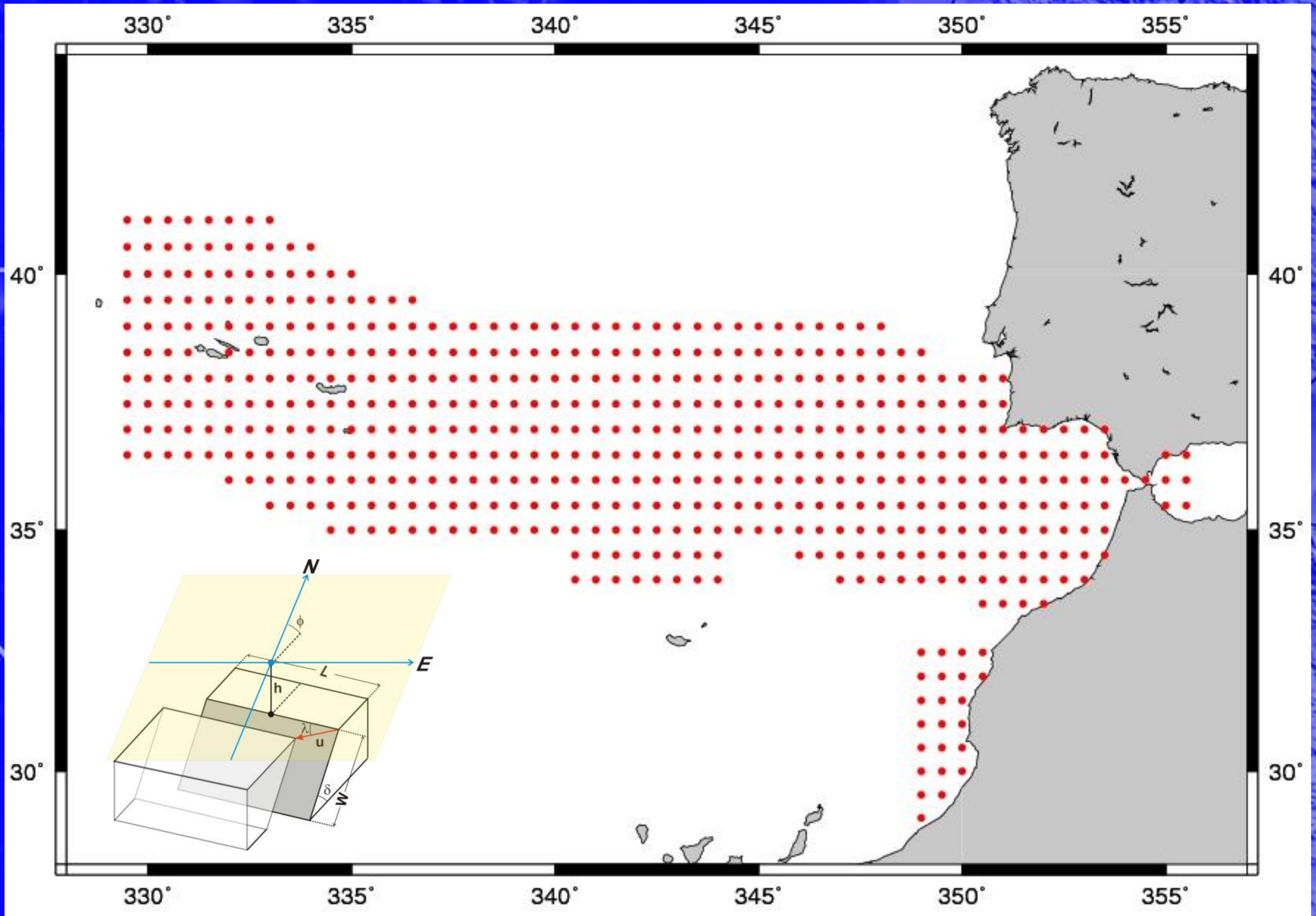


Each UCO is considered to be equipped with 3C ground motion sensors and 1 absolute pressure gauge

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



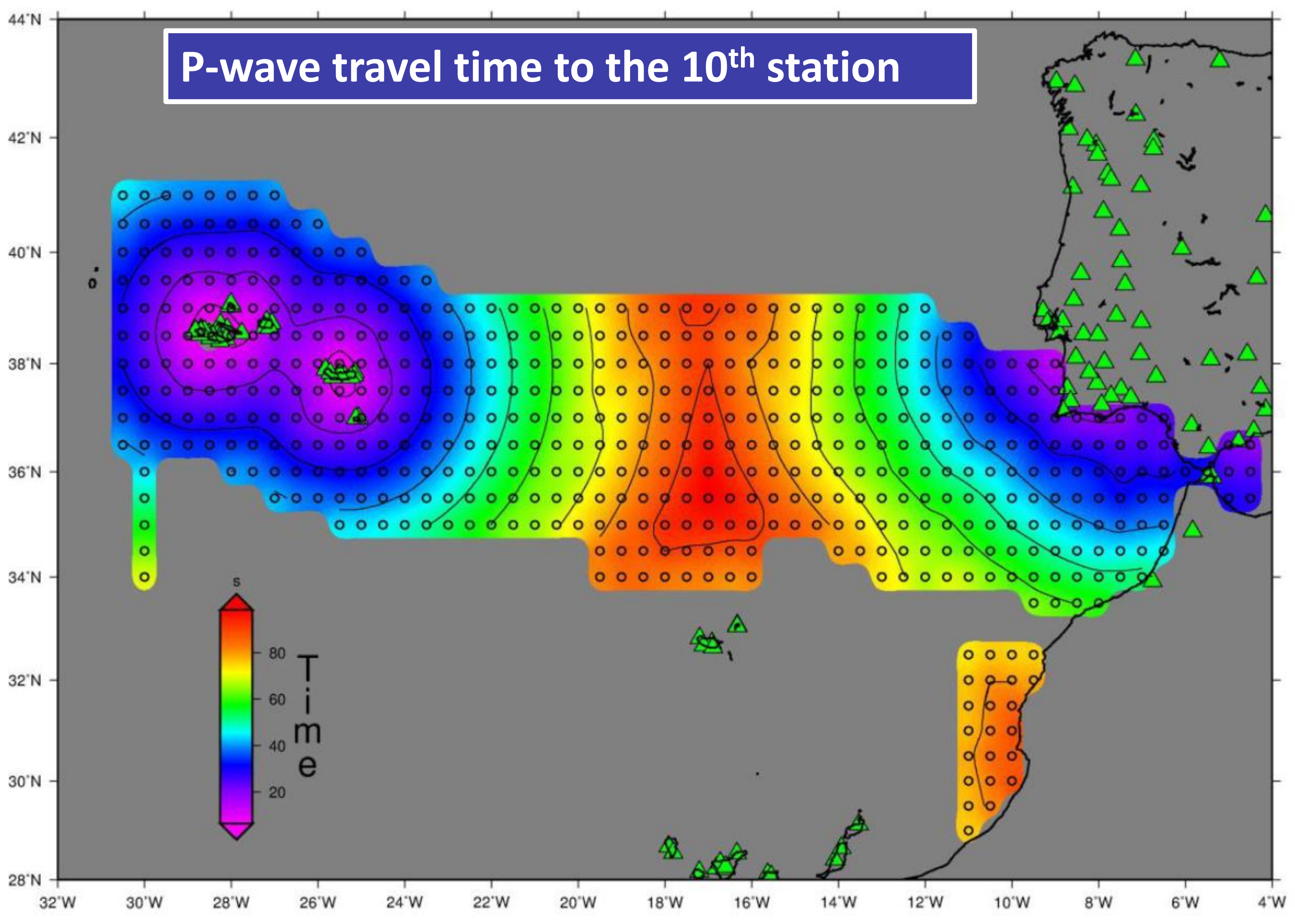
Added value to earthquake monitoring

- We selected 4 parameters relevant to earthquake early warning and to the quality of fast and real-time earthquake parameter computation

