Report on result uncertainty assessment workshop

Final Version of 31/03/2020

Deliverable Number D.3.5.2.

Project Acronym	SOUNDSCAPE
Project ID Number	10043643
Project Title	Soundscapes in the north Adriatic Sea and their impact on marine biological resources
Priority Axis	3
Specific Objective	3.2
Work Package Number	3
Work Package Title	Soundscape assessment
Activity Number	3.5
Activity Title	Definition of processing protocols
Partner in Charge	IOF
Partners Involved	CNR, BWI, ARPA FVG
Authors	Predrag Vukadin (IOF)
Status	Final
Distribution	Public
Citation	Vukadin P. Report on result uncertainty assessment workshop. SOUNDSCAPE project, WP3, 24pp, 2020

Summary

1 Abstract

Document describes all activities involved in planning and executing the monitoring uncertainty workshop. Document includes agenda, participants, and presentations given at the workshop, disscussion as well as conclusion and the recommendations for further work.

2 Introduction

According to the project work plan, the network of the underwater noise monitoring stations is to be set up in the Northern Adriatic Sea (Activity 3.2). The continuous underwater noise produced by anthropogenic activities such as marine traffic (both commercial and recreational) and hydrocarbon exploitation will be monitored.

Also, the soundscape modeling for the Northern Adriatic Sea is to be carried out (Activity 5.2.). The modelling of underwater noise is to address the cumulative effect antropogenic noise as well as the natural noise generated by wind and waves, and possibly rain. Directly observed environmental and acoustic measurements are used to provide locally valid assessment of modelled predictions.

When reporting the result of a measurement of any physical quantity, in this case underwater noise levels, it is very important that some quantitative indication of the quality of the result be given so that those who use it can assess its reliability. Without such an indication, measurement results are hard to compare. The same goes also to underwater noise modeling.

The concept of ***measurement uncertainty*** is used to assess the reliability of the measurement process. The concept of *uncertainty* as a quantifiable attribute is relatively new in the history of measurement but a worldwide consensus on the evaluation and expression of uncertainty in measurement permits the significance of a vast spectrum of measurement results to be readily understood and properly interpreted.

It was considered important that all partners involved in noise measurement and modelling aquire knowlwdge on the uncertainity concept as well as possibility to asses the uncertainity of a general measurement and modelling process. Therefore, this workshop was prepared and carried out. Although there is a significant knowledge gap in definition and uncertainty quantification of continuous underwater noise measurements and modeling, tentative possible sources of uncertainty in a measurement and modeling are presented and discussed.

3 Workshop activities

3.1 Introduction

The measurement uncertainity assesment workshop was held in Venice on 26th November 2019. in the premises of project partner CNR/ISMAR. The workshop was held during the partners three days meeting on which workshops on operators training and processing as well as meetings of Scientific and Monitoring committee were held. The agenda of the workhop was planed as follows:

- Introduction on measurement uncertainty in continuous underwater noise measurements (presented by IOF)
- Introduction on uncertainty in underwater noise modelling (presented by QuietOceans)
- Discussion on monitoring uncertainty, conclusions for the further work and wrap up (all partners – moderator IOF)

The workshop was attended by 30 participants including partner's stuff planned for working with the equipment, external experts as well as the wider scientific stuff interested in gaining knowledge on underwater noise measurement. The part of participants list is shown on the Figure 1 and number of participants per project partner in Table 1.

Table 1 Number of participants per project partner of the monitoring uncertainity workshop held in CNR/ISMAR, Venice on 26th November 2019

No.	Project partner name	Number of participants
1	ARPA FVG	2
2	Fondazione Cetacea	2
3	CNR - IRBIM	4
4	IOF	6
5	BWI	4
6	CNR - ISMAR	6
7	University of Gdansk	2
8	Regione Marche	1
9	Quiet ocean	1
10	MEE	2

Figure 2 The participants of the monitoring uncertainity workshop held in CNR/ISMAR, Venice

3.2 Introduction on measurement uncertainity in continuous underwater noise measurements

When reporting the result of a measurement of a physical quantity, it is very important that some quantitative indication of the quality of the result be given so that those who use it can assess its reliability. Without such an indication, measurement results are hard to compare. The concept of *uncertainty* as a quantifiable attribute is relatively new in the history of measurement but a worldwide consensus on the evaluation and expression of uncertainty in measurement permits the significance of a vast spectrum of measurement results to be readily understood and properly interpreted.

In general, the concept of *accuracy* is also used to describe how sure we are of the measurement results.

Accuracy of measurement is the older concept and its internationally agreed definition is '… *the closeness of the agreement between the result of a measurement and a* ***true value*** *of the measurand*'. The definition adds: '... *accuracy is a qualitative concept*', so is often expressed as being high or low, but not with numbers.

In the case of the underwater noise measurements, this concept breaks down because it inherently assumes that a true value can be defined, known and realised perfectly which is not the case. Underwater noise levels which are measured are neither known nor defined.

Uncertainty of measurement concept acknowledges that no measurements can be perfect and is defined as a '… ***parameter, associated with the result of a measurement, that characterises the dispersion of values that could reasonably be attributed to the measurand***'. It is typically expressed as a range of values in which the value is estimated to lie, within a given statistical confidence. It does not attempt to define or rely on one unique true value.

The "bible" of measurement uncertainty is the document **JCGM 100:2008** – Evaluation of measurement data **– Guide to the expression of uncertainty in measurement** (ISO/IEC Guide 98-3). All partners are encouraged to get acquainted with this document and to study parts that can be useful in assessment of the uncertainty in underwater noise measurements.

The result of any quantitative measurement has two essential components:

- A numerical value which gives the best estimate of the quantity being measured (the measurand). This estimate may well be a single measurement or the mean value of a series of measurements.
- A measure of the uncertainty associated with this estimated value.

The example of the result of underwater noise level measurement is:

SPL = X dB ± Y dB at confidence level Z (%)

The concept of *uncertainty* is an attempt to quantify measurement accuracy without knowledge of the true value. An uncertainty provides bounds around the measured value within which it is believed that

the true value lies, with a specified level of confidence. However, it is only possible to state the probability that the value lies within a given interval.

The uncertainty of the result of a measurement generally consists of several components. The components are regarded as random variables, and may be grouped into two categories according to the method used to estimate their numerical values:

Type A, which is method of evaluation of uncertainty by the statistical analysis of series of observations, and

Type B, which is method of evaluation of uncertainty by means other than the statistical analysis of series of observations. These may include:

- Information associated with an authoritative published numerical quantity
- Information associated with the numerical quantity of a certified reference material
- Data obtained from a calibration certificate
- Information obtained from limits deduced through personal experience
- Scientific judgment.

