Framework Service Contract EEA/DIS/R0/20/001 Lot 1 for Services supporting the European Environment Agency's (EEA) cross-cutting coordination of the Copernicus programme's in situ data activities – Observational data

Coastal sea level stations providing geocentric sea level data and vertical land movement information for a better assessment of sea level rise.

Issue: Final
Date: April 26th, 2021

[DOCUMENT RELEASE]

	Name(s)	Affiliation
Coordinated by:	Begoña Pérez Gómez	Puertos del Estado (Spain)
Contributions:	Laurent Testut, Médéric Gravelle	SONEL-CNRS (France)
Advisory Panel:	Philip Woodworth	NOC (UK) / PSMSL
	Andrew Mathews	NOC (UK) / PSMSL
	Gwenaële Jan	Shom (France)
Approval:		

Prepared for:	European Environment Agency (EEA)
Represented by: (Project Manager)	Henrik Steen Andersen
Contract No.	EEA/DIS/R0/20/001 Lot 1

[Change Record]

Version	Date	Changes
1.0	February 28th, 2021	First draft release
2.0	March 3rd, 2021	Second draft release
3.0	March 12th, 2021	Third draft release
4.0	April 9th, 2021	Draft release
Final	April 26th, 2021	Final version after revision by EuroGOOS Office

Table of Contents

Executive Summary

Sea level rise is one of the consequences of climate change with a large impact on coastal populations. Its effects will require significant resources dedicated to planning and adaptation measures during the next decades. Therefore, quantifying the spatial variability of the mean sea level rise along the coast will be critical. While the new satellite altimetry missions will progressively increase their spatial resolution and data quality near the coast, the tide gauge networks will continue to be a key component of the observing system for this application. This report presents the status of the European coastal sea level network of tide gauges for this purpose by: i) providing an updated list of those stations with geocentric sea level data and vertical land movement information, ii) performing an analysis of the network gaps and providing recommendations for a better assessment of sea level rise along the European coasts and iii) contribute to the increase of coastal sea level data provision to Copernicus services.

As a result of this analysis the following recommendations for the European region are derived:

1. A review of the GLOSS Core Network stations in Europe reveals that up to 9 of them would not pass the 30-year long record criteria of this study, possibly due to the lack of funding for maintenance or data processing in the last years. This will be transmitted to the GLOSS programme, particularly interested in the funding of these core stations.
2. It is necessary to fill the gaps in geodetic metadata information and provide GNSS collocated stations to all stations in GLOSS.
3. The current and future status of the tide gauge network of some European countries should be assessed in terms of density of the TG network along the coastline, existence of long-term records (either in digital format or still in paper archive), availability of real-time and public data, sustainability of the network. The countries for which we recommend this assessment are: Italy, Ireland, Portugal, Lithuania, Latvia, Estonia.
4. We have identified some regions where the lack of long in situ records is obvious. Investment in new sensors would require waiting for several decades for this application. Therefore, we recommend to pursue further this analysis to see if the recently reanalysis of coastal satellite altimetry can help in reducing those observation gaps (Benveniste et al., 2017).
5. For those countries where stations are working but not providing quality-controlled monthly mean sea levels to PSMSL, the focus should be on allocating resources to data quality control and processing.
6. Vertical land movement estimation will soon be significantly improved thanks to the use of the InSAR technique. New initiatives and services such as the Copernicus European Grand Motion Service (https://land.copernicus.eu/pan-european/european-ground-motion-service), based on time series analyses of Copernicus Sentinel-1 data, will complement the in situ GNSS component described in this report.

1. Introduction

Tide gauges have been used for tide prediction, national datum definition, navigation and harbour operations since the middle of the XIXth century. The Permanent Service for Mean Sea Level (PSMSL: https://www.psmsl.org/) was established in 1933, for the collection, publication, analysis and interpretation of monthly mean sea levels provided by national institutions all around the globe. This is today the global data bank for long-term sea level change from tide gauges, used in many scientific publications for estimating the observed global mean sea level rise. In 1985, the Global Sea Level Observing System (GLOSS: https://www.gloss-sealevel.org/) was created by the Intergovernmental Oceanographic Commission (IOC) of UNESCO to establish a well-designed, high-quality tide gauge network to support a broad research and operational user base. Today, GLOSS is the reference programme for in situ sea level measurements and a component of the Global Ocean Observing System (GOOS), and PSMSL is the GLOSS data bank that compiles means (monthly and annual) and produces sea level trends.

As tide gauges provide only mean sea level information relative to land (to a nearby tide gauge bench-mark), co-location of a tide gauge with a permanent GNSS (Global Navigation Satellite System) station is crucial for referring coastal sea level data to the ellipsoid (global and geocentric reference) and to distinguish changes in absolute mean sea level from the land movements at each site (Wöppelmann and Marcos, 2016; IOC, 2016). This is important for scientific assessment of mean sea level rise associated with climate change and for validation of altimetry data near the coast. Therefore, GLOSS has strongly recommended increasing the number of tide gauge stations co-located with a GNSS (GNSS@TG hereafter). The SONEL (Système d'Observation du Niveau des Eaux Littorales, http://www.sonel.org/) is the GLOSS data bank that acts as the official data assembly centre for GNSS information in the vicinity of tide gauges. This information includes: ellipsoidal height, vertical land movement and levelling information between the tide gauge and the nearby GNSS.

In Europe, hundreds of tide gauges transmit real time data to the GLOSS real time data portal (IOC Sea Level Station Monitoring Facility: http://www.ioc-sealevelmonitoring.org/), which also provides a service for tsunami warning applications. Additionally, data from more than 400 tide gauges are also integrated in near-real time in the Copernicus Marine Service data portal: CMEMS In Situ TACs: http://www.marineinsitu.eu/dashboard/, along with other oceanographic parameters. As these data are mainly used by the operational oceanography community, the above-mentioned ancillary geodetic data is not usually attached to the tide gauge data flow and it is therefore unknown or incomplete for the Copernicus programme. Compilation of this information with existing SONEL and PSMSL data banks, and with tide gauge operators, is therefore needed for a more efficient use and interpretation of coastal sea level data within Copernicus.

The EuroGOOS Tide Gauge Task Team has conducted several actions in this direction since its establishment in 2015: for example, proposing new mandatory and recommended attributes in CMEMS In-Situ TAC NetCDF files, to allow inclusion of this geodetic information[1], and compiling a first list of tide gauges co-located with GNSS in CMEMS in 2018[2].

This report aims to contribute to the increase and improvement of coastal sea level data information provided to the Copernicus programme, by:

[1] https://eurogoos.eu/download/NetCdf_Recommendations_forCMEMS_EuroGOOSTGTT_October_2017.pdf

[2] https://eurogoos.eu/download/TG_GNSS_2018.pdf

- Identifying and updating information of European coastal sea level stations capable of providing geocentric sea level data and vertical land movement information
- Compiling and providing this latest geodetic information to users, data portals and scientists, and
- Performing an analysis of gaps and recommendations for new stations to get a better assessment of sea level rise along the European coasts.

The work will be based on a survey launched by SONEL to national tide gauge operators, and on the information available in SONEL and PSMSL data banks. Because this work is focused on the in situ component of the observing system, a detailed analysis of the potential complementary information available from the satellite altimetry missions is out of the scope of this report but will be briefly described in section 3.5.

2. Coastal sea level stations in Europe with geocentric data and vertical land movement information

Several stations of the GLOSS network and of the European network (a densification of the GLOSS network in Europe) have a GNSS station nearby. However, only a subset is geodetically tied (i.e. the Tide Gauge Bench Mark, hereafter TGBM, is levelled to the reference point of the GNSS antenna) and can therefore be used for this application. Apart from this geodetic tie, the distance between the GNSS and the tide gauge is critical: if too far away, the vertical land movement derived from the GNSS station might be different from the one at the tide gauge site; in this case a periodic geodetic tie between both stations is required, and this is not always available (Woodworth et al., 2017).

The EuroGOOS Tide Gauge Task Team requested information in 2017 from SONEL and from European national network operators in order to produce a first list of GNSS@TG stations for Europe. The criteria for station selection followed at that time were:

1. tide gauge data already included in CMEMS In Situ TAC;
2. geodetic information available from SONEL or national institutions;
3. distance TG-GNSS < 1km and geodetic tie available.

According to these criteria, a list of 27 stations for which TGBM ellipsoidal height was available was published in the document: https://eurogoos.eu/download/TG_GNSS_2018.pdf. Of these, 20 stations had also reliable estimates of vertical land movement information at the GNSS site.

In the present project, SONEL has conducted a new and more complete survey for European countries, in order to update missing information in the SONEL data bank, which is mainly on the levelling between the GNSS antenna and the TGBM. Details of the survey and the methodology followed by SONEL, designed to be regularly performed in a more automatic way, are provided in the following report available at the EuroGOOS Tide Gauge Task Team website: https://eurogoos.eu/download/other_documents/task_teams/SONEL_EuroGOOS_GNSS@TG_metadata_campaign_report.pdf.

For this new survey, we have considered all the stations with a GNSS co-location and an ellipsoidal height of the primary TGBM. The campaign involved contacting 152 national operators from 24 countries and has resulted in the identification of a total of 112 tide gauges with an ellipsoidal height of the TGBM (green and orange points in Figure 1).

In the above-mentioned SONEL survey report[3], additional metadata have been requested from national operators, to relate the tide gauge datum or reference level for sea level measurements to the estimated ellipsoidal height (see Figure 1 in SONEL's report of the survey[3]). In the survey of 2017, this information was not available and the ellipsoidal height was only referred to the TGBM.