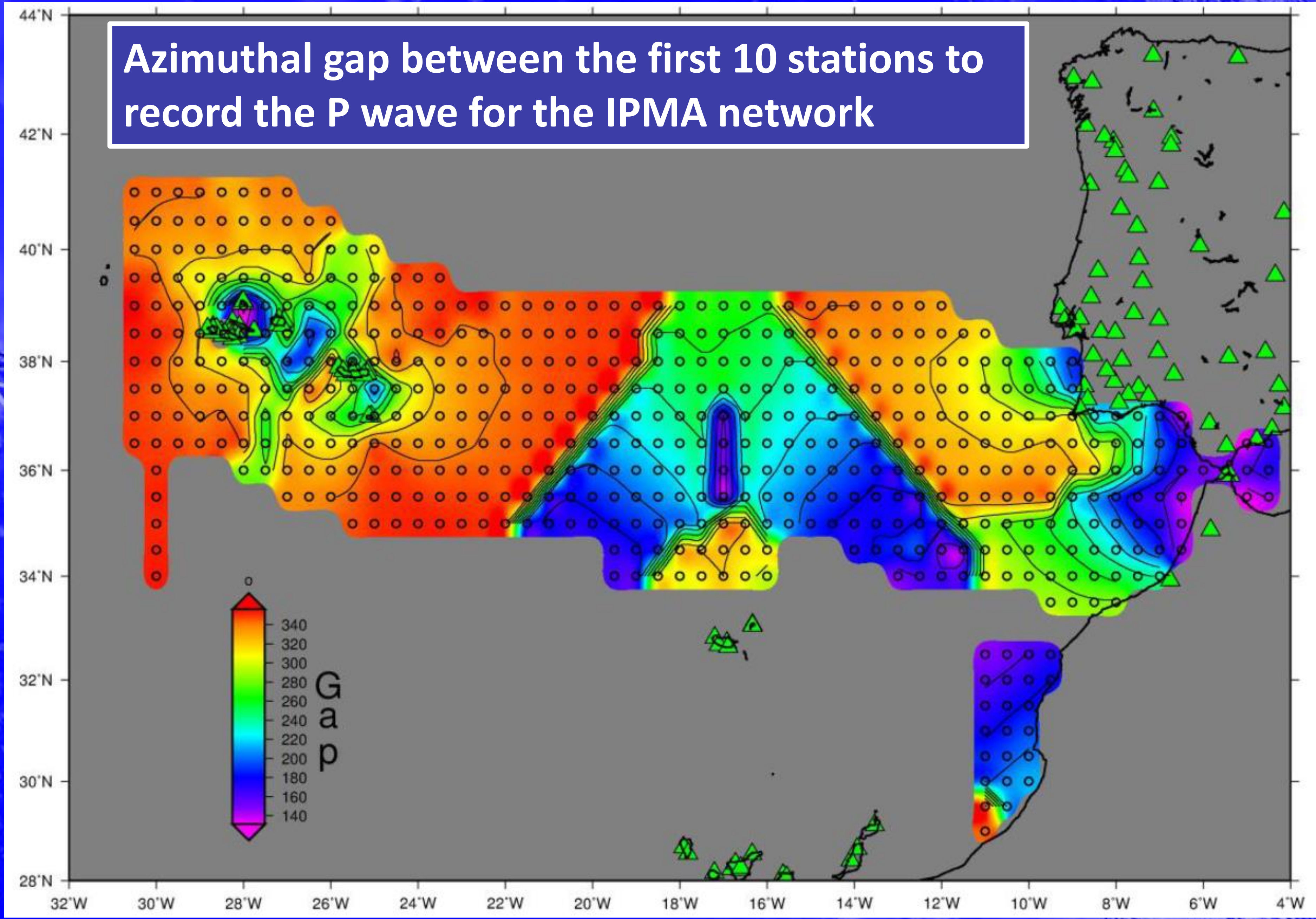
1. travel-time10: the time that it takes for the seismic waves to reach the 10 closest stations with P waves
2. GAP: It is defined as the maximum azimuthal gap between any pair of stations belonging to the set of the 10 first stations to detect the event
3. Emaj: the major semi-axis of the horizontal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