The type A uncertainty (precision) corresponds to the previous classification of *random* uncertainty or *repeatability* and may be assessed by making repeated measurements of a quantity and examining the statistical spread in the results. Type A uncertainty is a measure of the precision in the measurement, high precision is obtained if the measurements are repeatable with little dispersion in the results.

The type B uncertainty (bias) corresponds to the previous classification of *systematic* uncertainty and represents the potential for systematic bias in a measurement. This category of uncertainty cannot be assessed using repeated measurements and must be evaluated by consideration of the potential influencing factors on the measurement accuracy.

Any detailed report of the uncertainty should consist of a complete list of the components, specifying for each the method used to obtain its numerical value.

The combined uncertainty should be characterized by the numerical value obtained by applying the usual method for the combination of variances. The combined uncertainty and its components should be expressed in the form of “standard deviations”.

In practice, there are many possible sources of uncertainty in a measurement, including:

- incomplete definition of the measurand;
- imperfect realization of the definition of the measurand;
- nonrepresentative sampling — the sample measured may not represent the defined measurand;
- inadequate knowledge of the effects of environmental conditions on the measurement or imperfect measurement of environmental conditions;
- personal bias in reading analogue instruments;
- finite instrument resolution or discrimination threshold;
- inexact values of measurement standards and reference materials;

- inexact values of constants and other parameters obtained from external sources and used in the data-reduction algorithm;
- approximations and assumptions incorporated in the measurement method and procedure;
- variations in repeated observations of the measurand under apparently identical conditions.

The results of the continuous underwater noise monitoring which are assessed by the measurement should consist of, as stated previously, numerical value which is the estimate of the measured noise level, and the measure of the uncertainty associated with this estimated value. The uncertainty components of the continuous underwater noise measurement would be of the type B uncertainty as continuous underwater noise is random process. Therefore, it makes no sense repeating measurements as the source levels during the new measurement will differ from the previous ones.

For assessing of measurement uncertainty, a complete list of all the components specifying for each the method used to obtain each numerical value should be produced.

There is a significant knowledge gap in definition and quantification of the uncertainty components of continuous underwater noise measurement. Therefore, only tentative possible sources of uncertainty in a measurement are proposed that may include some of the following.

Validity of any assumptions made. In designing, setting up and deploying continuous underwater noise measuring system, various assumptions are made e.g. assumptions of the acoustic field (free field, far field etc.). All assumptions made should be reconsidered and validated to mitigate possible uncertainties.

Equipment calibration. The calibration data will include uncertainty of calibration parameter e.g. hydrophone sensitivity or amplifier gain, and will contribute to the overall uncertainty. Good calibration laboratory traceable to appropriate standards can calibrate hydrophone with an uncertainty of less than 0.5 dB, and the overall uncertainty of the continuous underwater noise measuring system calibration can be of the order of 1 dB.

Temporal sampling of the continuous underwater noise. In order to extend deployment period which is limited by memory and battery capacity, recording can be intermittent (on-off) which means that data are recorded for some period (on) following by the standby period (off) in which the system is idle. If this is the case, the average level of the recorded noise in the "on" period can differ from the average level that would be recorded if the recording was continuous over the whole period. The recorded level of the continuous underwater noise using intermittent (on-off) recording scheme will contain the uncertainty component due to the difference in recorded period averaged noise level to overall period averaged noise level. There are no scientific or engineering data of the possible quantity of this uncertainty component which represents another knowledge gap in the assessment of the overall measurement uncertainty. Nevertheless, as this component can be in some cases significant, this issue should be considered important to address in the future

Spatial position of the hydrophone. Depending on the measurement and/or deployment methodology the hydrophone will be placed on the different position in the water column. All reflective surfaces in the hydrophone's environment will theoretically affect reception of the direct noise signal. The reflected signal received by the hydrophone together with the direct signal would produce interferences and changes in the received noise level. Also, parts of the deployment gear (e.g. flotations) or t he case

containing batteries and electronics can add to the diffraction or the shadowing of the sound waves also affecting the received levels. The assessment of this component of the overall uncertainty is not an easy task as it is case (deployment) as well as frequency dependent. In the case of bottom-based system where

hydrophone can be very close (1-2 m) to the eventually hard bottom, reflections from the bottom will surely have not negligible effect on the levels recorded. Also, on the low frequencies where wavelengths are long (10 – 20 m) recorder casing or the flotations with typical dimensions of tens of centimeters will have minimal reflective or diffractive influence. There are no scientific or engineering data of the possible uncertainties caused by the hydrophone position in different deployment settings but as the illustration, Figure 3 shows the difference in sensitivity diagrams for the hydrophone close to the reflective surface (fixed) and away from it (cabled) in the case the sound incides from the direction parallel to the hydrophone.

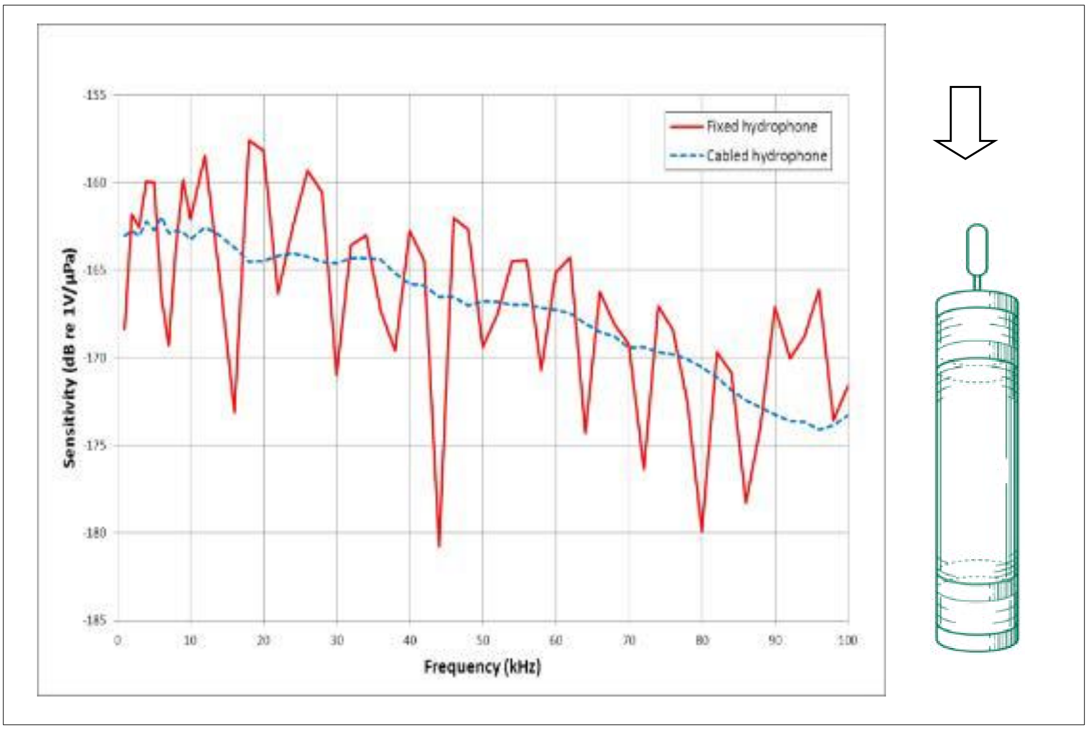


Figure 3 The difference in sensitivity diagrams for the hydrophone close to the reflective surface (fixed) and away from it (cabled)