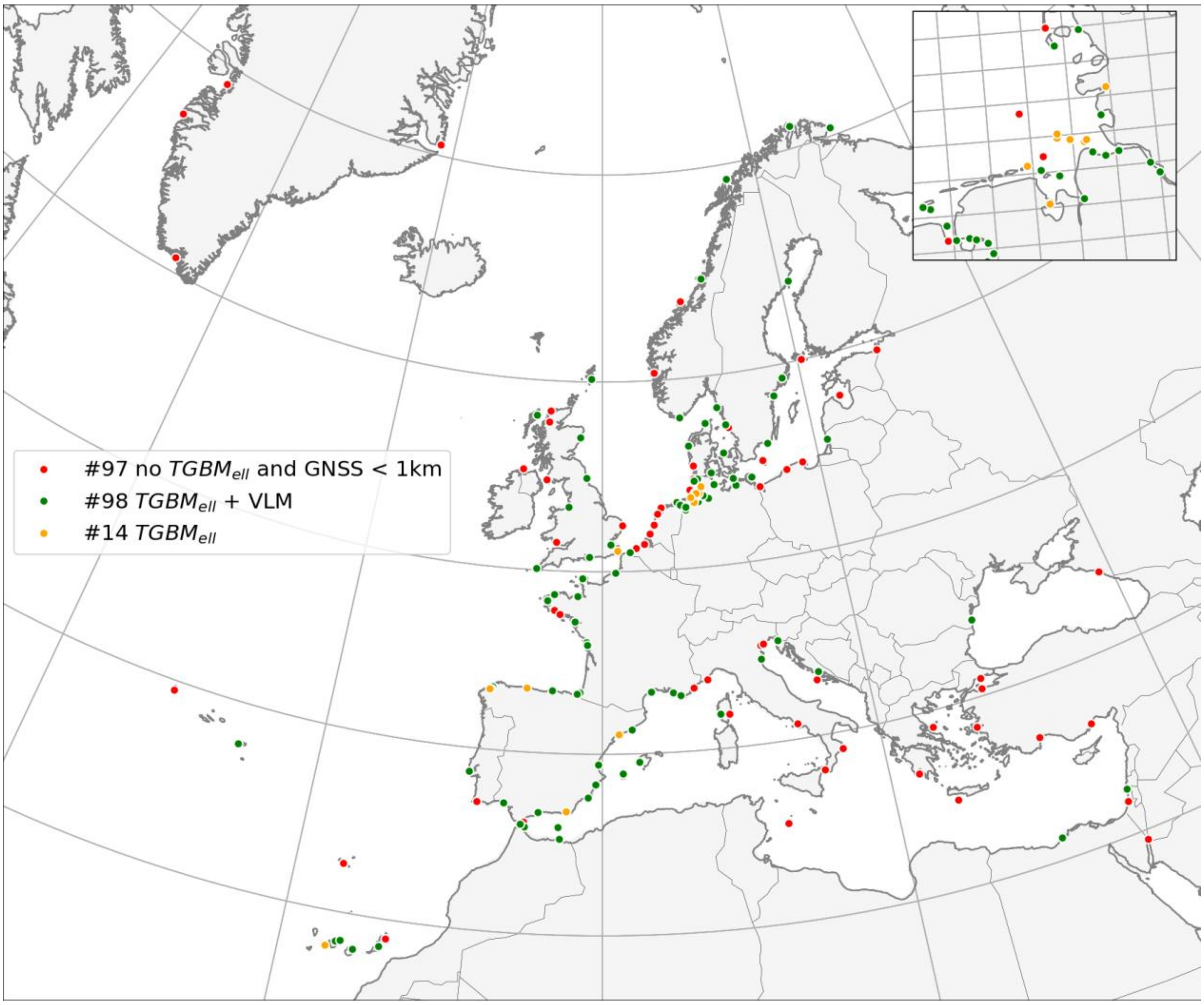

Figure 1: Map of tide gauges for which we have an ellipsoidal height estimation of the primary TGBM and a robust VLM estimation at the co-located GNSS station (green dots), the orange dots are the stations where VLM is missing but we have an estimation of ellipsoidal height of the primary TGBM. The red dots represent the station for which we do not have an ellipsoidal height of the primary TGBM but we know there is a co-located GNSS nearby (< 1km), so an optical leveling can be easily done to estimate the TGBM ellipsoidal height. The inset is a zoom center on the western side of the German coastline where a large number of tide gauges is present.

Figure 1 summarizes the present geodetic metadata availability for the 24 countries concerned with the campaign. From this survey we can draw some important information

1. 112 stations (i.e., the green and orange dots) from 15 countries have an ellipsoidal height of their tide gauge TGBM (for 104 of them the ellipsoidal height of the tide gauge datum can be estimated as well)
2. 77.6 % of these stations are concentrated in only 4 countries (Germany, Spain, France and UK)
3. 87.5 % of these 112 tide gauges (98) have in addition a VLM estimate from a co-located GNSS station
4. 97 tide gauges have no ellipsoidal height of their TGBM but a GNSS nearby (< 1 km)

[3] https://eurogoos.eu/download/other_documents/task_teams/SONEL_EuroGOOS_GNSS@TG_metadata_campaign_report.pdf

5. 11 countries do not (yet) provide any ellipsoidal height for the TGBM

The list of 112 tide gauges and their associated metadata at the time of drafting this report is in the excel file attached to Annex 2 (TG_GNSS_metadata_2021.xlsx).

It is important to stress that the tide gauge datum or reference level is defined nationally or even locally by the network operators and it is one of the key metadata fields that should be regularly checked and confirmed with them by the different data centres.

This new survey shows an important increase in the number of stations able to provide geocentric sea level information in recent years. Though we cannot compare strictly with the survey of 2017, where only 27 stations were listed (only from those contributing at that time to the near-real time CMEMS In Situ TAC), the increase is noticeable for some countries like Spain, France or Norway. The main reasons in these cases are: i) the installation of new GNSS stations at or close to existing tide gauges; ii) the recovery of unknown levelling information and iii) the relatively easy to accomplish criterion on the required length of the GNSS time series (a vertical land movement estimation is provided with 3 years of data, less is required for estimation of the ellipsoidal height). However, there are no relevant changes in the network for a significant part of the Mediterranean Sea, Greenland, Iceland, Ireland and part of the Baltic Sea.

One of the main applications of this new metadata set is the possibility of linking or referring tide gauge data as an ellipsoidal height, a common global reference shared with the satellite altimetry data. This could be useful for the operational oceanography community within the Copernicus programme, if this metadata were attached to the NetCDF files produced by the CMEMS In Situ TAC. Tide gauges have different ID's and names in different data portals, what complicates confirmation of which of the stations gathered by SONEL survey are actually integrated in CMEMS In Situ TAC. In the excel file in annex 2 (TG_GNSS_metadata_2021.xlsx), those stations identified as contributing to CMEMS In Situ TAC are in blue color. A summary of relevant metadata information for these stations (61) is provided in the table in Annex 1.

However, for local sea level rise assessment, where vertical land movement information is required, it is finally the length of the tide gauge time series which makes the difference for sea level trend estimation from in situ data, as a minimum of 30 years of data are usually considered necessary by the PSMSL and sea level scientists. Many of these stations will not fulfil this requirement, while some historical tide gauges will not have information of vertical land movement from a GNSS. This will be shown and analyzed in more detail in section 3.

The new methodology developed for this report will allow SONEL experts to perform their periodic surveys, update their data banks and publish the information on the SONEL website in a more efficient way in the future. For further information on the status of all identified GNSS@TG co-located pairs in Europe, including information from different GNSS stations in the vicinity of the tide gauge, SONEL must be contacted as the reference organization.

3. Gap analysis and recommendations for a better assessment of sea level rise along the European coasts

Gap analysis is primarily based on information extracted from the main international programmes dealing with mean sea levels from tide gauges. The objective is twofold: i) to summarize and present the status of the European coastal sea level network and its validity for assessing the spatial variability of sea level rise; ii) to identify the main gaps and provide recommendations for improvement, funding and installation of new sensors. The analysis will necessarily discard many new tide gauges, co-located with GNSS or not, that were installed in recent years and that are not yet valid for this application (many of the stations provided in section 2). However, many of them are by now also being used for operational or tsunami warning applications.

3.1 Methodology and datasets

This study is spatially limited to our definition of the European coastline that has been defined by the polygon shown in Figure 2. This polygon spans the Mediterranean Sea and includes the Northern African coast. We have also considered the coast of Greenland. The polygon intersects or includes 58 countries.

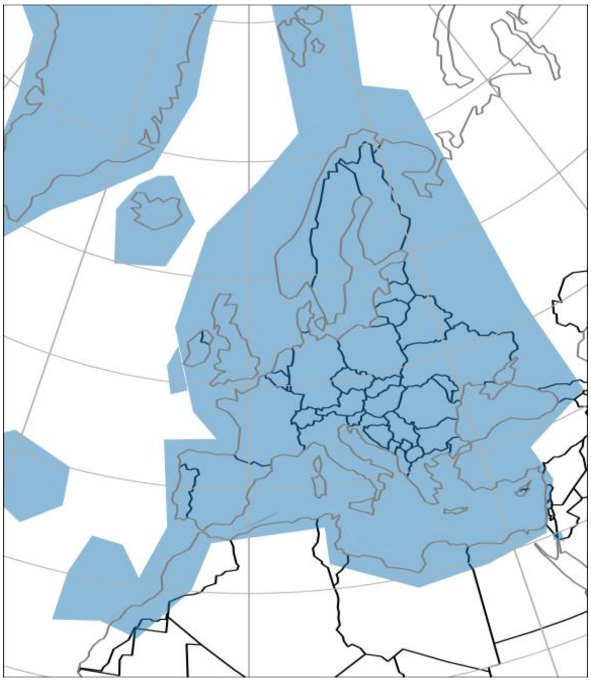

Figure 2: area of study, spanning the Mediterranean Sea, Iceland, Greenland, Azores and the Canary Islands.

The backbone of the GLOSS programme is the Core Network (GCN) composed of 290 stations evenly distributed worldwide, of which 38 stations belong to the study area (Figure 3, left). Although these are the key stations of the global network for scientific applications, GLOSS has different data portals whose applications result in them acquiring and distributing data from hundreds of stations around the world. For the purpose of this study, we have based our analysis in the following main GLOSS datasets:

1. PSMSL: important for long term sea level rise estimation, and widely used in climate science studies, the PSMSL catalog contains a dataset of 2361 records with different quality and length. In the study area, the PSMSL contains monthly mean sea levels from 692 stations (Figure 3, right). This will be the main source of information to assess the availability of “long” sea level records along the European coastline for different periods, and it includes the GCN stations.

2. SONEL: geodetic data information obtained from GNSS stations near the tide gauges, mainly ellipsoidal height and vertical land movement information at the TGBM, as described in section 2.