- 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

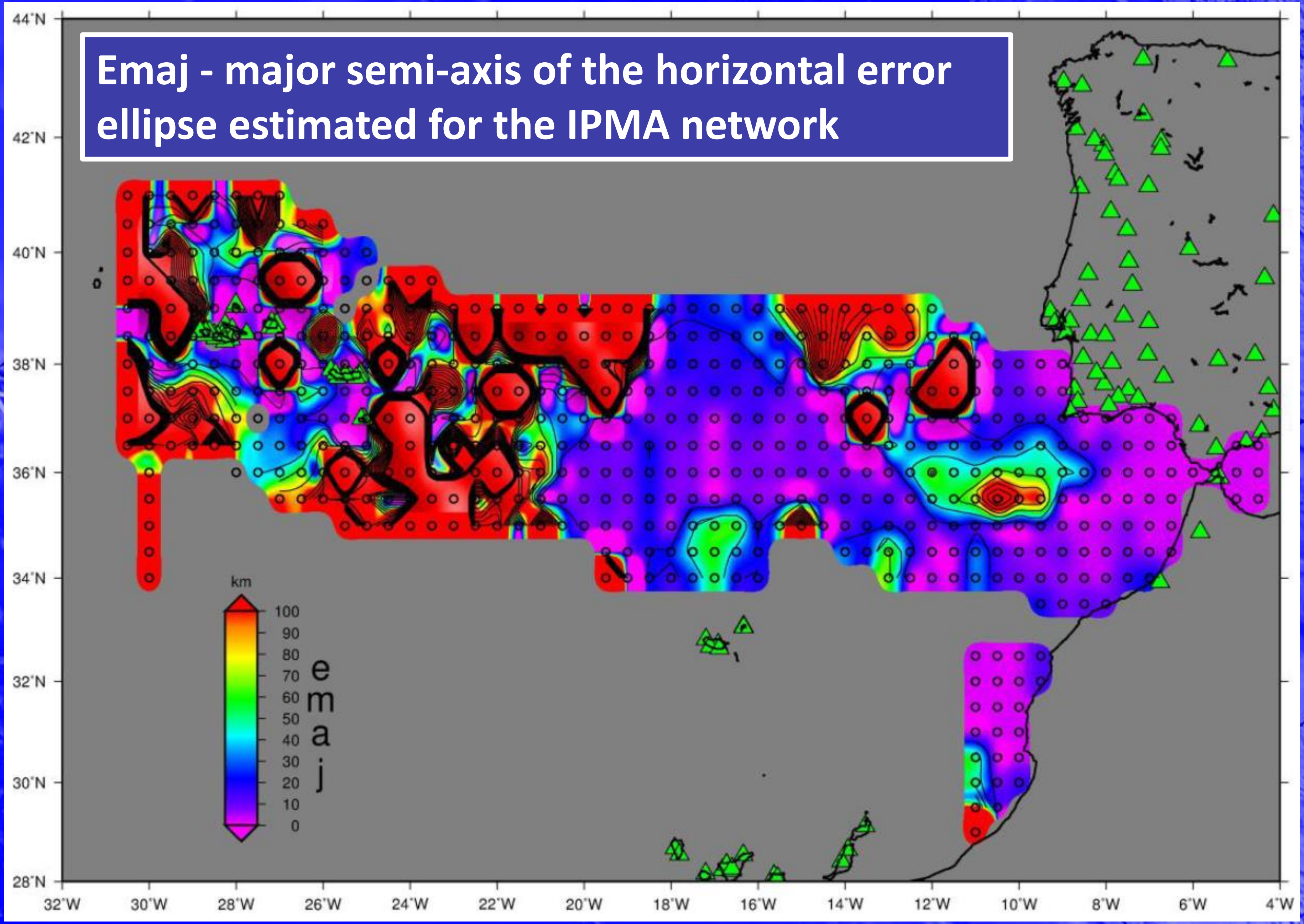
Background scenario: land stations only



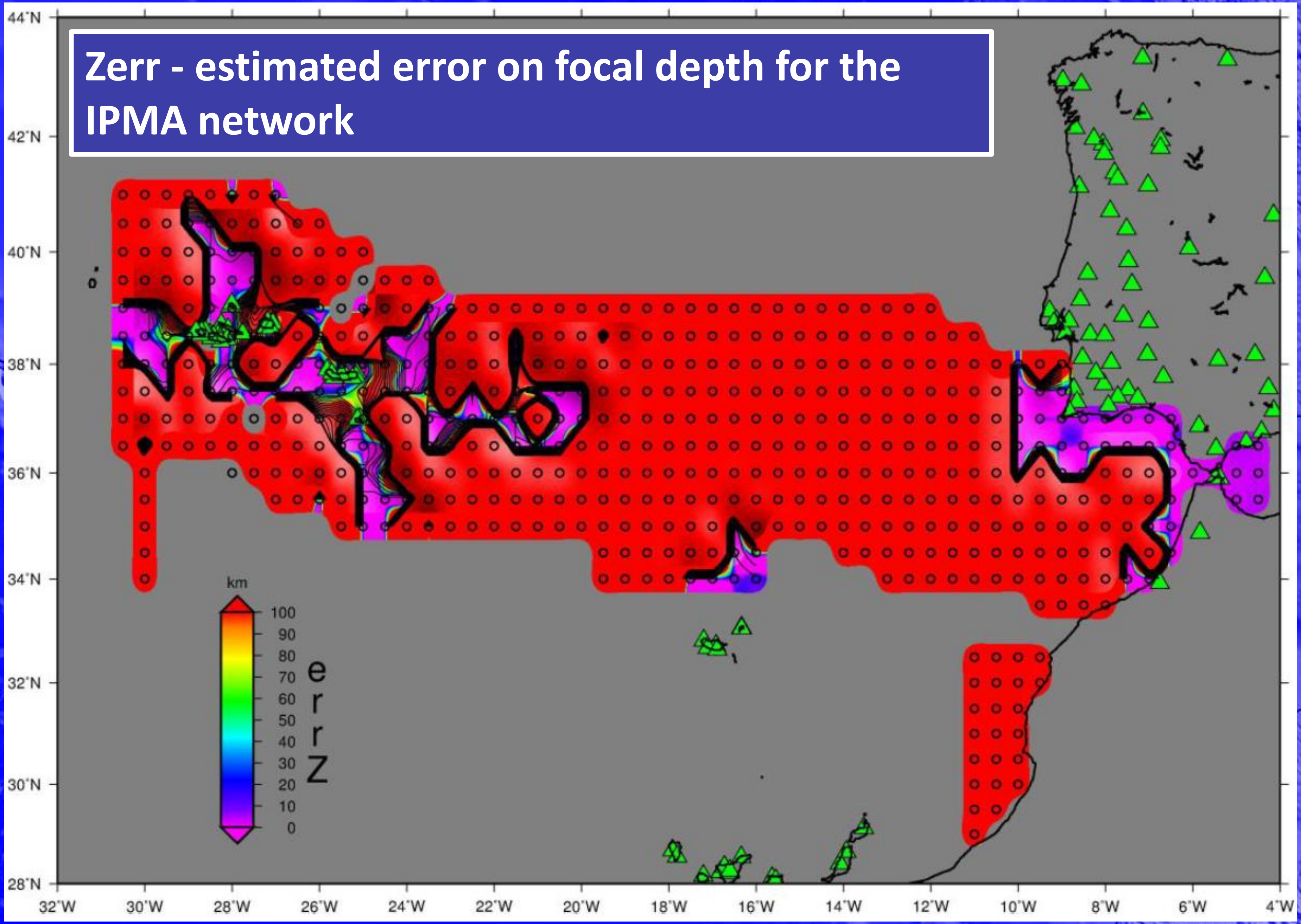
Background scenario: land stations only



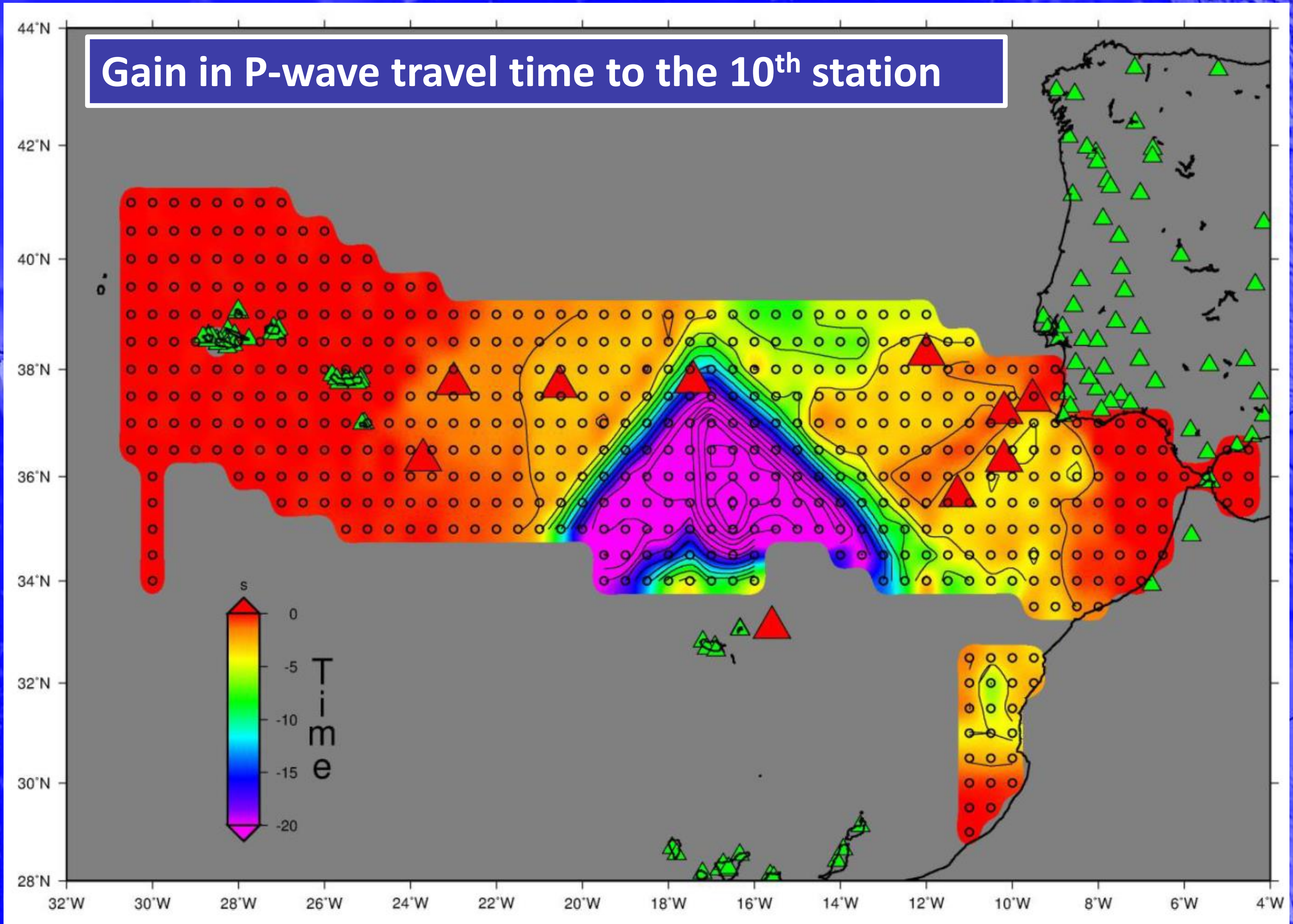
Background scenario: land stations only



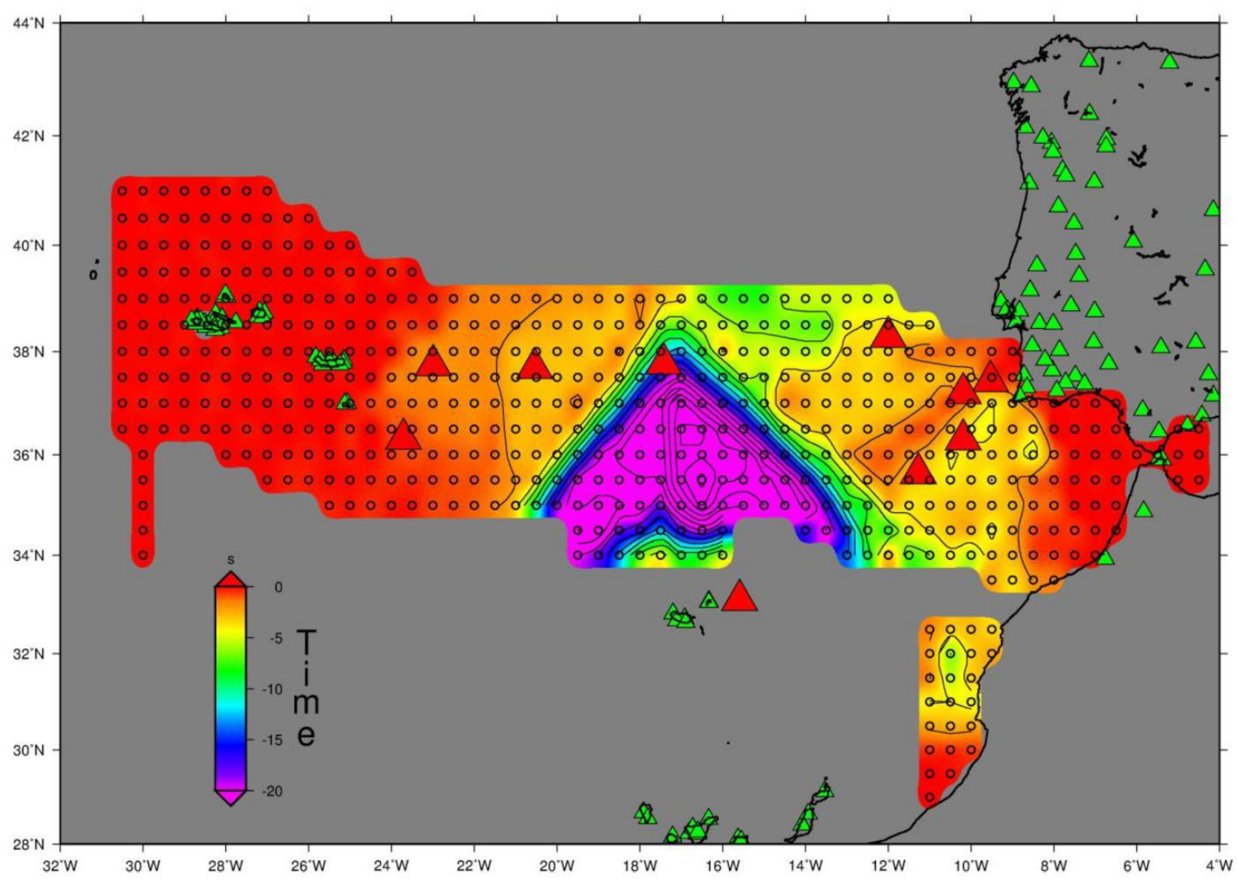
Background scenario: land stations only



Gain with SMART-CAM



Gain with SMART-CAM

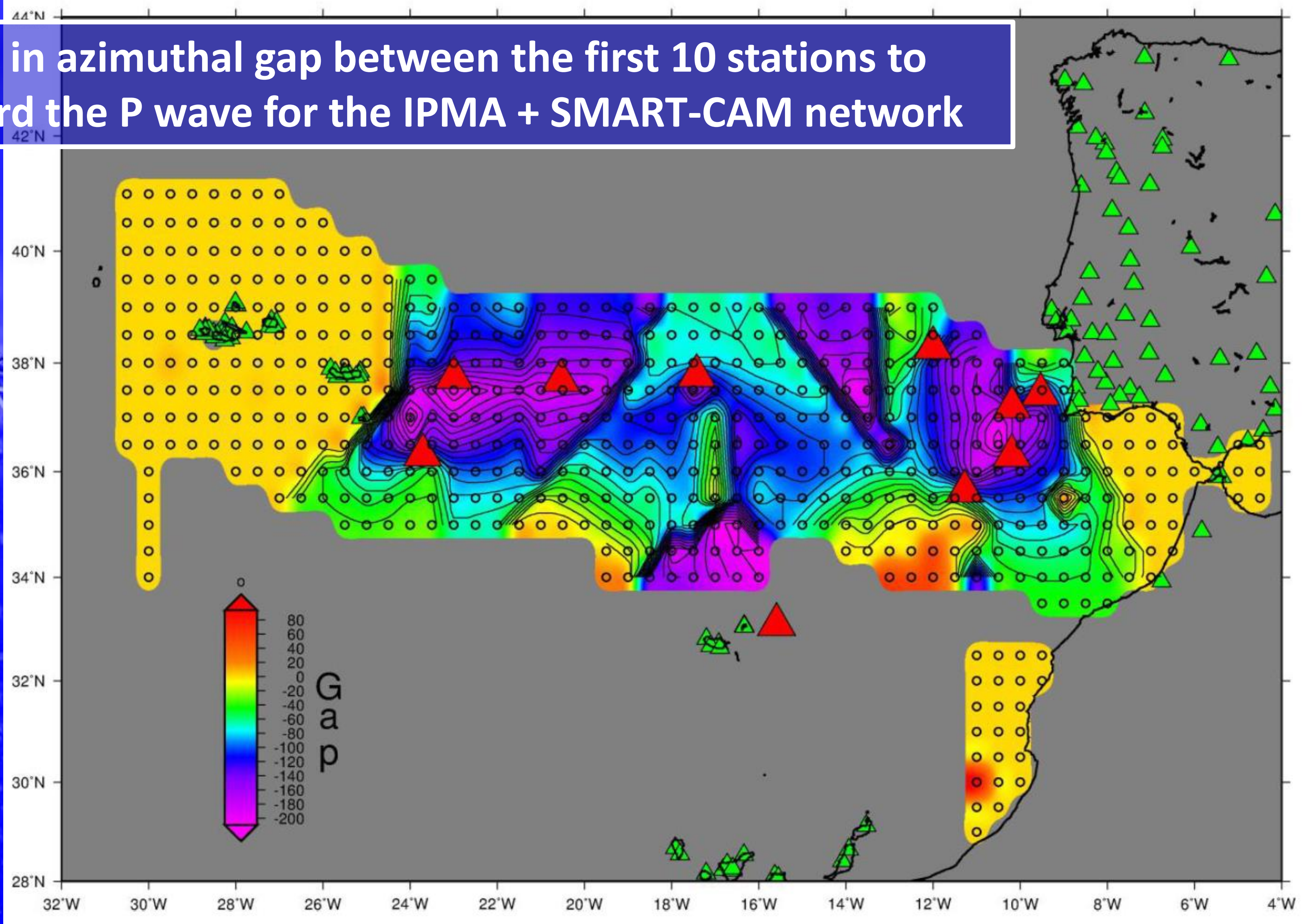


Gain in P-wave travel time to the 10th station