Another look in the lower spectrum part as displayed on Figure 4 shows pronunced case resonances and scaterings for the hydrophone rigidly attached close to the recorder casing

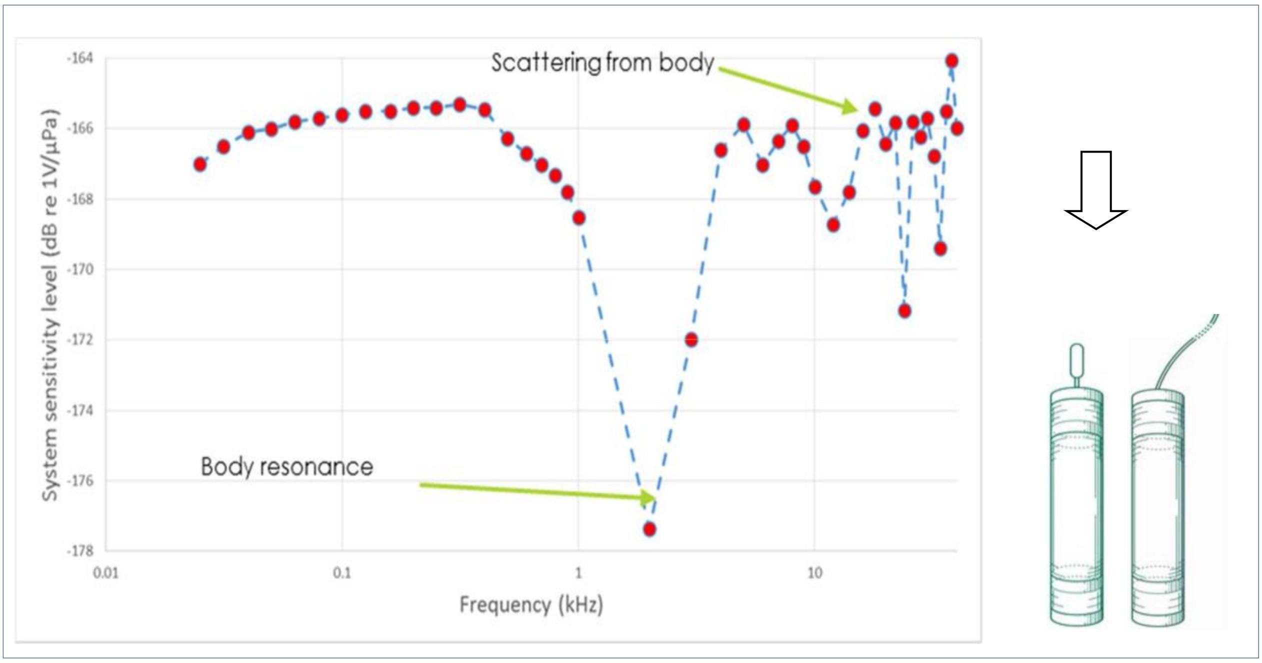


Figure 4

It is obvious that broadband as well as one third octave measured levels will differ depending on the hydrophone placing and that this component may seriously influence the uncertainity of the measurement result.

Again, there is substantial knowledge gap in determining this measurement uncertainity component.

Although there is substantial knowledge gap in determining this measurement uncertainity component, it is strongly recommended that additional effort should be devoted to this issue as it is evident that this component may seriously compromise the results of the measurement.

Platform and/or deployment induced (unwanted) sound. In spite of every attempt to eliminate sources of unwanted sounds caused by platform and/or deployment gear such are those identified in section 4.2, some residual effects will be present in some measurement methods. It is recommended that the levels of these unwanted sounds be assessed and checked against the lowest levels expected to be recorded. If level of unwanted sound caused by platform and/or deployment gear is well below the lowest levels expected, the contribution of this component to the overall measurement uncertainty can be very low and ignored.

Environmental parameters. Some parts of the measurement system, mostly hydrophone, can perform differently if environmental parameters differ from those encountered during calibration. The hydrophones are usually calibrated in calibration tanks at room temperature and in shallow water (low pressure). If this hydrophone is put in deep water (e.g. maximum rated depth) it will be exposed to much higher pressure and lower temperature than when calibrated. It can cause it to have a different sensitivity or frequency linearity. It is recommended that any change in any measurement system component specification be assessed if used in environmental parameters different to reference ones.

Bio fouling of the hydrophone can also affect sensitivity and/or frequency linearity.

3.3 Introduction on uncertainty in underwater noise modelling and mapping

The underwater sound propagation model calculates estimates of the sound field generated from underwater sound sources. The modelling results are used to determine the potential impact distances (noise maps/contour plots) from the identified significant underwater noise sources for the various identified marine life for the area. Based on source location and underwater source sound level, the acoustic field at any range from the source is estimated using acoustic propagation model. The sound propagation modelling uses acoustic parameters appropriate for the specific area of interest, including the water column sound speed profile, the bathymetry, and the bottom geo-acoustic properties, to produce site-specific estimates of the radiated noise field as a function of range and depth. The received level at any three-dimensional location away from the source is calculated by combining the source level and transmission loss, both of which are direction-dependent. Underwater acoustic transmission loss and received underwater sound levels are a function of depth, range, bearing, and environmental properties.

The uncertainity of model predictions depends both on employing an appropriate model and on the quality of the input data. Confidence in model predictions further requires validation (calibration) with field measurements of noise levels, and these measurements can also be used to optimise model parameters.

The structure of modeling is displayed on Figure 5. The data needed, maritime data defining noise source levels and environmental data (sound speed profile, bathymetry, bottom properties) as well as the results of field measurements of the underwater noise are inputed in the mode. Model than calculate received noise levels and make corrections of the modeling parameters with measurements. The modeling results are then used within planing tool(s).