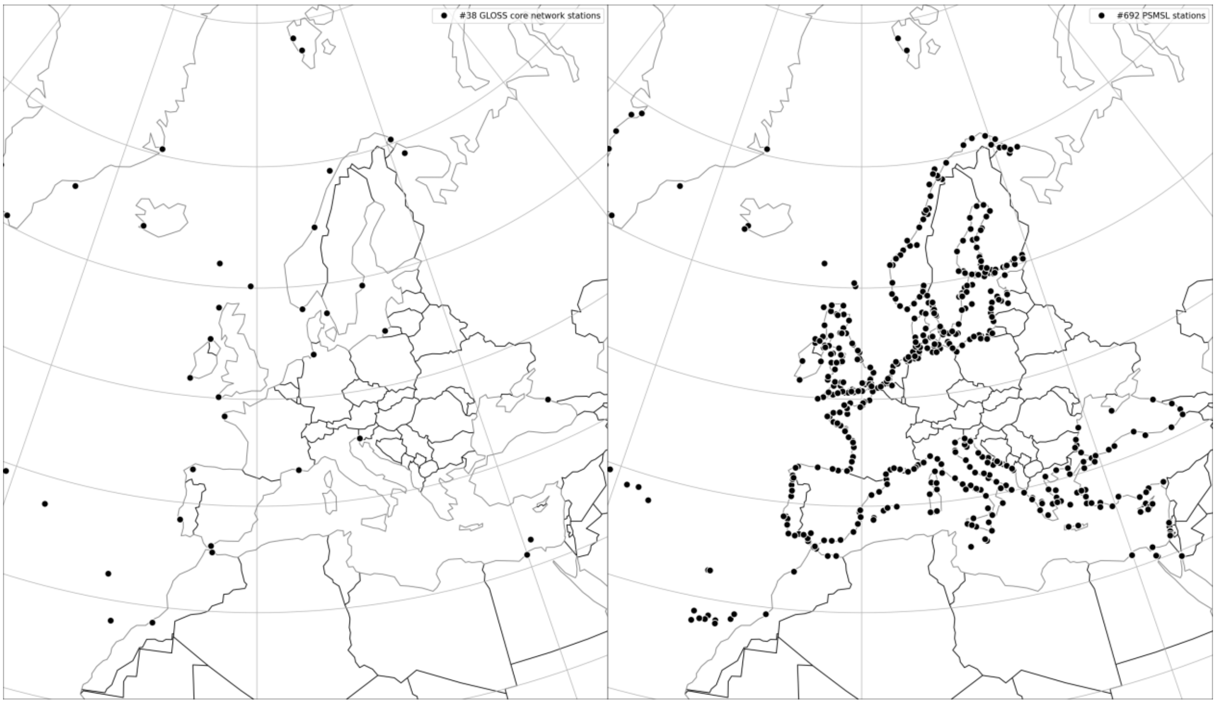

Figure 3: Stations available in the study area, belonging to: the GLOSS Core Network (left: 38 stations) and contributing to the PSMSL for monthly means (right: 692 stations).

In order to assess the usefulness of these stations for the targeted application, we will follow the criteria of the PSMSL for determination and publication of robust trends and will consider those stations with a minimum length of 30 years of valid data (with at least 70% of annual means)[4]. Considering that monthly mean sea levels are provided to the PSMSL with some delay, the study will be based on those stations with data available up to 2018. One reference period will be 1988-2018, coincident with the period with data from satellite altimetry, the other main source of data for this application. This information will be combined with the one obtained in Section 2 from GNSS@TG data, to present a picture of the network capacity for sea level rise assessment nowadays and an estimation of the situation in 10 years from now.

3.2 Current status of the network for mean sea level rise assessment

A first analysis is made for tide gauge records available in the PSMSL for the two following periods:

1) 70 years windows (1948-2018): existing long-term records
2) 30 years windows (1988-2018): potential long-term records in a near future

[4] https://psmsl.org/products/trends/methods.php

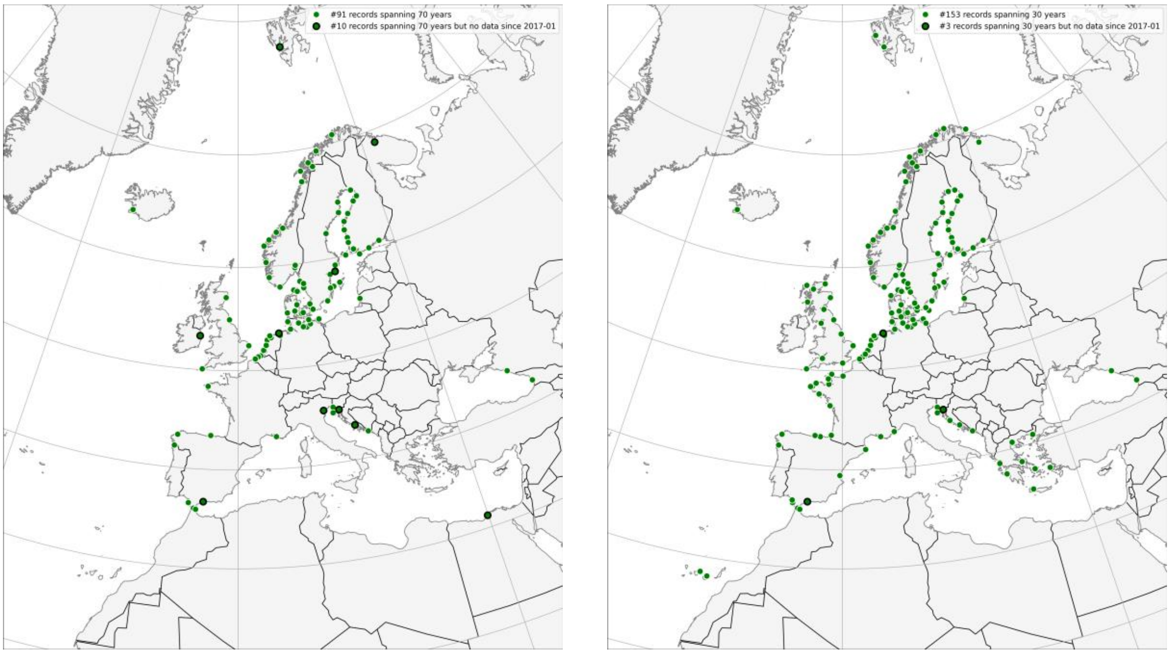

Figure 4: PSMSL stations with historical records spanning 70 years (left) and 30 years (right). Stations with no update since 2017 have been contoured in thick black

From the two maps in Figure 4 it is clear that Northern Europe (Norway, Sweden, Finland and Denmark) including the coastline of Belgium, Netherlands and Germany is by far the most complete in terms of long-term in situ sea level monitoring. The Black Sea and the East part of the Baltic Sea are poorly sampled in terms of in situ data. The lack of long in situ records in these regions has many possible reasons (data policy, hostile conditions, funding capacity, …). The Black Sea has two long-term records in Tuapse (Russia) and Poti (Georgia). On the other hand, the Northern African coast and the far East of the Mediterranean Sea (Israel, Lebanon, Syria, Turkey) have no long term reliable estimation of sea level rise. In between those two extreme cases, there falls for example the UK, France and Spain where there are some long-term tide-gauge records covering a small portion of the coastline. For these countries the situation seems to have improved significantly in the recent decades with new potential long term records (which have at present at least 30-years of data). However, the observed gaps do not always imply lack of tide gauges, but rather lack of monthly mean sea levels obtained and provided to the PSMSL. This could be the case, for example, of Italy and Portugal, that according to some existing data portals displaying near-real time data (e.g. IOC SLSMF: http://www.ioc-sealevelmonitoring.org/ or EMODnet Physics: https://map.emodnet-physics.eu/) operate today several tide gauges. Indeed, for Italy it seems that data have not been sent to PSMSL data bank since 2015. The case is similar for Portugal, where most of the records are short or not updated.

For a complete assessment of sea level rise we also need information of vertical land movements at each site. For the next step of the analysis we have focused on the 30-year records only and added the criteria of GNSS co-location based on the output of section 2, according to PSMSL/SONEL criteria. The results of the analysis are mapped in Figure 5.

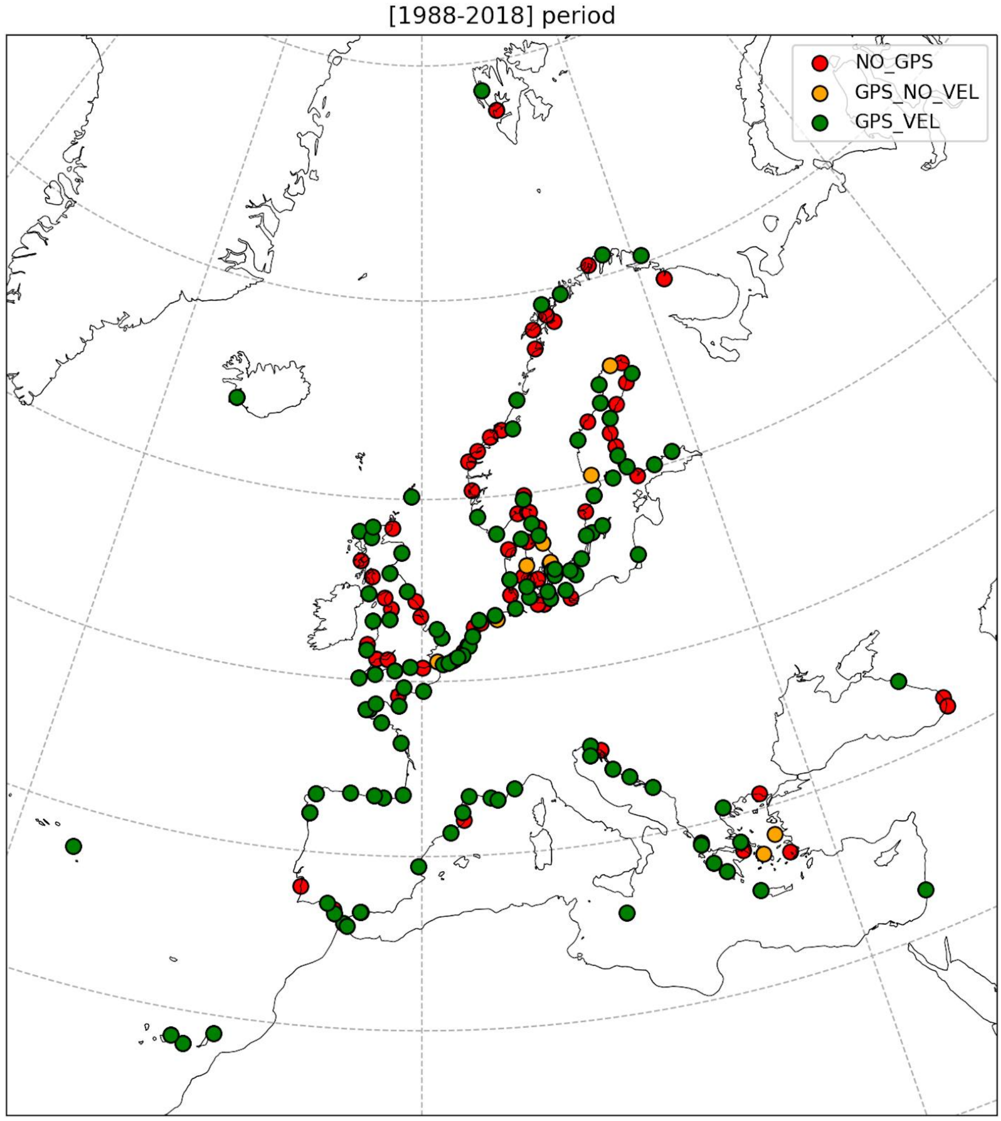

*Figure 5: Map of the PSMSL tide gauges reporting at least 70% of annual means in the last 30 years. **Green**: tide gauge co-located with a GNSS and with robust vertical land movement information; **orange**: tide gauge co-located with a GNSS but with no robust vertical land movement information yet; **red**: tide gauge not co-located with GNSS.*