The improvement on the earthquake early warning time is 2 s or greater for most of the area East of 22ºW. The gain is larger than 10 s in a triangular shaped area in the central part of the investigated domain, North of Madeira. The geometry of the repeaters network does not allow any improvement in the Azores.

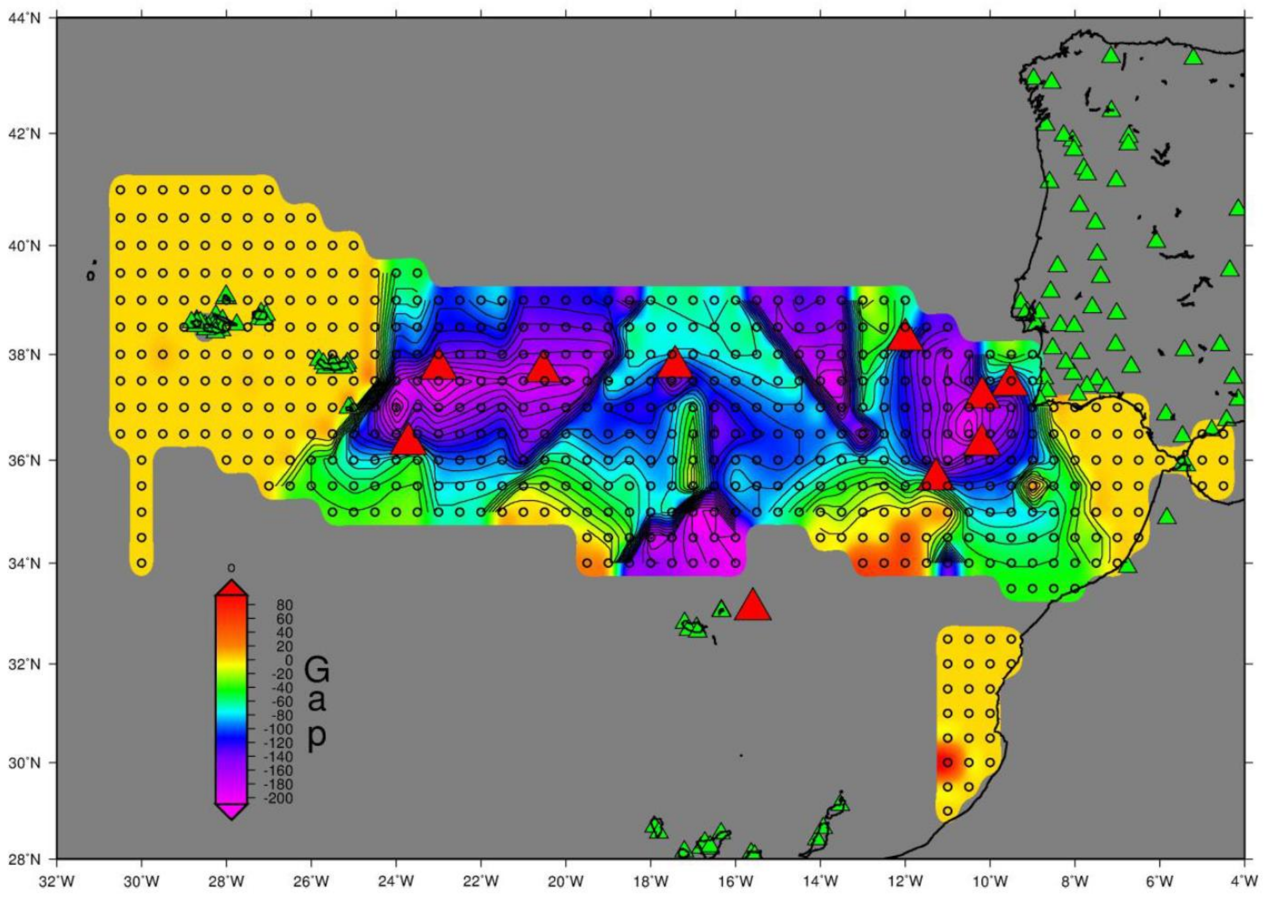
Gain with SMART-CAM

Gain in azimuthal gap between the first 10 stations to record the P wave for the IPMA + SMART-CAM network



Gain with SMART-CAM

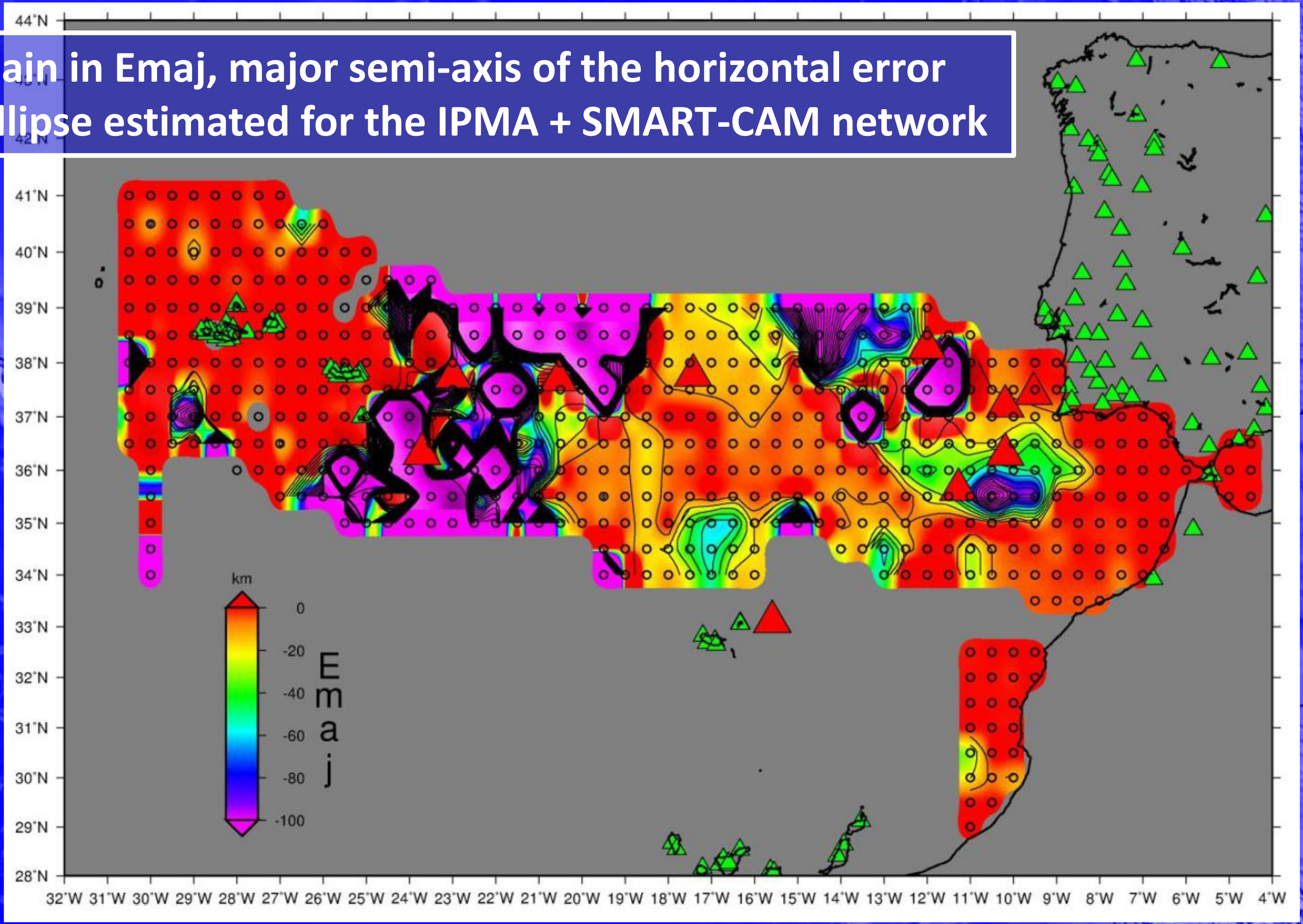
Gain in azimuthal gap between the first 10 stations to record the P wave for the IPMA + SMART-CAM network