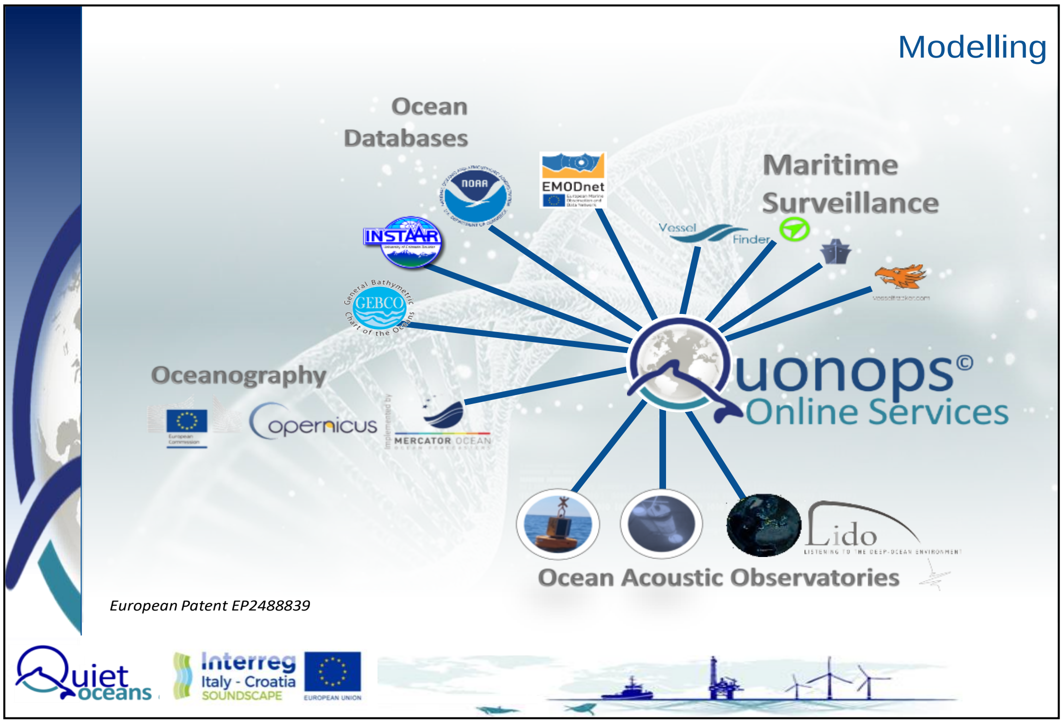
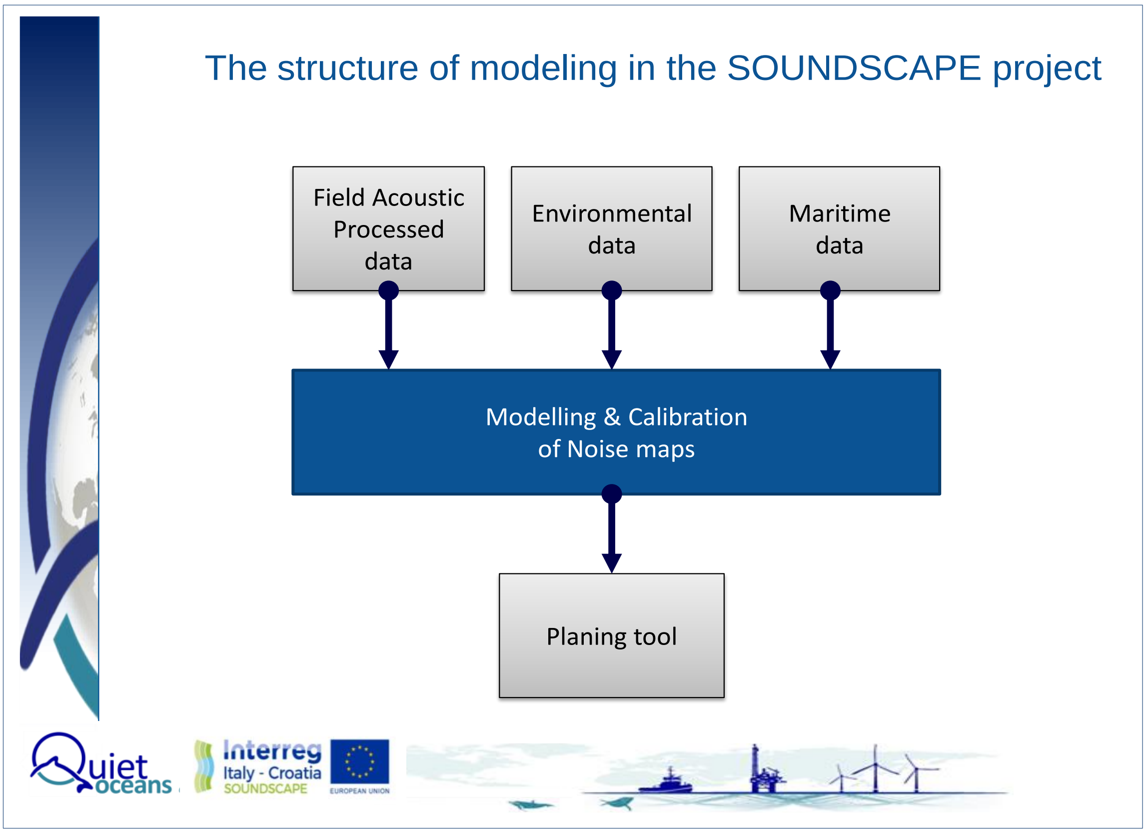


Figure 5 The structure of modeling

Underwater noise mapping is referred to the representation of sound levels at a specific area using colour scales or contours. It has been used extensively for predicting noise levels in urban areas and has been a major subject of research and development in the framework of the EC Directive on noise control.

The data are usualy obtained from various sources and databases. Figure 6 displays some of sources of data for modeling in Soundscape project.