From the Figure 5 we can see that a large number of countries in Europe can potentially have reliable estimation of the current sea level change along their coast. An increasing number of stations have a co-located GNSS station that has a long enough record to derive a robust Vertical Land Motion (VLM) estimate (green points in the map). In term of GNSS co-location, there was a significant increase of the number of co-located sites for the countries in Western Europe, South and Northern Europe (with the exception of Ireland, Italy and Portugal). Some countries are close to seeing their network fully co-located with a permanent GNSS station (France and Spain for example). Not surprisingly the Northern African coast and the Middle East countries bordering the Mediterranean Sea remains a desert of observation (at least of publicly available observations).

3.3 Status of the GLOSS Core Network

An analysis of the Gloss Core Network (which is a small subset of the above PSMSL stations) has been made to see if they pass the full range of criteria.

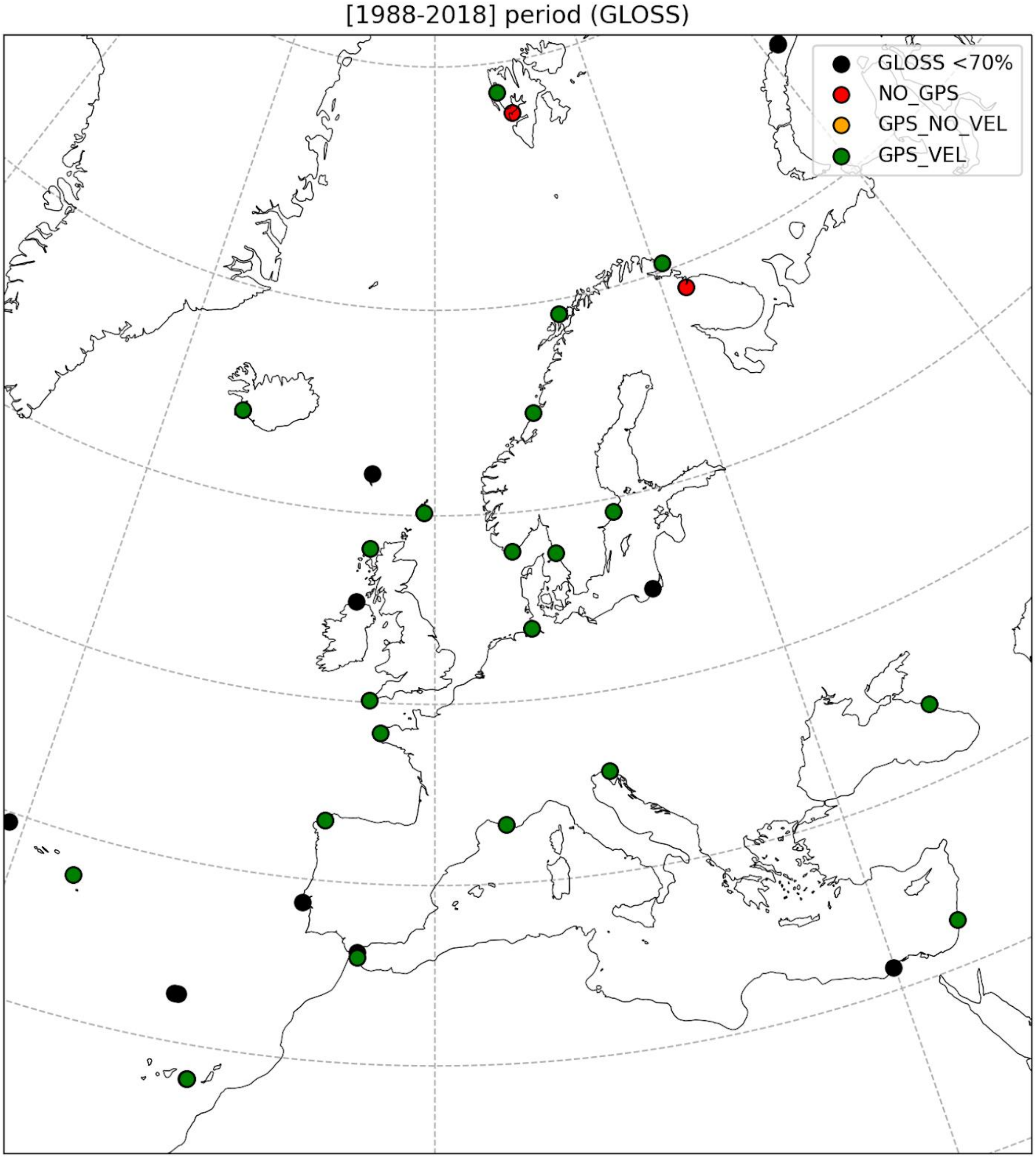

Figure 6: Map of the GLOSS Core Network. ***Black****: less than 30 years of valid data for the period.* ***Green****: TG + co-located GNSS +robust VLM;* ***orange****: tide gauge co-located with a GNSS but with no robust vertical land movement information yet;* ***red****: tide gauge not co-located with GNSS.*

A significant fraction of the GLOSS stations inside our region of interest do not pass the 30-year criterion in terms of data availability, and two of them (Barentsburg #231, Murmansk #274) do still not have gauges co-located with a GNSS.

3.4 Perspective of the status of the network in 10 years from now

In this section we have tried a perspective exercise to map the network in 2028, for PSMSL stations with the same 70% of valid data in 2028. We have considered that all existing tide gauge and GNSS stations will work without any failure until 2028, i.e., that the allocated funding for maintenance and data processing remains constant. Then, if no new Tide Gauge or GNSS equipment is installed, it is considered to be a best-case scenario. The idea of this exercise was to see the 'natural' evolution of the network that will comply with all criteria (30-year long records and a co-located GNSS within 1 km).

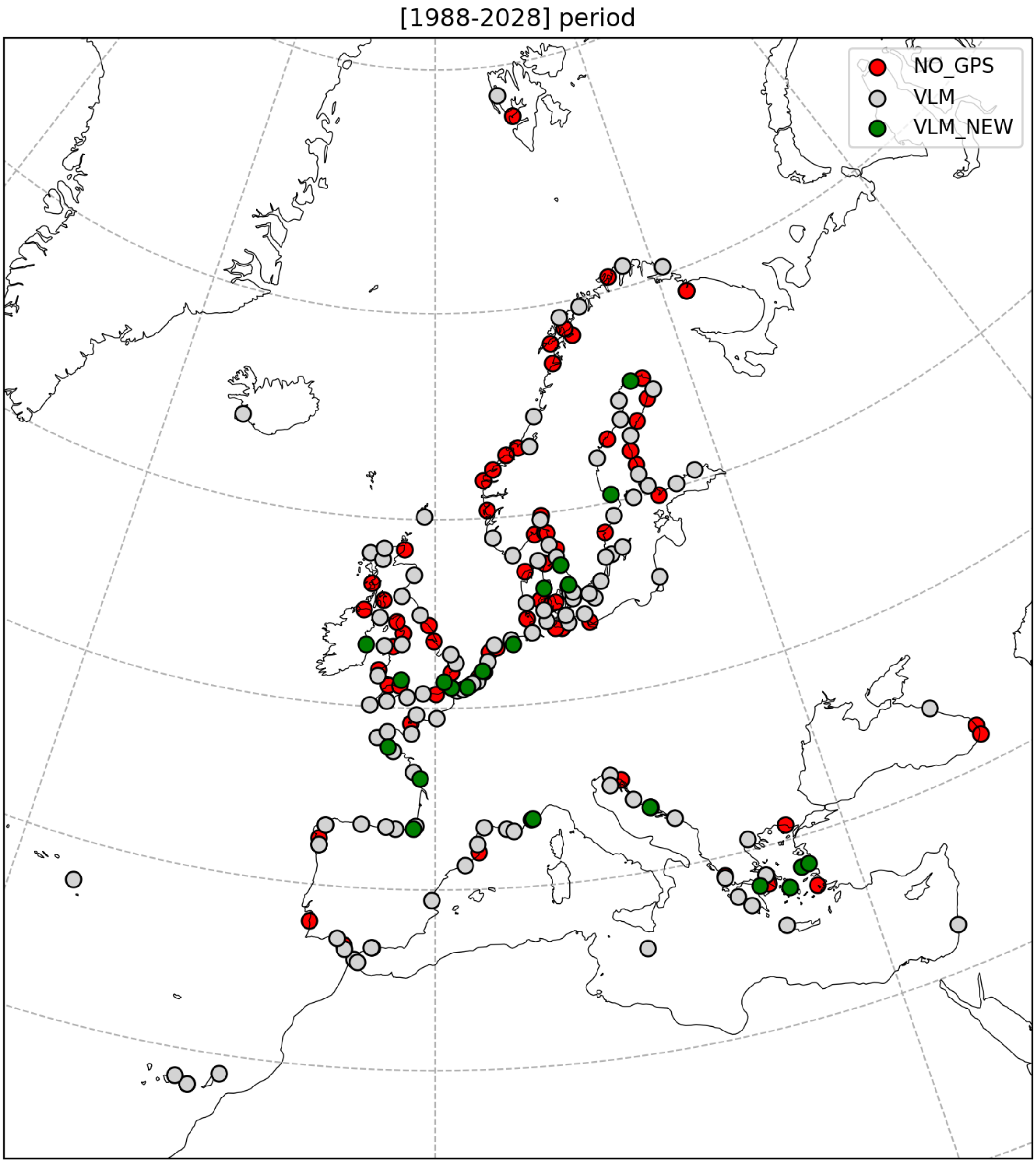

*Figure 7: Map of the PSMSL TG reporting at least 70% of annual means in the last 30 years. **Grey**: TG + co-located GNSS + robust VLM (equivalent to the green stations in Figure 5). **Green**: TG + co-located GNSS +robust VLM. **Red**: TG with no co-located GNSS.*

Under this scenario, 14 new stations appear in the map (green dots in Figure 7) because they will fulfil the 30 years of data criterion with at least 70% of annual means. 10 of them will have a green status, because they already have a GNSS attached and 4 of them will stay red because they do not have any co-located GNSS. The grey stations are the ones that already fulfil the criteria. The red dots on the upper map can be seen has a priority for co-location of GNSS stations, because they will have soon at least 30-years of valid data but no information on VLM as yet.