The yellow and red areas show where the offshore network does not improve the gap quality parameter. The Azores and close to the land in Portugal mainland and Morocco, gap is not improved. The offshore network improves the quality of earthquake locations in all other areas. It is noteworthy the improvement SW of Portugal mainland, along the Gloria fault and North of Madeira

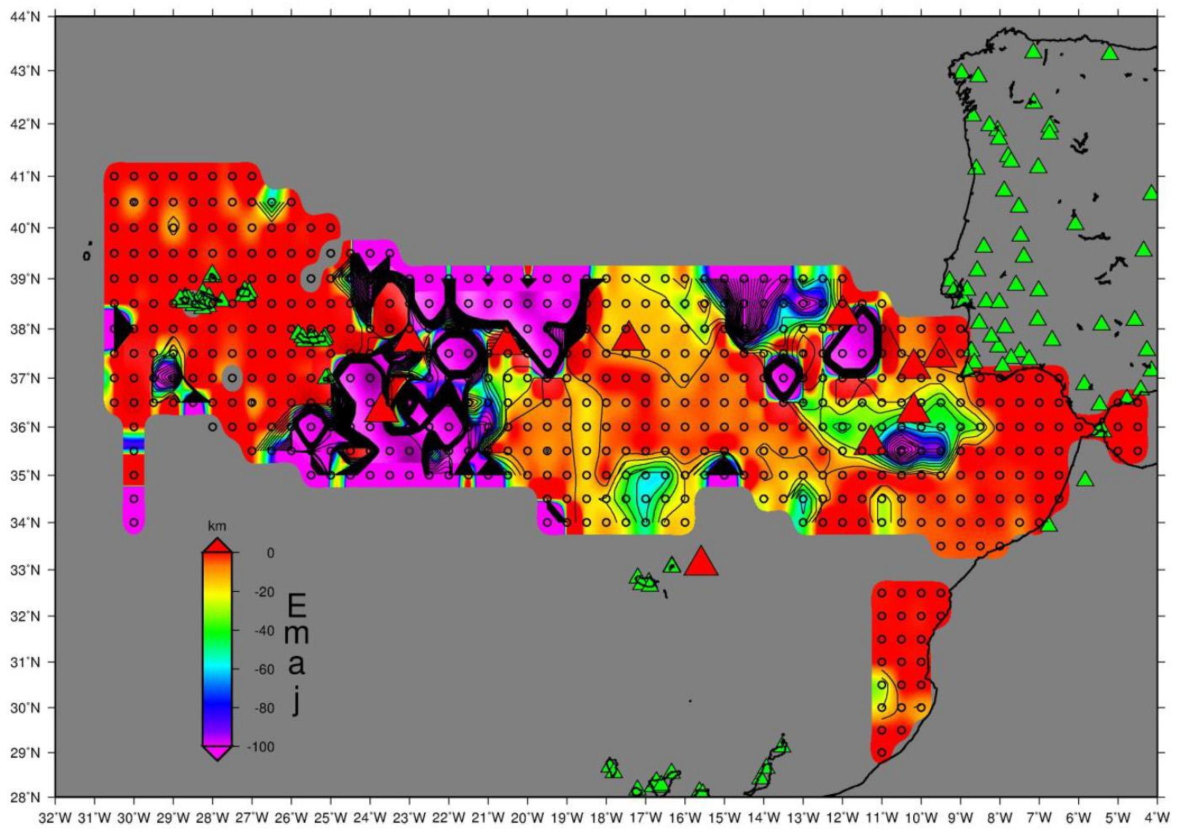
Gain with SMART-CAM

Gain in Emaj, major semi-axis of the horizontal error ellipse estimated for the IPMA + SMART-CAM network



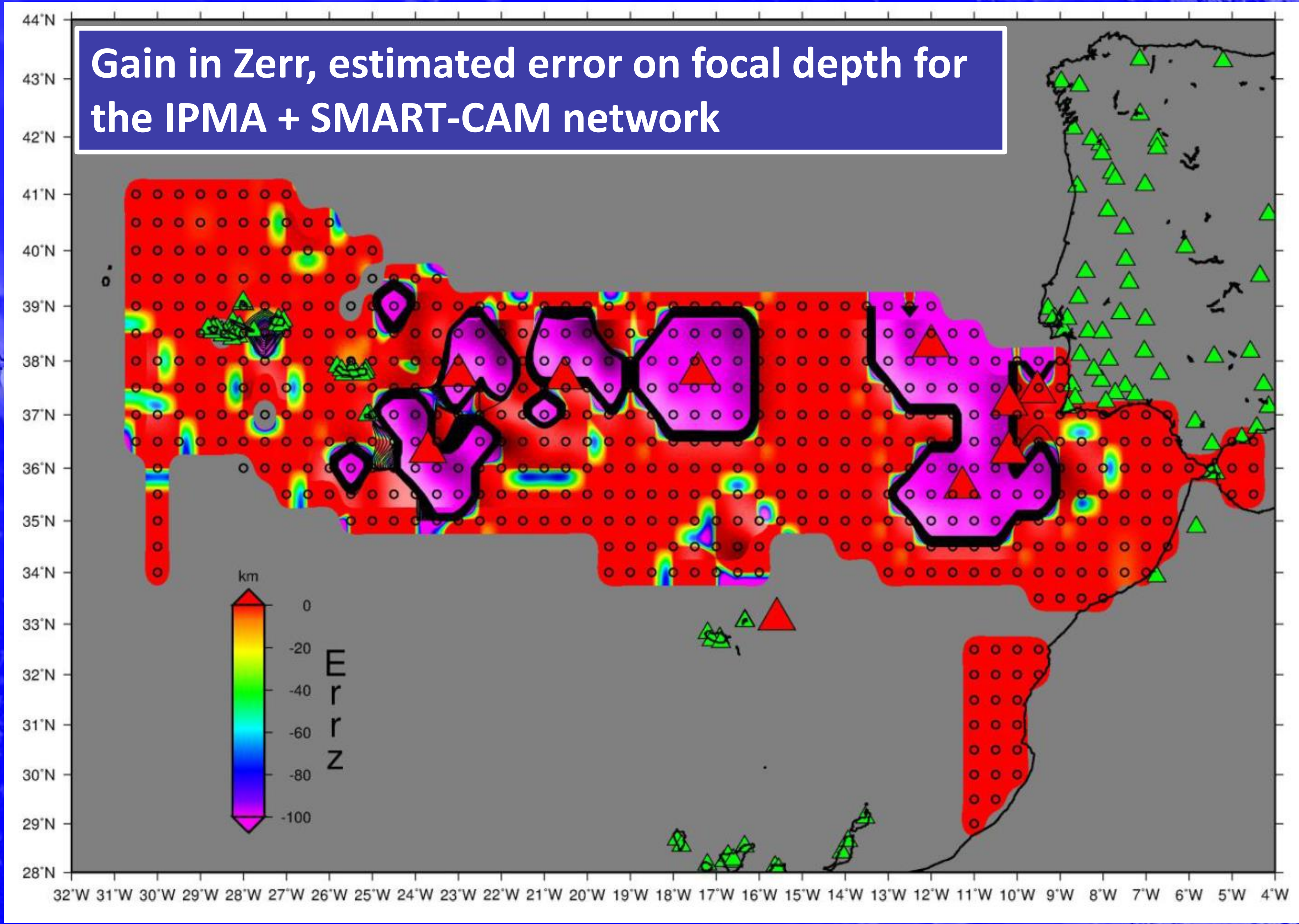
Gain with SMART-CAM

Gain in Emaj, major semi-axis of the horizontal error ellipse estimated for the IPMA + SMART-CAM network