The structure of modeling in the SOUNDSCAPE project

Field Acoustic Processed data

Environmental data

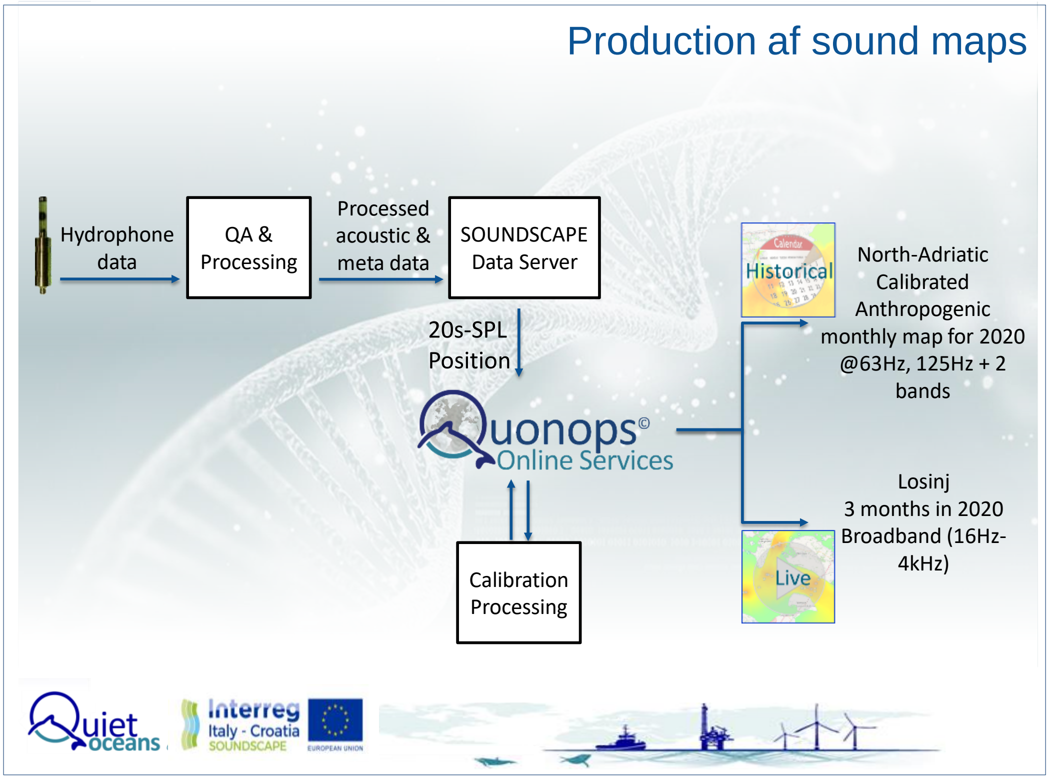
Maritime data

Modelling & Calibration of Noise maps

Planing tool

Figure 6 Some of the sources of data for modeling in Soundscape project.

The production of sound maps is shown on Figure 7. The outputs from all monitoring recorders are stored on data server. Modeling tool uses them to recalibrate modeling parameters. For the Soundscape project two sets of sound maps will be produced, North Adriatic for the whole year and local for the Losinj area.



Production af sound maps

Hydrophone data → QA & Processing → Processed acoustic & meta data → SOUNDSCAPE Data Server

20s-SPL Position

Quonops© Online Services

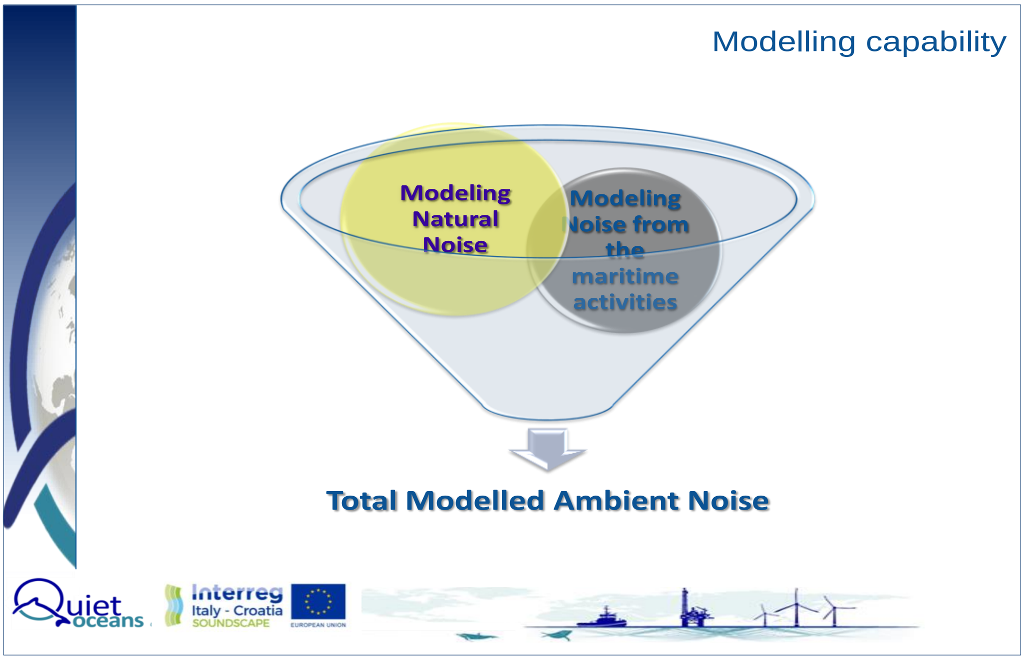
Calibration Processing

North-Adriatic Calibrated Anthropogenic monthly map for 2020 @63Hz, 125Hz + 2 bands

Losinj 3 months in 2020 Broadband (16Hz-4kHz)

Figure 7 The production of sound maps in Soundscape project

The model is capable of separately modeling natural sound in the water depending mostly from waves (especially in shallow water) and man-made noise generated by maritime activities as shown on Figure 8.



Modelling capability

Modeling Natural Noise

Modeling Noise from the maritime activities

Total Modelled Ambient Noise

Figure 8 Modelling capabilities

The example of modeling of the natural sound is shown on Figure 9. Both modeled and measured values in one-month period for a location in Baltic sea are displayed.

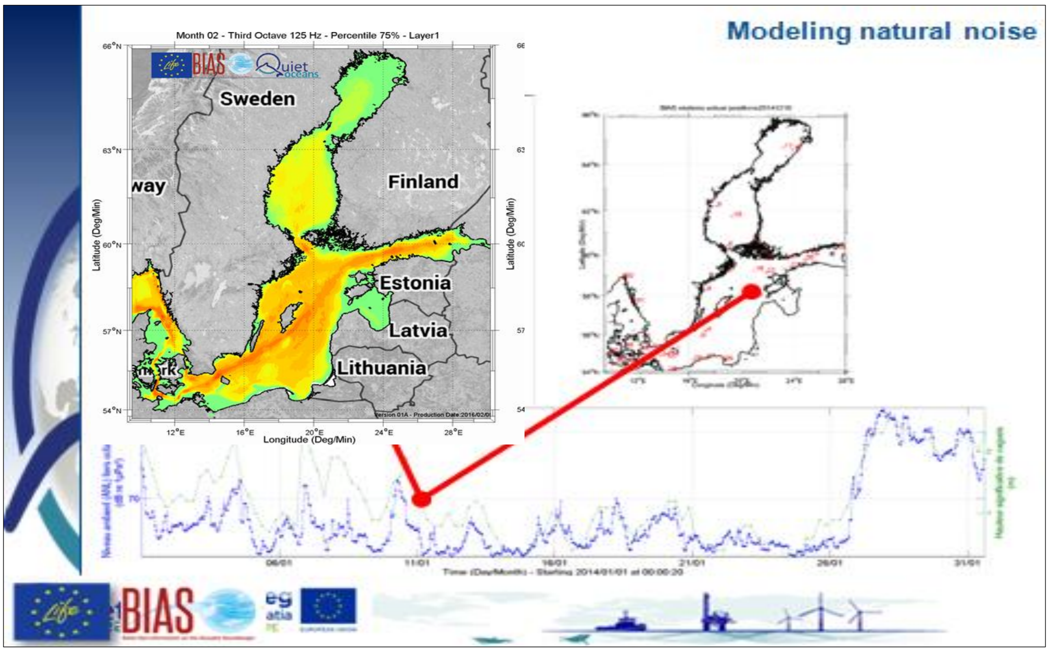


Figure 9 The example of modeling of the natural sound

The example of modeling of the maritime activities underwater noise is shown on Figure 10. Median sound pressure level in the 125 Hz 1/3 octave band averaged over one-month period are shown.