According to this best-case scenario estimation, however, it is evident that even in 10 years from now it will be impossible to have in situ data available for sea level rise assessment in some areas (e.g. southern Mediterranean Sea and Greenland). Some important spots like the Strait of Gibraltar are well covered, while others like the Strait of Sicily are not. The latter is a key point connection for water dynamics between the Western and the Eastern parts of the Mediterranean Sea. In some places there may be stations that are not yet reflected in SONEL data bank and that will be hopefully integrated in future updates of the survey.

3.5 Brief review of the satellite altimetry datasets

Satellite altimetry is a fundamental and clear complement of in situ data that could help to fill in some of the network gaps. Since the launch of the first satellite altimetry mission in 1992 (Topex-Poseidon), there have been a number of new satellites launched to monitor sea surface height using different orbits. From these multi-mission datasets, altimetry-based regional sea level grids have been produced in the frame of the Copernicus Marine Environmental Service (CMEMS). These gridded (¼ degree) “low resolution” datasets are produced with standard altimetry processing known to flag the data near to the coast and don’t represent accurately the coastal sea level variability. Recently, in the framework of the Coastal sea level project of the ESA Climate Change Initiative, a new coastal sea level product from the Jason-1, 2 and 3 missions over 2002-2018 has been made available (Benveniste et al., 2020).

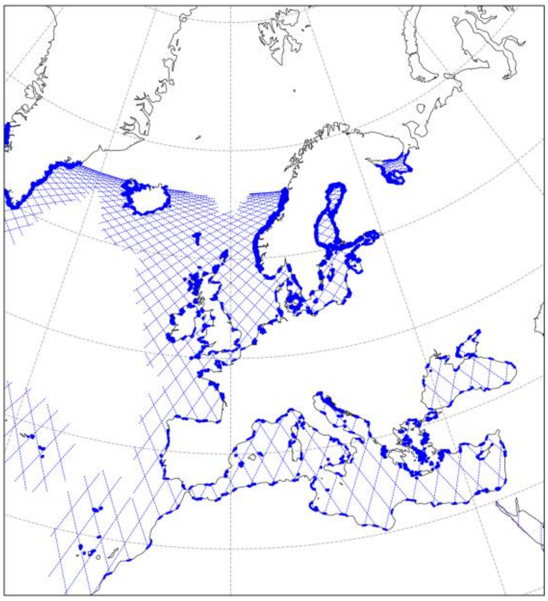

Figure 8: The blue lines indicate the ground tracks of the Jason missions within 400 km from the coast. The blue patches at the coast correspond to the part of the coastlines that have a ground track within 30 km of the coast.

This product consists of along-track high-resolution (20 Hz, i.e., ~350 m) sea level anomalies and coastal sea level trends derived from a complete reprocessing of the Jason altimetry data in several coastal regions worldwide. This product is only available for some regions of the world. In Figure 8 is shown the tracks of the Jason series of missions less than 400 km from the coast. When fully validated this type of dataset can produce estimation of the coastal sea level trend at few km from the coast (between 4 and 10 km) for the period 2002-onward. It is worthwhile mentioning that in the future, the higher spatial resolution of the ESA Sentinel altimetry missions (Sentinel-3 and -6) should also provide valuable estimates of sea level trends at the coast. Nevertheless, the in situ data from tide gauges will always be required to validate this satellite altimetry products.

4. Conclusions and recommendations

4.1 Gaps in the in situ sea level monitoring system

From the analysis presented above it appears that there are existing gaps in terms of our capacity to estimate long-term sea level trends from tide gauges along the European and adjacent coasts. Interestingly, other regions display however a high density of stations with relevant geodetic metadata. This seems to reflect the differences in national resources and investments, that seem to be more stable in some countries than in others. This heterogeneity is also a consequence of networks being designed to fulfil local purposes and applications.

The most striking gaps in the sea level monitoring system are well known by the tide gauge community and have been previously identified in various different publications for this and other applications (e.g.: Woodworth et al. 2009). They concern mainly the Mediterranean Sea, where the Northern African coast, and the Middle East countries remain void of publicly available observations. This has become a permanent problem for the region, where political aspects and different data policies have played a key role on the access to oceanographic data for decades. Particularly interesting is the gap observed in countries such as Italy and Portugal, where many tide gauges are operational and contributing to near-real time applications, but historical mean sea levels have not been provided to PSMSL in recent years.

In a similar way, the polar region appears poorly sampled in terms of in situ networks as well as for conventional satellite altimetry (i.e., the Jason orbit is limited to 66°North). The Black Sea and the East part of the Baltic Sea are also poorly sampled. The lack of long in situ records in these regions has many possible reasons (data policy, hostile conditions, funding capacity, …).

In order to summarize our analysis, we have made a tentative map of the existing gaps along the European coastline, including tide gauges and the satellite altimetry. From Figure 9 one can see that satellite altimetry will have in the future, with increasing length of time series and improved coastal processing, a potential but still partial capacity to fill the gaps in the European long-term sea level observing system. But the conclusion raised for polar regions and part of the Mediterranean countries will remain valid.

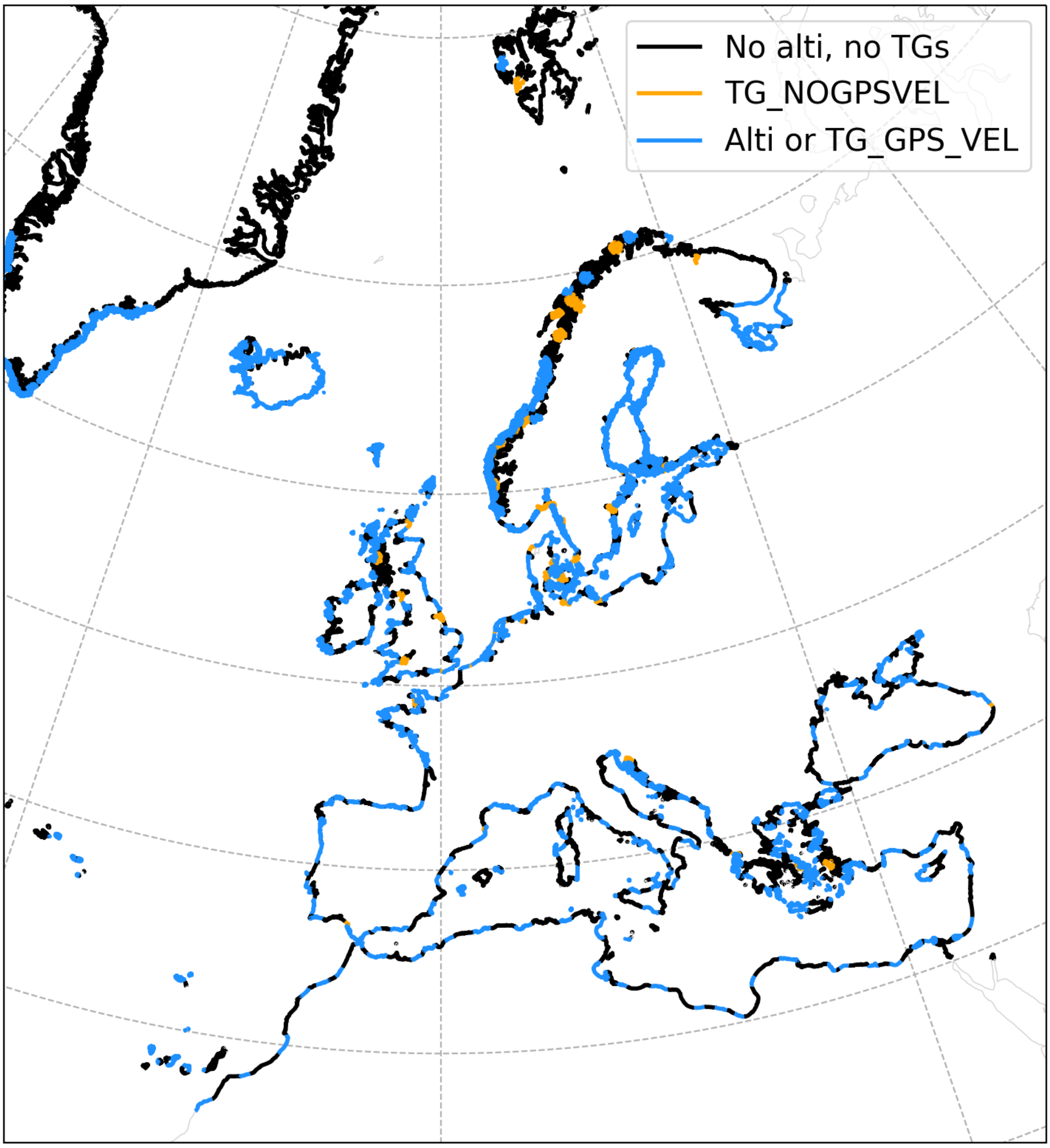

Figure 9: "sea level" observation gaps along the European Coastline. The portion of the coast in black is not monitored by tide gauge or altimetry, the blue portions have altimetry and/or state of the art tide-gauge systems (long records + co-located GNSS + VLM estimates). The orange portion have only individual tide-gauges and co-located GNSS but not yet robust VLM estimation. For the portions of coast only relative sea level trends can be computed.