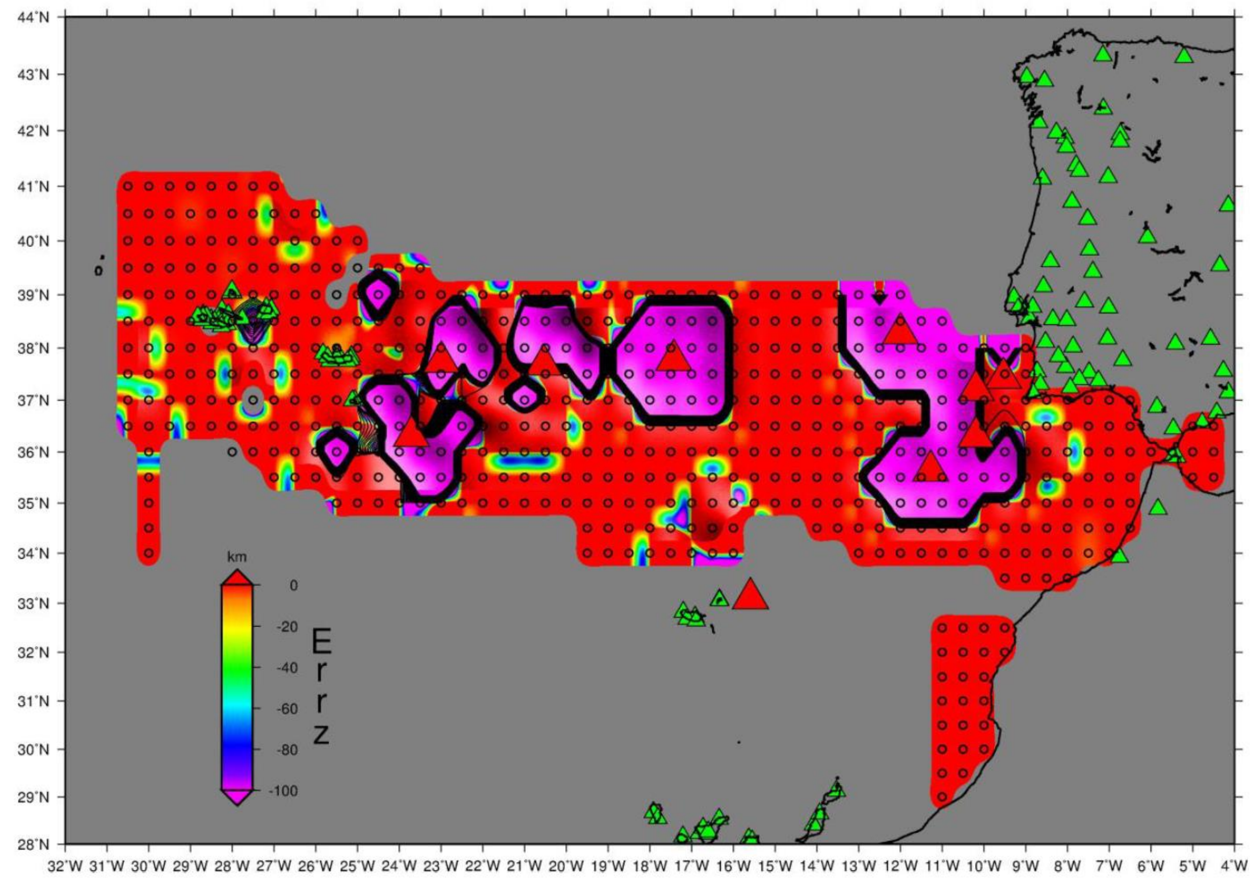
There is a significant improvement on the major semi-axis of the horizontal error ellipse in two main areas, East of the Azores, roughly between 26º and 20ºW, and W and SW of Portugal mainland. Some erratic locations with an improvement on this quality indicator are also found.

Gain with SMART-CAM



Gain with SMART-CAM

Gain in Zerr, estimated error on focal depth for the IPMA + SMART-CAM network



There is a considerable improvement on the estimated focal depth uncertainty in the areas that surround the offshore sensors. This figure shows the importance of the proximity of seismic stations to infer the focal depth and its uncertainty. Given the geometry of the offshore sensors, no improvement is observed in the Azores

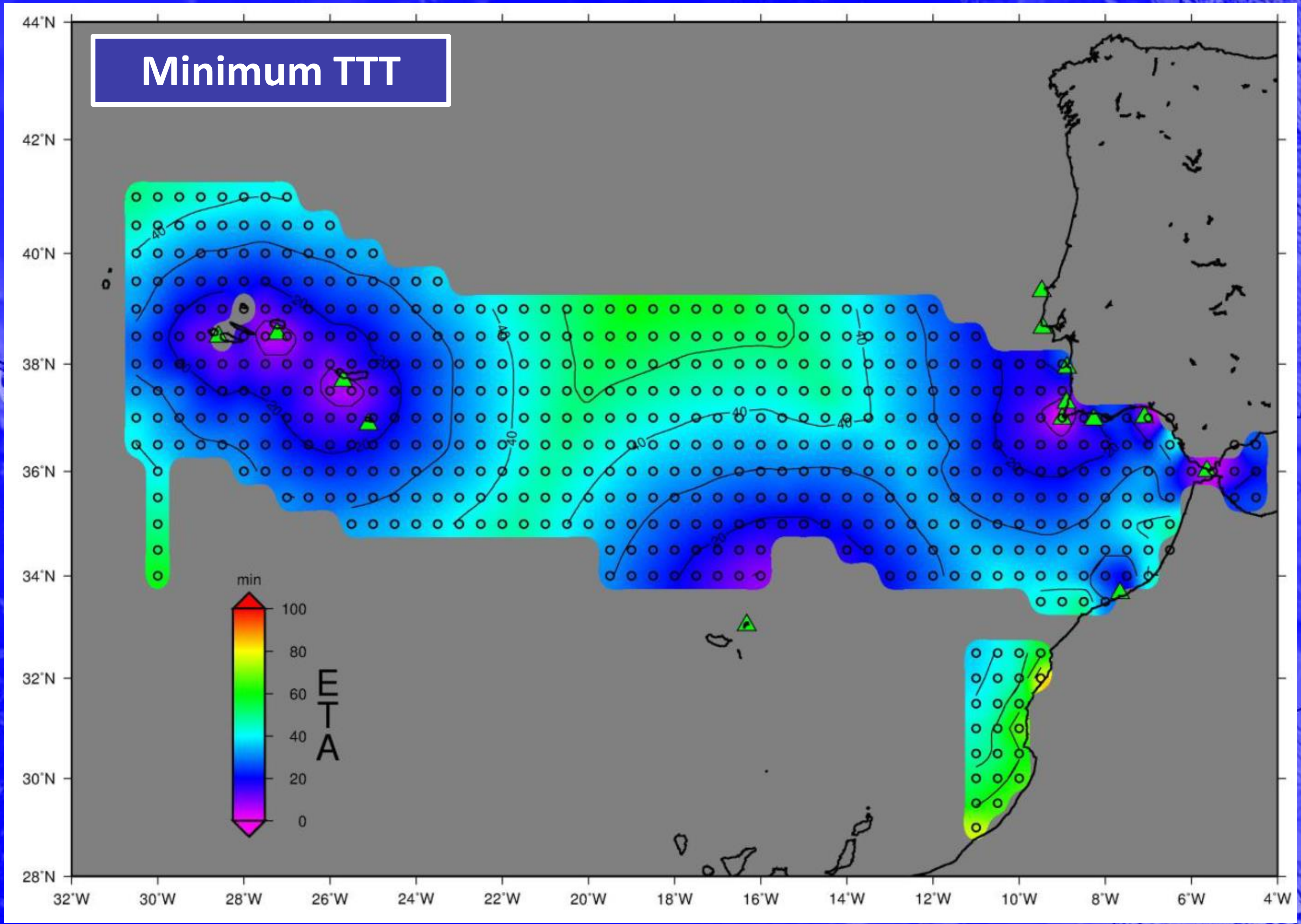
Added value to tsunami monitoring

- The 2 parameters we use to evaluate the contribution of SMART-CAM to tsunami monitoring are:

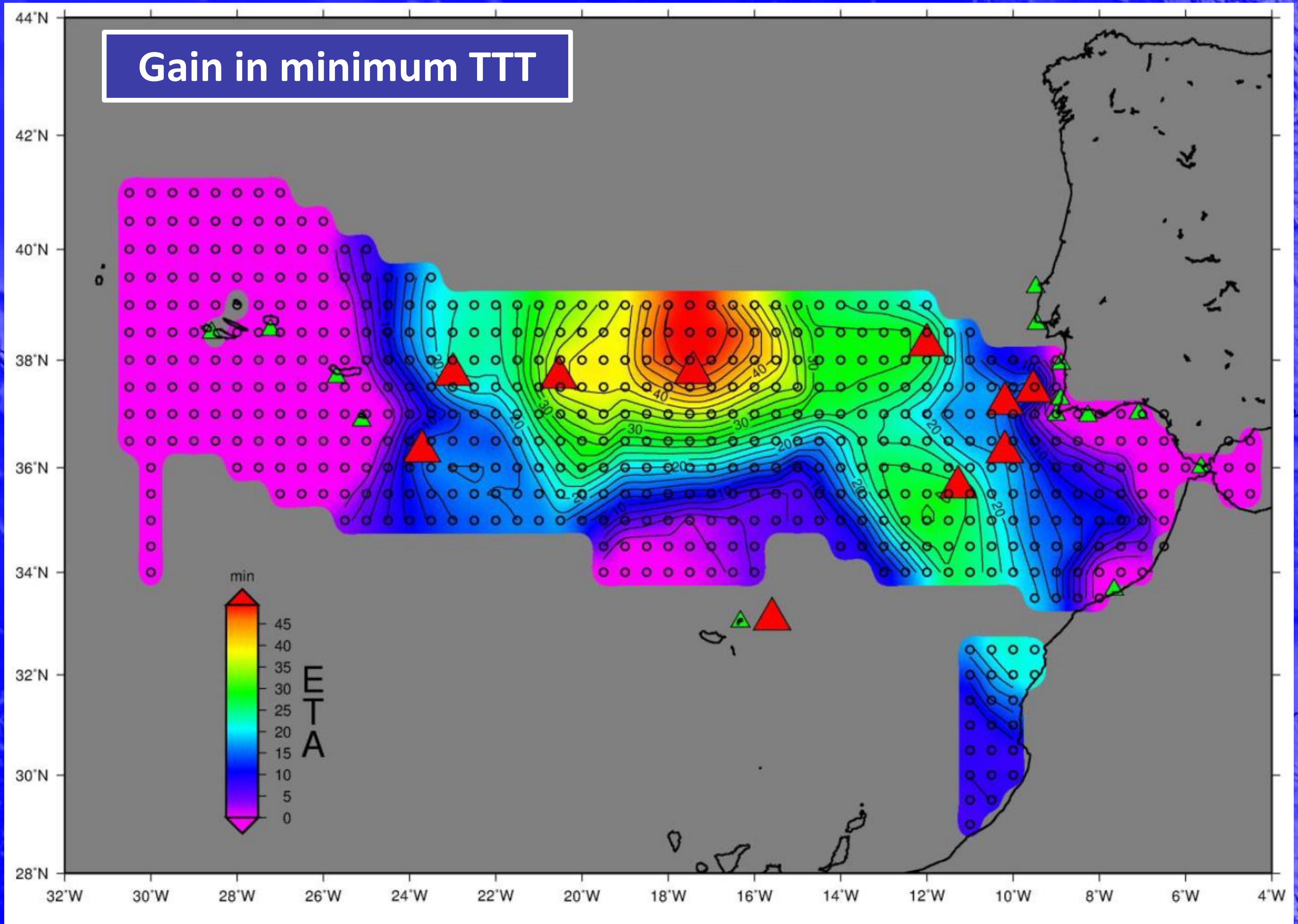
1. Minimum-TTT: the time it takes for a tsunami wave to reach the closest tide-gauge
2. Quality of the recorded sea-level signal

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 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.

Background scenario: coastal tide-gauges only

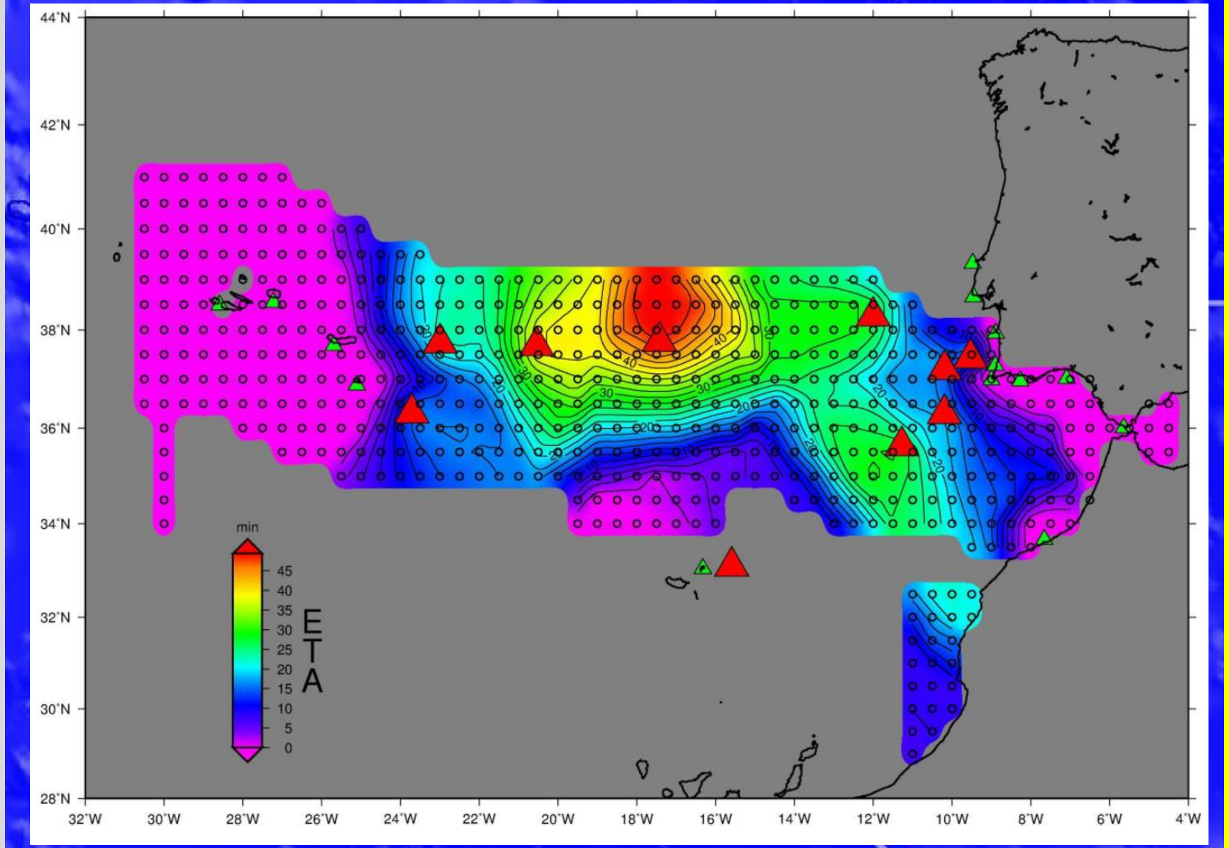


Added value to tsunami monitoring



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 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.

Quality of recorded sea-level changes

In addition to the gain on the minimum-TTT, we assume that the proposed cabled sensors will allow improving the performance of the PtTWS through recording tsunami signals of better quality than the ones typically recorded by the coastal tide-gauge network (CTG)

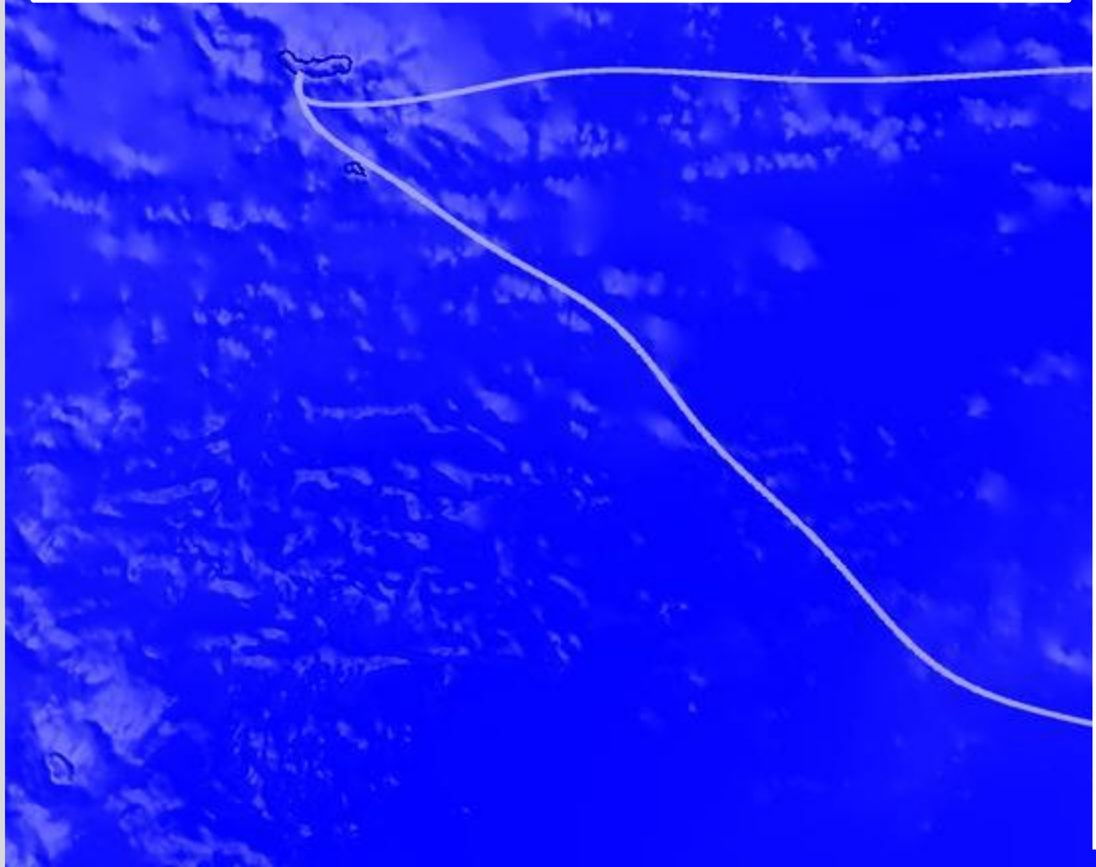
The preparation of the tsunami confirmation messages by the TWS operator requires the identification and measurement of tsunami wave characteristics (arrival time, wave height, and period). Sometimes, this task is hard to perform due to the quality of the sea-level signal at CTG that usually includes tidal variation, coastal effects and noises able to mask the tsunami signal. Any additional treatment of the sea-level signal to isolate the tsunami signal (de-tiding) and measure the waves characteristics is time-consuming