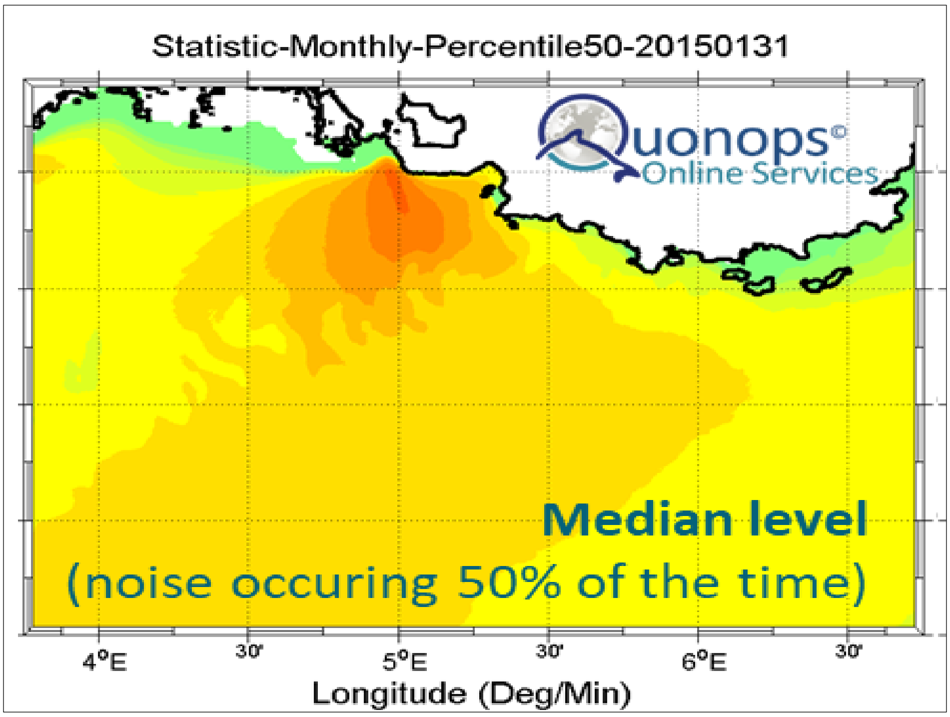
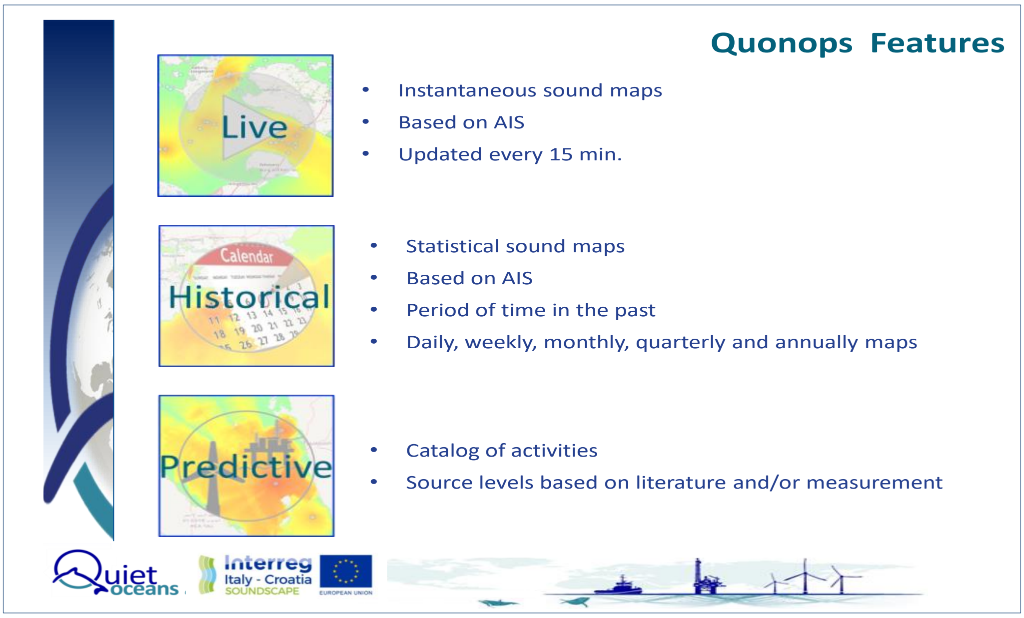


Figure 10 The example of modeling of the maritime activities underwater noise

The noise maps produced can be described within three categories: live, historic and predictive as shown on Figure 11. Live maps are produced instantaneously from the current AIS data on maritime traffic. All other data for the area (environmental) of interest are already in the model. The maps are updated every 15 minutes as soon as they are calculated. Historical maps are statistical noise maps produced by averaging noise levels over some period in the past. The period can be day, week, month or year as fit for the purpose. The maps can also be predictive where source levels are presumed based on existing theoretic or measurement data.



Quonops Features

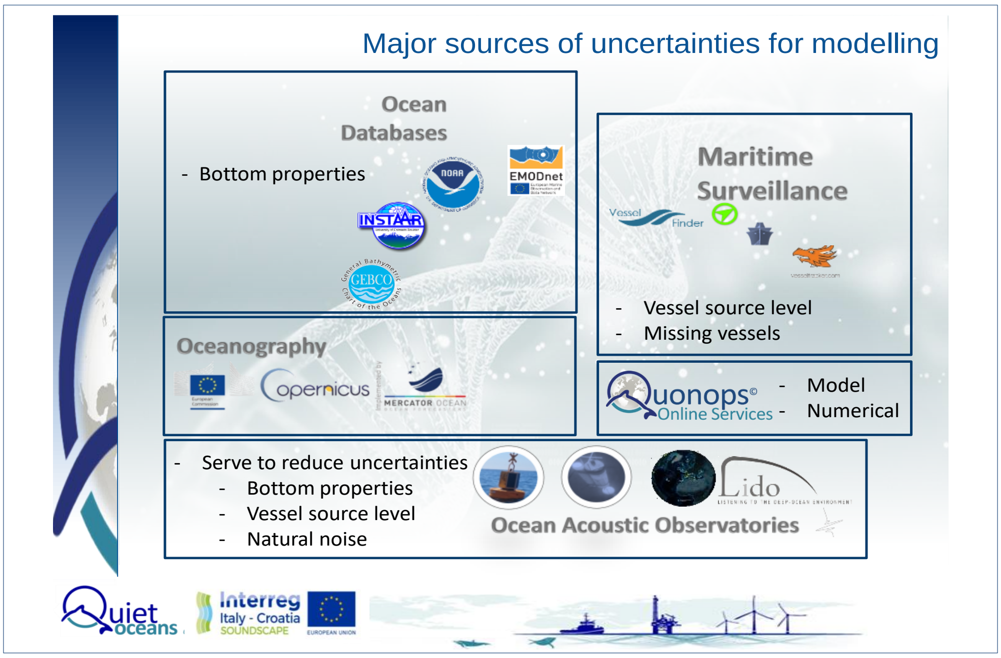
Live
- Instantaneous sound maps
- Based on AIS
- Updated every 15 min.