4.2 Recommendations

Based on this preliminary study, to be completed and accomplished periodically by the PSMSL and SONEL GLOSS data portals, we provide the following recommendations for the European region:

7. A review of the GLOSS Core Network stations in Europe reveals that up to 9 of them would not pass the 30-year long record criteria of this study, possibly due to the lack of funding for maintenance or data processing in the last years. This will be transmitted to the GLOSS programme, particularly interested in the funding of these core stations.
8. It is necessary to fill the gaps in geodetic metadata information and provide GNSS collocated stations to all stations in GLOSS.

9. The current and future status of the tide gauge network of some European countries should be assessed in terms of density of the TG network along the coastline, existence of long-term records (either in digital format or still in paper archive), availability of real-time and public data, sustainability of the network. The countries for which we recommend this assessment are: Italy, Ireland, Portugal, Lithuania, Latvia, Estonia.
10. In section 4.1 we have identified some regions where the lack of long in situ records is obvious. Investment in new sensors would require waiting for several decades for this application. Therefore, we recommend to pursue further this analysis to see if the recently reanalysis of coastal satellite altimetry can help in reducing those observation gaps (Benveniste et al., 2017).
11. For those countries where stations are working but not providing quality-controlled monthly mean sea levels to PSMSL, the focus should be on allocating resources to data quality control and processing.
12. Vertical land movement estimation will soon be significantly improved thanks to the use of the InSAR technique. New initiatives and services such as the Copernicus European Grand Motion Service (https://land.copernicus.eu/pan-european/european-ground-motion-service), based on time series analyses of Copernicus Sentinel-1 data, will complement the in situ GNSS component described in this report.

References

Benveniste, J. et al. Coastal sea level anomalies and associated trends from Jason satellite altimetry over 2002–2018. Sci. Data 7, 357 (2020).

IOC (2012). Global Sea Level Observing System (GLOSS): Implementation Plan 2012. 41 http://www.ioc-unesco.org/components/com_oe/oe.php?task=viewDocFilesPopup&docID=9546.

IOC (2016). Manual on Sea Level measurement and interpretation, IOC Manuals Guides 14, vol. 1–4, Paris, http://www.psmsl.org/train_and_info/training/manuals/

Wöppelmann, G., and M. Marcos (2016), Vertical land motion as a key to understanding sea level change and variability, Rev. Geophys., 54, 64–92, doi:10.1002/2015RG000502.

Woodworth, P. L. and Player, R. (2003). The Permanent Service for Mean Sea Level: An Update to the 21st Century. J. Coast. Res. 19, 287–295.

Woodworth, P. L., Rickards, L. J., and Pérez Gómez, B. (2009). A survey of European sea level infrastructure, Nat. Hazards Earth Syst. Sci., 9, 927–934, https://doi.org/10.5194/nhess-9-927-2009.

Woodworth, P. L., G. Wöppelmann, M. Marcos, M. Gravelle, and R. M. Bingley (2017), Why we must tie satellite positioning to tide gauge data, Eos, 98, doi:10.1029/2017EO064037.

Annex 1

List of tide gauge stations with a TGBM Ellipsoidal Height along European and nearby coasts, contributing to CMEMS In Situ TAC (March 2021)

TG_NAME	*CMEMS_CODE*	*COUNTRY*	*LON*	*LAT*	*GNSS ID*	*DIST (M)*	*DATUM*	*TGBM_DATUM*	*TGBM_ELLIPSOIDAL_HEIGHT*	*GPS_VEL (MM/YR)*
AJACCIO	**AjaccioTG**	France	8.76295	41.922699	AJAC	530.0	ZH	2.905	50.204 +/- 0.002	0.26 +/- 0.23
BREST	**BrestTG**	France	-4.494838	48.38285	BRST	292.0	ZH	9.541	56.584 +/- 0.003	-0.25 +/- 0.18
MARSEILLE	**MarseilleTG**	France	5.35386	43.278801	MARS	1.0	ZH	1.99	50.559 +/- 0.003	-0.39 +/- 0.31
LA ROCHELLE	**LaRochelleTG**	France	-1.220736	46.158478	LROC	121.0	ZH	9.107	52.556 +/- 0.002	-0.28 +/- 0.23
CHERBOURG	**CherbourgTG**	France	-1.63563	49.651299	CHTG	1.0	ZH	9.238	52.990 +/- 0.005	-2.45 +/- 1.40
DUNKERQUE	**DunkerqueTG**	France	2.36664	51.0481	DUNQ	1.0	ZH	9.504	50.353 +/- 0.005	-0.01 +/- 1.25
SAINT JEAN-DE-LUZ	**SocoaTG**	France	-1.681623	43.395239	SCOA	1.0	ZH	7.975	54.554 +/- 0.002	-2.67 +/- 0.41
SAINT-NAZAIRE	**SaintNazaireTG**	France	-2.20155	47.266862	STNA	450.0	ZH	9.252	53.894 +/- 0.007	-0.71 +/- 0.64
SETE	**SeteTG**	France	3.69911	43.397598	SETE	3.0	ZH	6.422	55.578 +/- 0.004	-1.13 +/- 0.36
TOULON	**ToulonTG**	France	5.913222	43.11736	TLTG	1.0	ZH	1.41	46.522 +/- 0.001	-4.40 +/- 1.17
ROSCOFF	**RoscoffTG**	France	-3.965664	48.718443	ROTG	1.0	ZH	12.983	58.225 +/- 0.004	-1.82 +/- 0.40
SAINT-MALO	**SaintMaloTG**	France	-2.027477	48.641108	SMTG	1.0	ZH	14.485	56.397 +/- 0.004	-1.26 +/- 0.47
DIEPPE	**DieppeTG**	France	1.08444	49.92918	DIPP	1.0	ZH	10.33	50.060 +/- 0.005	0.43 +/- 1.26
ILE D'AIX	**IleDAixTG**	France	-1.174333	46.007353	ILDX	293.0	ZH	7.65	51.012 +/- 0.002	-0.96 +/- 0.48
ALMERIA 2	**AlmeriaTG**	Spain	-2.478335	36.830051	ALM1	639.0	Harbour Datum	3.99	53.522 +/- 0.002	-0.53 +/- 0.32
PALMA DE MALLORCA 2	**PalmadeMallorcaTG**	Spain	2.63748	39.56015	MAL1	4.0	REDMAR Datum	1.627	50.748 +/- 0.007	2.73 +/- 1.57
VALENCIATG	**ValenciaTG**	Spain	-0.311000	39.441900	VALE	4901.0	REDMAR Datum	2.276	52.211 +/- 0.002	-1.22 +/- 0.52
HUELVA	**HuelvaTG**	Spain	-6.83369	37.13202	HUE1	2.0	Harbour Datum	4.517	53.369 +/- 0.001	2.79 +/- 1.24
IBIZA	**IbizaTG**	Spain	1.449867	38.911231	IBIZ	78.0	Harbour Datum	0.884	49.708 +/- 0.004	-2.53 +/- 0.28
TENERIFETG	**TenerifeTG**	Spain	-16.241117	28.477217	TN01	5.0	Harbour Datum	3.749	47.607 +/- 0.004	-1.46 +/- 0.30
MELILLATG	**MelillaTG**	Spain	-2.92853	35.29061	MELI	2345.0	Harbour Datum	2.050	50.978 +/- 0.012	-0.92 +/- 0.88
FUERTEVENTURATG	**FuerteventuraTG**	Spain	-13.858215	28.492563	FUER	722.0	Harbour Datum	4.269	47.639 +/- 0.03	-0.95 +/- 0.95
TARIFA 2	**TarifaTG**	Spain	-5.603333	36.006667	TARI	214.0	Harbour Datum	6.589	47.549 +/- 0.006	0.55 +/- 0.73
BARCELONA	**BarcelonaTG**	Spain	2.165676	41.341774	BCL1	1.0	REDMAR Datum	4.419	53.244 +/- 0.004	0.52 +/- 1.11
GIJON II	**GijonTG**	Spain	-5.69835	43.55803	XIX1	2.0	Harbour Datum	6.026	56.323 +/- 0.001	
TARRAGONATG	**TarragonaTG**	Spain	1.21325	41.07897	TRRG	0.0	REDMAR Datum	4.964	53.76 +/- 0.03	
FERROLTG	**FerrolTG**	Spain	-8.325	43.463333	FRRL	1084.0	Harbour Datum	6.567	58.808 +/- 0.03	1.80 +/- 1.14
LAGOMERATG	**LaGomeraTG**	Spain	-17.108289	28.0878	GOM1	1.0	Harbour Datum	2.899	45.739 +/- 0.03	
LANGOSTEIRATG	**LangosteiraTG**	Spain	-8.53012	43.34653	LNGS	1.0	Harbour Datum	7.071	59.315 +/- 0.03	
VARDOETG	**VardoeTG**	Norway	31.104015	70.374978	VAR1	1.0	TGZ	3.921	19.123 +/- 0.03	2.93 +/- 0.63
ANDENESTG	**AndenesTG**	Norway	16.134848	69.326067	AND1	2.0	TGZ	5.245	38.724 +/- 0.03	1.37 +/- 0.48
TREGDETG	**TregdeTG**	Norway	7.55611	58.007309	TGDE	1.0	TGZ	2.716	42.641 +/- 0.03	1.52 +/- 0.37
HONNINGSVAAGTG	**HonningsvaagTG**	Norway	25.972697	70.980318	HONS	450.0	nan	nan	28.07 +/- 0.03	2.12 +/- 0.64
RORVIKTG	**RorvikTG**	Norway	11.228922	64.85917	VIKC	803.0	nan	nan	42.681 +/- 0.03	3.36 +/- 0.64