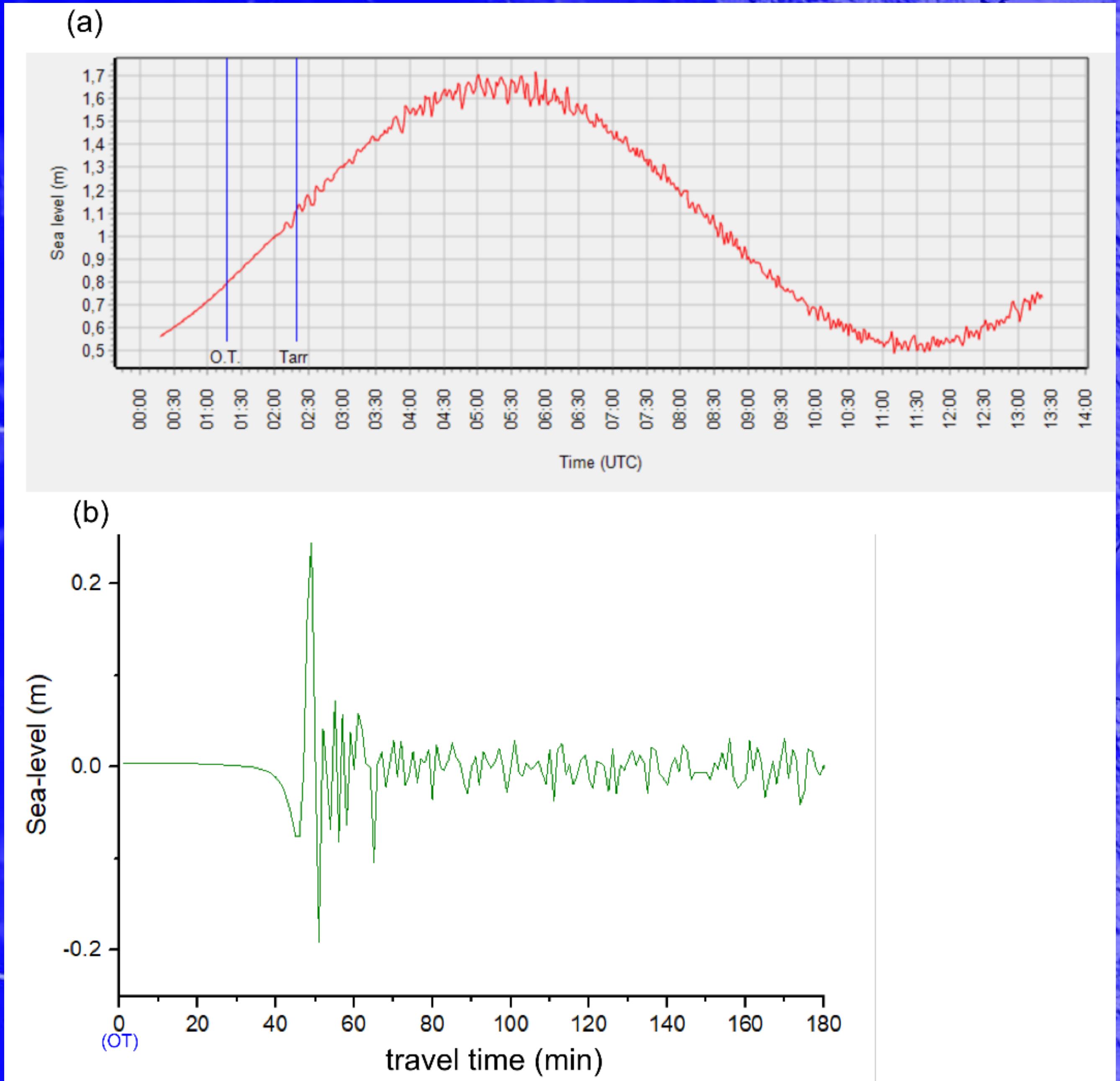
The presence of cabled sensors will allow overcoming this limitation as they will offer the possibility to record the tsunami in the open ocean without the tidal and coastal effects

Quality of recorded sea-level changes

Sea-level signal quality comparison.
(a) signal recorded at the Ponta Delgada TG

(b) signal recorded by a cabled sensor (simulation)

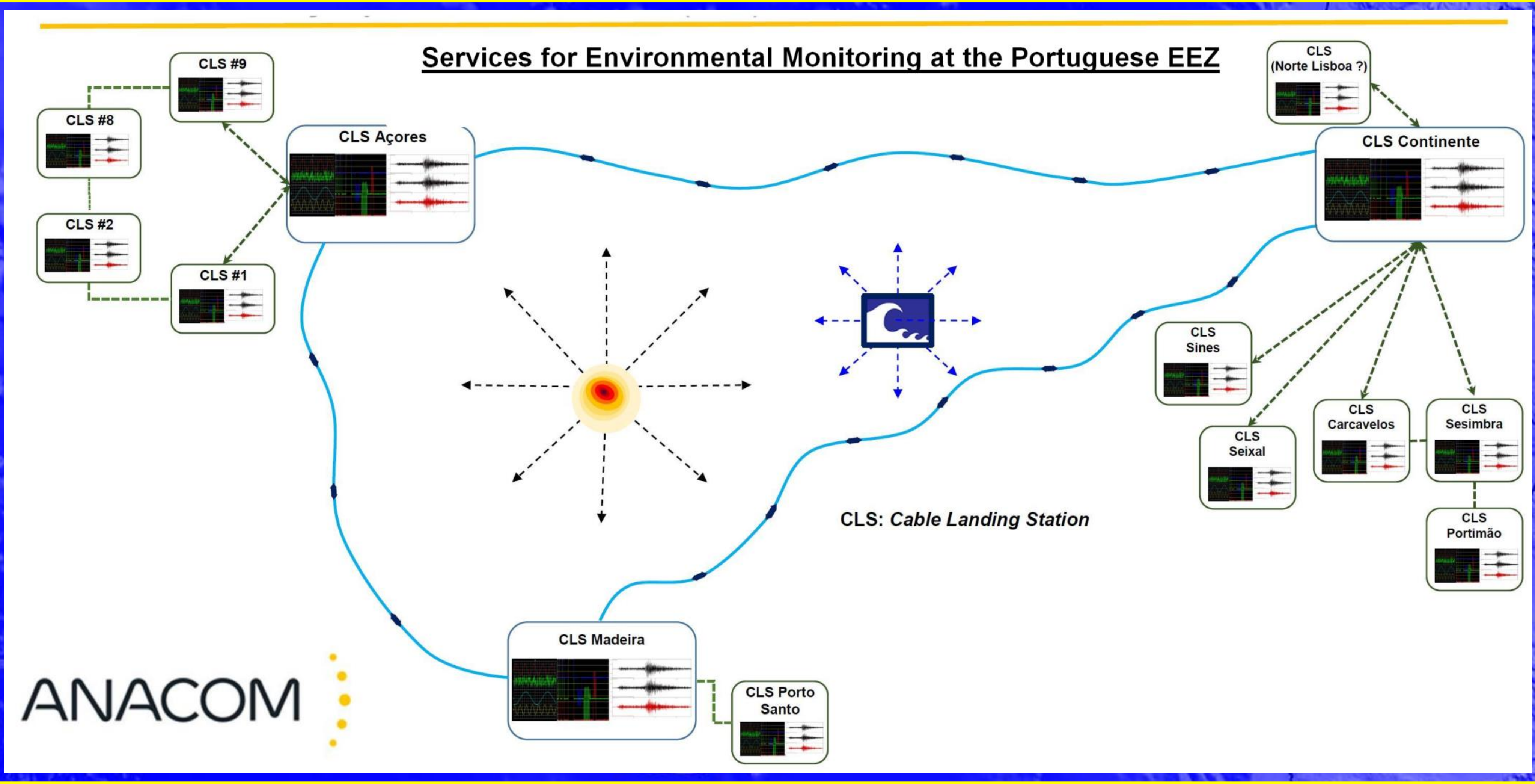




Conclusion

- A methodology was proposed to evaluate the contribution of the SMART CABLE technology to earthquake and tsunami monitoring of offshore tectonic sources that are not properly dealt by land based sensor networks
- The scenario investigated for SMART-CAM was a minimal option with only 10 UCOs. Despite this, gains in earthquake and tsunami early warning parameters are significant, leading to a high expectation of increasing the future efficiency of EWSs
- An optimal SMART-CAM set of sensors would comprise UCOs typically every 50 km along the cables
- The methodology and results obtained are valuable to encourage national authorities to implement the SMART cable concept in the technical specifications for future telecommunication submarine cables
- The scientific community is engaged in all efforts to lobby in favour of the SMART-CAM solution. No other opportunity will appear in the next 25 years

The SMART-CAM approach has been recently suggested by the ANACOM President (the Portuguese regulator for telecommunications advising the national authorities) for the cables that must be operational in early 2024



Acknowledgements to ANACOM for fruitful discussions and encouragement

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