Historical
- Statistical sound maps
- Based on AIS
- Period of time in the past
- Daily, weekly, monthly, quarterly and annually maps

Predictive
- Catalog of activities
- Source levels based on literature and/or measurement

Figure 11 Categories of noise maps

Major sources of uncertainty for modeling are shown on Figure 12.



Major sources of uncertainties for modelling

Ocean Databases
- Bottom properties

Maritime Surveillance
- Vessel source level
- Missing vessels

Oceanography

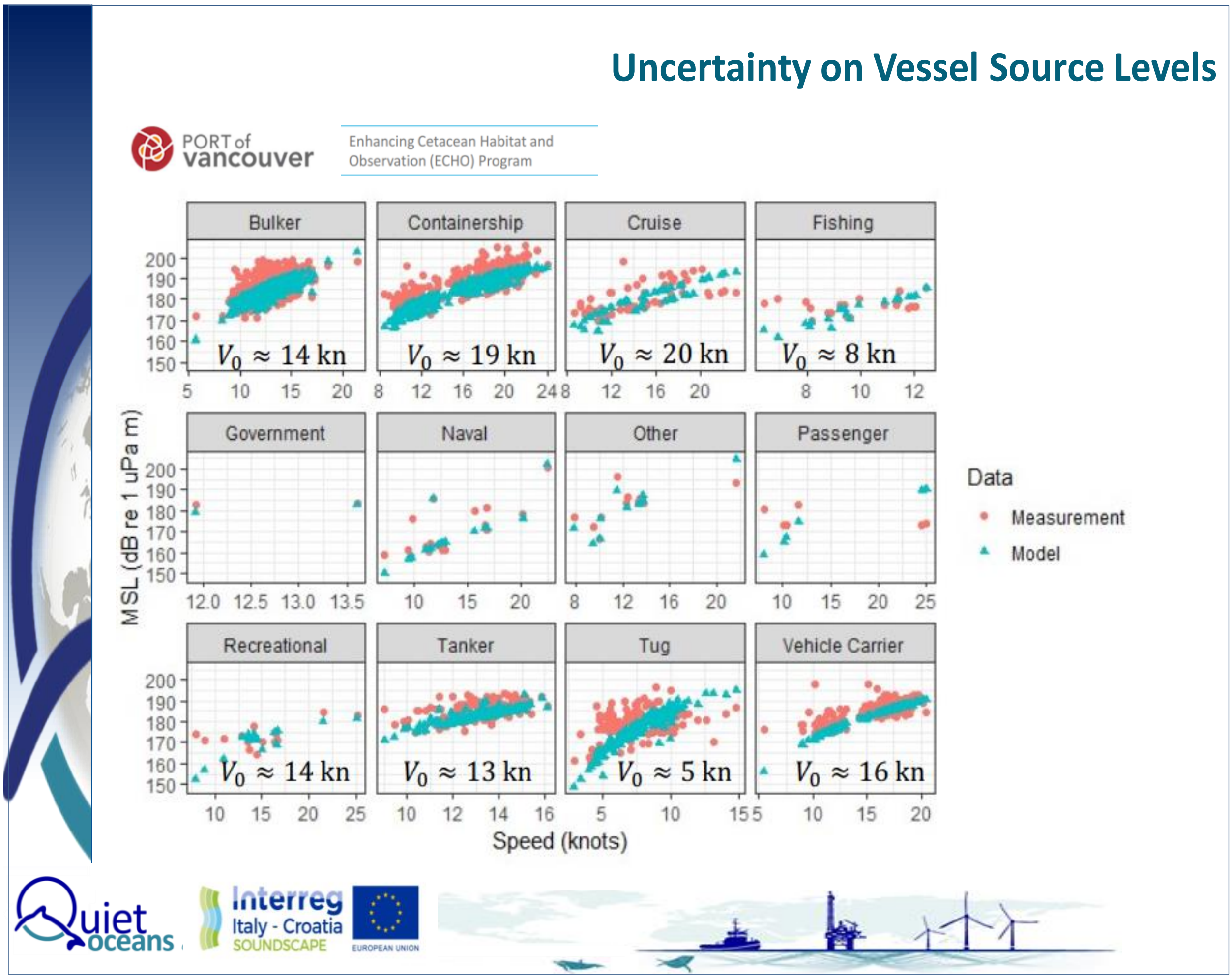
Quonops© Online Services
- Model
- Numerical

- Serve to reduce uncertainties
  - Bottom properties
  - Vessel source level
  - Natural noise

Ocean Acoustic Observatories

Figure 12 Major sources of uncertainty for modeling

In reference to Figures 2-6 and 2-12, the major sources of uncertainty for modeling are bottom properties for which data are usually too coarse and general, source level of vessels, and “missing” vessels. Missing vessels are vessels which are not equipped with AIS and therefore not taken into consideration with the consequence that their contribution to the overall source level being neglected. The vessel source level greatly depends on the vessel’s type, size, speed and drought. As these parameters are not known for the each vessel and some of them are frequently changed along vessels route it is very hard to define vessels source level exactly. The Figure 13 shows summary of the number of measurements and models of vessel source levels in various vessel categories. The span of source levels within category of alike vessels is clearly visible as well as possible difference between measurement and modeled data.