ONSALA	**Onsala**	Sweden	11.919167	57.391944	ONS1	495.0	Baltic Sea Chart Datum 2000	2.547	38.921 +/- 0.010	1.64 +/- 0.75
RATAN	**Ratan**	Sweden	20.895031	63.986056	RAT0	58.0	Baltic Sea Chart Datum 2000	3.417	24.493 +/- 0.01	10.46 +/- 0.64
KUNGSHOLMSFORT	**Kungsholmsfort**	Sweden	15.589303	56.1052	KUN0	108.0	Baltic Sea Chart Datum 2000	1.101	33.797 +/- 0.010	1.61 +/- 0.62
SMOGEN	**Smogen**	Sweden	11.217878	58.353621	SMO0	17.0	Baltic Sea Chart Datum 2000	3.742	45.266 +/- 0.03	4.11 +/- 0.49
STOCKHOLM	**Stockholm**	Sweden	18.08	59.32	0MOS	373.0	Baltic Sea Chart Datum 2000	1.111	24.112 +/- 0.010	4.69 +/- 0.89
ARKO	**Arko**	Sweden	16.960556	58.484167	0ARK	157.0	Baltic Sea Chart Datum 2000	2.692	29.482 +/-0.010	4.04 +/- 0.95
CASCAIS	**CascaisTG**	Portugal	-9.415384	38.693158	CASC	274.0	CD	6.390	64.091 +/- 0.002	-0.30 +/- 0.23
STORNOWAY	**Stornoway**	UK	-6.388888	58.207722	SWTG	1.0	TGZ (ACD)	6.368	60.054 +/- 0.004	0.26 +/- 0.33
LIVERPOOL (GLADSTONE DOCK)	**Liverpool**	UK	-3.017	53.45	LIVE	22.0	TGZ (ACD)	14.475	61.701 +/- 0.007	0.41 +/- 0.37
PORTSMOUTH	**Portsmouth**	UK	-1.1113	50.8023	PMTG	7.0	TGZ (ACD)	6.007	49.079 +/- 0.005	-0.36 +/- 0.30
SHEERNESS	**Sheerness**	UK	0.743408	51.445702	SHEE	1.0	TGZ (ACD)	7.532	49.448 +/- 0.001	1.30 +/- 0.30
DOVER	**Dover**	UK	1.32255	51.114395	DVTG	1.0	TGZ (ACD)	10.491	51.090 +/- 0.001	
NORTH SHIELDS	**NorthShields**	UK	-1.439867	55.007419	NSTG	1.0	TGZ (ACD)	6.754	52.923 +/- 0.008	0.52 +/- 0.49
NEWLYN	**Newlyn**	UK	-5.54279	50.103001	NEWL	1.0	TGZ (ACD)	7.801	57.723 +/- 0.002	-0.37 +/- 0.23
ABERDEEN	**Aberdeen**	UK	-2.08022	57.144001	ABER	1.0	TGZ (ACD)	6.318	53.807 +/- 0.005	0.85 +/- 0.29
LERWICK	**Lerwick**	UK	-1.140381	60.154003	LWTG	1.0	TGZ (ACD)	4.570	52.652 +/- 0.005	0.38 +/- 0.37
GEDSER	**Gedser**	Denmark	11.925481	54.573726	GESR	182.0			37.995 +/- 0.03	0.11 +/- 0.43
HIRTSHALS	**HirtshalsTG**	Denmark	9.963	57.595	HIRS	511.0			38.18 +/- 0.03	2.26 +/- 0.39
FYNSHAVN	**Fynshav**	Denmark	9.986944	54.995	FYHA	158.0			40.018 +/- 0.03	-0.21 +/- 0.75
KOPER	**KOPER**	Slovenia	13.72455	45.54811	KOPE	1.0	Datum	4.036	46.474 +/- 0.004	-0.44 +/- 0.34
ALBORAN ISLAND	**AlboranTG**	Spain	-3.033732	35.938903	ALBO	130.0			49.042 +/- 0.004	-1.57 +/- 1.13
LA CORUNA 2	**Coruna2TG**	Spain	-8.398887	43.364347	ACOR	2.0	Alicante Mean Sea Level	3.4865	57.825 +/- 0.004	-2.28 +/- 0.33
ALICANTE	**Alicante2TG**	Spain	-0.48123	38.33892	ALAC	1.0	Alicante Mean Sea Level	2.122	51.973 +/- 0.004	0.10 +/- 0.31
PUERTO DE LA CRUZ	**Tenerife3TG**	Spain	-16.550486	28.418278	TN02	30.0	Tenerife Island Mean Sea Level	2.652	48.613 +/- 0.004	-1.35 +/- 0.79
ALMERIA	**Almeria3TG**	Spain	-2.484951	36.832228	ALM1	1	Alicante Mean Sea Level	2.630	52.336 +/- 0.004	
SANTA CRUZ DE TENERIFE I	**Tenerife2TG**	Spain	-16.241157	28.477183	TN01	1	Tenerife Island Mean Sea Level	4.672	48.531 +/- 0.004	-1.46 +/- 0.30
PUERTO DEL ROSARIO	**Fuerteventura3TG**	Spain	-13.859086	28.496583	FUER	270.0	Fuerteventura Island Mean Sea Level	2.793	47.661 +/- 0.004	-0.95 +/- 0.95

Summary list of stations with ellipsoidal height estimation for the TGBM. Distances and heights provided in meters. In the last column the VLM estimates is obtained from ULR6a solution[5] derived over a minimum of 3 years of GNSS data between two position discontinuities. Only the subset of stations contributing to CMEMS In Situ TAC[6], at the time of writing, included in this table.

[5] https://www.sonel.org/-Vertical-land-movement-estimate-.html

[6] http://www.marineinsitu.eu/dashboard/

Annex 2

TG_GNSS_metadata_2021.xlsx

#RLRID	TG_Name	CMEMS_Code	Country	LONG (deg)	LAT (deg)	GNSS ID	DIST (m)	sea_level_datum	TGBM_name	TGBM_sea_l	TGBM_GNSS	TGBM_ellips	Epoch	GPS_vel (mm
2144	PORTO GARIBALDI		Italy	12.249167	44.676944	GARI	1	TGZ	TGBM0	3.537	4.022 +/- 0.0	43.681 +/- 0.	2020.0000	-3.73 +/- 0.53
1929	AJACCIO	AjaccioTG	France	8.762950	41.922699	AJAC	530	ZH	FM"-5	2.905	48.511 +/- 0.	50.204 +/- 0.	2020.0000	0.26 +/- 0.23
1	BREST	BrestTG	France	-4.494838	48.382850	BRST	292	ZH	A	9.541	9.229 +/- 0.0	56.584 +/- 0.	2020.0000	-0.25 +/- 0.18
61	MARSEILLE	MarseilleTG	France	5.353860	43.278801	MARS	1	ZH	M.AC-O- VIII	1.990	11.223 +/- 0.	50.559 +/- 0.	2020.0000	-0.39 +/- 0.31
466	LA ROCHELLE	LaRochelleTG	France	-1.220736	46.158478	LROC	121	ZH	A	9.107	5.293 +/- 0.0	52.556 +/- 0.	2020.0000	-0.28 +/- 0.23
467	CHERBOURG	CherbourgTG	France	-1.635630	49.651299	CHTG	1	ZH	C	9.238	1.933 +/- 0.0	52.990 +/- 0.	2020.0000	-2.45 +/- 1.40
468	DUNKERQUE	DunkerqueTG	France	2.366640	51.048100	DUNQ	1	ZH	A	9.504	0.737 +/- 0.0	50.353 +/- 0.	2020.0000	-0.01 +/- 1.25
469	SAINT JEAN-DE-LUZ	SocoaTG	France	-1.681623	43.395239	SCOA	1	ZH	D	7.975	4.883 +/- 0.0	54.554 +/- 0.	2020.0000	-2.67 +/- 0.41
457	SAINT-NAZAIRE	SaintNazaireTG	France	-2.201550	47.266862	STNA	450	ZH	A	9.252	21.551 +/- 0.	53.894 +/- 0.	2020.0000	-0.71 +/- 0.64
958	SETE	SeteTG	France	3.699110	43.397598	SETE	3	ZH	H	6.422	-1.685 +/- 0.0	55.578 +/- 0.	2020.0000	-1.13 +/- 0.36
980	TOULON	ToulonTG	France	5.913222	43.117360	TLTG	1	ZH	L	1.410	5.350 +/- 0.0	46.522 +/- 0.	2019.9644	-4.40 +/- 1.17
1347	ROSCOFF	RoscoffTG	France	-3.965664	48.718443	ROTG	1	ZH	A	12.983	-2.120 +/- 0.0	58.225 +/- 0.	2020.0000	-1.82 +/- 0.40
454	SAINT-MALO	SaintMaloTG	France	-2.027477	48.641108	SMTG	1	ZH	A	14.485	1.331 +/- 0.0	56.397 +/- 0.	2020.0000	-1.26 +/- 0.47
474	DIEPPE	DieppeTG	France	1.084440	49.929180	DIPP	1	ZH	A	10.330	5.180 +/- 0.0	50.060 +/- 0.	2020.0000	0.43 +/- 1.26
2236	ILE D'AIX	IleDAixTG	France	-1.174333	46.007353	ILDX	293	ZH	B	7.650	8.062 +/- 0.0	51.012 +/- 0.	2020.0000	-0.96 +/- 0.48
484	LA CORUNA 1		Spain	-8.397751	43.368605	ACOR	479	RLR	NAPG 467	10.140	9.239 +/- 0.0	57.638 +/- 0.	2020.0000	-2.28 +/- 0.33
2056	ALMERIA 2	AlmeriaTG	Spain	-2.478335	36.830051	ALME	3015	Harbour Datum	Clavo Mareografo	3.990	73.942 +/- 0.	53.543 +/- 0.	2020.0000	-0.53 +/- 0.32
485	SANTANDER 1		Spain	-3.790700	43.461300	CANT	1329	RLR	NGU 84	10.506	45.680 +/- 0.	53.571 +/- 0.	2020.0000	-0.21 +/- 0.27
498	CEUTA		Spain	-5.315706	35.892459	CEUT	561	RLR	NG R 101	10.300	6.338 +/- 0.0	45.493 +/- 0.	2020.0000	-0.57 +/- 0.85
1892	MALLORCA		Spain	2.638912	39.552381	MALL	1232	RLR	Clavo Mareografo Pal	9.600	10.463 +/- 0.	51.563 +/- 0.	2020.0000	-0.64 +/- 0.33
2061	PALMA DE MALLORCA 2	PalmadeMallorcaTG	Spain	2.637480	39.560150	MAL1	4	REDMAR Datum	NGAB Mareog Palma	1.627	3.029 +/- 0.0	50.748 +/- 0.	2020.0000	2.73 +/- 1.57
1813	ValenciaTG	ValenciaTG	Spain	-0.311000	39.441900	VALE	4901	REDMARDatum	NGW596	2.276	25.341 +/- 0.	52.211 +/- 0.	2020.0000	-1.22 +/- 0.52
565	LAS PALMAS C (PUERTO DE LA LUZ)		Spain	-15.407609	28.146709	PLUZ	1	RLR	NGU 340	9.700	3.693 +/- 0.0	44.390 +/- 0.	2013.6263	-1.92 +/- 0.17
1883	HUELVA	HuelvaTG	Spain	-6.833690	37.132020	HUE1	2	Harbour Datum	SS PD	4.517	3.044 +/- 0.0	53.369 +/- 0.	2019.9890	2.79 +/- 1.24
1810	MALAGA 2		Spain	-4.417090	36.711840	MALA	2635	RLR	SP FARO	9.783	68.874 +/- 0.	50.946 +/- 0.	2020.0000	-1.55 +/- 0.36
1932	IBIZA	IbizaTG	Spain	1.449867	38.911231	IBIZ	78	Harbour Datum	IB1	0.884	10.159 +/- 0.	49.708 +/- 0.	2020.0000	-2.53 +/- 0.28
2338	Pasaia harbour, San Sebastian		Spain	-1.931535	43.322003	PASA	26	RLR	NAPE 564	9.800	16.237 +/- 0.	51.125 +/- 0.	2020.0000	-0.25 +/- 0.36
1803	TenerifeTG	TenerifeTG	Spain	-16.241117	28.477217	TN01	5	Harbour Datum	SS 412	3.749	16.237 +/- 0.	47.607 +/- 0.0	2017.0000	-1.46 +/- 0.30
2057	MelillaTG	MelillaTG	Spain	-2.928530	35.290610	MELI	2345	RLR	CN	8.900	37.827 +/- 0.	50.978 +/- 0.	2020.0000	-0.92 +/- 0.88
2048	FuerteventuraTG	FuerteventuraTG	Spain	-13.858215	28.492563	FUER	722	Harbour Datum	NGAB-MAREO	4.269	37.827 +/- 0.	47.639 +/- 0.0	2019.0000	-0.95 +/- 0.95
2054	TARIFA 2	TarifaTG	Spain	-5.603333	36.006667	TARI	214	Harbour Datum	NG AB MAR	6.589	2.354 +/- 0.0	47.549 +/- 0.	2020.0000	0.55 +/- 0.73
488	TARIFA		Spain	-5.602620	36.008508	TARI	1	RLR	CRUZ	9.200	6.015 +/- 0.0	43.888 +/- 0.	2020.0000	0.55 +/- 0.73
1460	CARTAGENA		Spain	-0.974345	37.597321	CARG	91	Alicante Mean Sea Level	NG X 944	2.344	1.156 +/- 0.0	51.721 +/- 0.0	2020.0000	0.56 +/- 1.00
1811	BARCELONA	BarcelonaTG	Spain	2.165676	41.341774	BCL1	1	REDMAR Datum	Clavo 146	4.419	2.844 +/- 0.0	53.244 +/- 0.	2020.0000	0.52 +/- 1.11
1871	GIJON II	GijonTG	Spain	-5.698350	43.558030	XIX1	2	Harbour Datum	NGU-83	6.026	3.094 +/- 0.0	56.323 +/- 0.	2019.9890	
2182	TarragonaTG	TarragonaTG	Spain	1.213250	41.078970	TRRG	1	REDMAR Datum	CN1	4.964	3.094 +/- 0.0	53.76 +/- 0.0	2020.0000	
2052	FerrolTG	FerrolTG	Spain	-8.325000	43.463333	FRRL	1084	Harbour Datum	SSNoray1	6.567	3.094 +/- 0.0	58.808 +/- 0.0	2020.0000	1.80 +/- 1.14
2065	LaGomeraTG	LaGomeraTG	Spain	-17.108289	28.087800	GOM1	1	Harbour Datum	B.M.	2.899		45.739 +/- 0.0	2020.0000	
2308	LangosteiraTG	LangosteiraTG	Spain	-8.530120	43.346530	LNGS	1	Harbour Datum	CN	7.071		59.315 +/- 0.0	2020.0000	
524	VardoeTG	VardoeTG	Norway	31.104014	70.374978	VAR1	1	TGZ	O03N0018	3.921		19.123 +/- 0.0	2019.0000	2.93 +/- 0.63
425	AndenesTG	AndenesTG	Norway	16.134153	69.325713	AND1	46	TGZ	L07N0042	5.245		38.724 +/- 0.0	2019.0000	1.37 +/- 0.48
302	TregdeTG	TregdeTG	Norway	7.556110	58.007309	TGDE	1	TGZ	D40N0053	2.716		42.641 +/- 0.0	2019.0000	1.52 +/- 0.37
1267	HonningsvaagTG	HonningsvaagTG	Norway	25.970000	70.980000	HONS	375		W02N001			28.07 +/- 0.0	2019.0000	2.12 +/- 0.64
1241	RorvikTG	RorvikTG	Norway	11.228922	64.859170	VIKC	803		H20N0062*			42.681 +/- 0.0	2019.0000	3.36 +/- 0.64
2331	Onsala	Onsala	Sweden	11.919167	57.391944	ONS1	495	Baltic Sea Chart Datum 200	827a	2.547		38.921 +/- 0.0	1999.5000	1.64 +/- 0.75
88	Ratan	Ratan	Sweden	20.895031	63.986056	RAT0	58	Baltic Sea Chart Datum 200	h	3.417		24.493 +/- 0.0	1999.5000	10.46 +/- 0.6
70	Kungsholmsfort	Kungsholmsfort	Sweden	15.589303	56.105200	KUN0	108	Baltic Sea Chart Datum 200	a	1.101		33.797 +/- 0.0	1999.5000	1.61 +/- 0.62
179	Smogen	Smogen	Sweden	11.217878	58.353621	SMO0	17	Baltic Sea Chart Datum 200	g	3.742		45.266 +/- 0.0	1999.5000	4.11 +/- 0.49
78	STOCKHOLM	Stockholm	Sweden	18.080000	59.320000	0MOS	373	Baltic Sea Chart Datum 200	a (LMV 108*2*6503)	1.111		24.112 +/- 0.0	1999.5000	4.69 +/- 0.89
2359	ARKO	Arko	Sweden	16.960556	58.484167	0ARK	157	Baltic Sea Chart Datum 200	111	2.692		29.482 +/- 0.	1999.5000	4.04 +/- 0.95
258	PONTA DELGADA		Portugal	-25.666700	37.733299	PDEL	1639	Hydrographic Zero	NP	3.016	51.890 +/- 0.	58.711 +/- 0.	2020.0000	-1.76 +/- 0.27
52	CASCAIS	CascaisTG	Portugal	-9.415384	38.693158	CASC	274	CD	O b 1	6.390	11.964 +/- 0.	64.091 +/- 0.	2020.0000	-0.30 +/- 0.23
1037	BORKUM FISHERBALJE		Germany	6.747902	53.557452	TGBF	3	TGZ	MB 3	10.374	14.073 +/- 0.	45.54		-0.65 +/- 0.70
397	SASSNITZ		Germany	13.643203	54.510976	SAS2	7	RLR	PFP_2/01	15.253	0.337 +/- 0.0	38.844 +/- 0.	2020.0000	0.62 +/- 1.56
11	WARNEMUNDE 2		Germany	12.103361	54.169728	WARN	126	RLR	PFP330	14.815	9.743 +/- 0.0	40.997 +/- 0.	2020.0000	0.36 +/- 0.48
789	KIEL-HOLTENAU		Germany	10.158333	54.372222	HOL2	125	RLR	TGBM	14.978	5.192 +/- 0.0	42.520 +/- 0.	2020.0000	0.30 +/- 0.44
7	CUXHAVEN 2		Germany	8.717500	53.867777	TGCU	1	TGZ	MB 724/7	8.756	5.703 +/- 0.0	43.086		-0.54 +/- 0.40
124	BREMERHAVEN		Germany	8.568183	53.544975	TGBH	1	TGZ	MB 2	9.425	5.703 +/- 0.0	44.108		-0.56 +/- 0.63
504	BUSUM		Germany	8.859187	54.121714	TGBU	1	TGZ	MB 22	13.524	5.703 +/- 0.0	48.124		-0.81 +/- 0.72
1046	DAGEBULL		Germany	8.687070	54.730486	TGDA	1	TGZ	MB 15	8.107	5.703 +/- 0.0	43.108		-0.43 +/- 0.72
624	EMDEN, NEUE SEESCHLEUSER		Germany	7.186277	53.336780	TGEM	1	TGZ	MB 40/50	13.187	5.703 +/- 0.0	48.649		-0.67 +/- 0.97
1797	HADERA		Israel	34.864101	32.470532	CSAR	3145	TGZ	BM 0013 on 'Dolphin'	18.000	10.960 +/- 0.	25.629 +/- 0.	2019.9890	0.28 +/- 0.22
314	STORNOWAY	Stornoway	United Kingdom	-6.388888	58.207722	SWTG	1	TGZ (ACD)	NB42283264	6.368	0.037 +/- 0.0	60.054 +/- 0.	2020.0000	0.26 +/- 0.33
1774	LIVERPOOL (GLADSTONE DOCK)	Liverpool	United Kingdom	-3.017000	53.450000	LIVE	22	TGZ (ACD)	SJ32499525	14.475	0.037 +/- 0.0	61.701 +/- 0.0	2020.0000	0.41 +/- 0.37
350	PORTSMOUTH	Portsmouth	United Kingdom	-1.111300	50.802300	PMTG	7	TGZ (ACD)	SU62700053	6.007	7.467 +/- 0.0	49.079 +/- 0.	2020.0000	-0.36 +/- 0.30
3	SHEERNESS	Sheerness	United Kingdom	0.743408	51.445702	SHEE	1	TGZ (ACD)	TQ90807549	7.532	3.892 +/- 0.0	49.448 +/- 0.	2020.0000	1.30 +/- 0.30
255	DOVER	Dover	United Kingdom	1.322550	51.114395	DVTG	1	TGZ (ACD)	TR31934074	10.491	-1.017 +/- 0.0	51.090 +/- 0.	2012.3943	
95	NORTH SHIELDS	NorthShields	United Kingdom	-1.439867	55.007419	NSTG	1	TGZ (ACD)	NZ35926823	6.754	4.002 +/- 0.0	52.923 +/- 0.	2020.0000	0.52 +/- 0.49
202	NEWLYN	Newlyn	United Kingdom	-5.542790	50.103001	NEWL	1	TGZ (ACD)	SW46762855	7.801	6.776 +/- 0.0	57.723 +/- 0.	2020.0000	-0.37 +/- 0.23
361	ABERDEEN	Aberdeen	United Kingdom	-2.080220	57.144001	ABER	1	TGZ (ACD)	NJ95250590	6.318	-0.316 +/- 0.0	53.807 +/- 0.	2020.0000	0.85 +/- 0.29