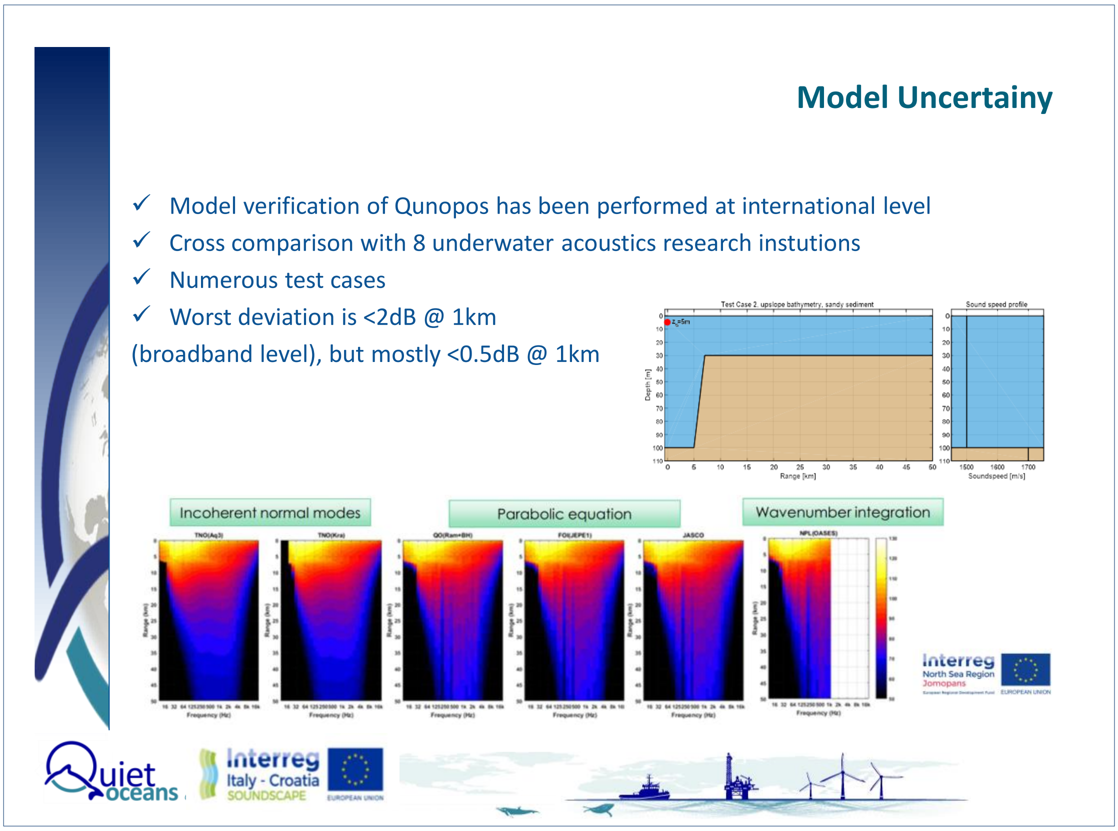
Uncertainty on Vessel Source Levels

PORT of vancouver

Enhancing Cetacean Habitat and Observation (ECHO) Program

Figure 13 Summary of the number of measurements and models of vessel source levels in various vessel categories

Figure 14 shows summary of various quality assurance tests to assess verification and uncertainty of the model.



Model Uncertainy

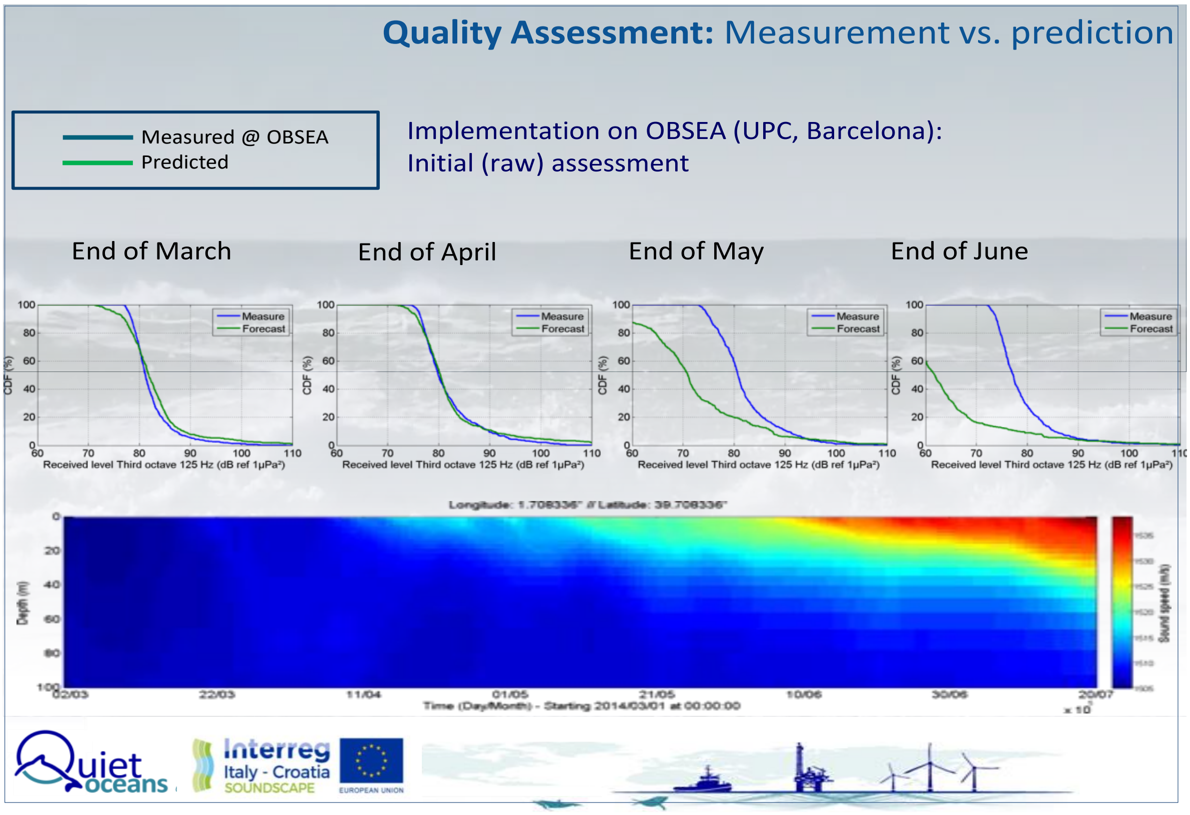
- ✓ Model verification of Qunopos has been performed at international level
- ✓ Cross comparison with 8 underwater acoustics research instutions
- ✓ Numerous test cases
- ✓ Worst deviation is <2dB @ 1km (broadband level), but mostly <0.5dB @ 1km

Figure 14 Summary of various quality assurance tests to assess verification and uncertainty of the model.

One of the key issues in quality assurance to decrease model uncertainty is the calibration of the model with field measurements of both noise and environmental parameters. The recommended measures include:

- ✓ **“Calibrate” or “ground truth” the noise map**
  - ○ “Assimilate” measured natural noise in the prediction
  - ○ Reduce uncertainty on the definition of the bottom geo-acoustic properties
  - ○ Method should be compatible with an operational service e.g. **pragmatic** approach
- ✓ **Natural noise assessment & assimilation method**
  - ○ Output of the filter gives an assessment of the natural noise contained in the measurement
  - ○ This assessment is introduced into the model
- ✓ **Reduce uncertainties on the bottom properties**
  - ○ Passive geo-acoustic inversion method developed and prototyped
  - ○ Method is based on a range independent “equivalent” bottom
  - ○ Convergence criteria is based on minimization of the predicted & measured pdf over a significant period of time

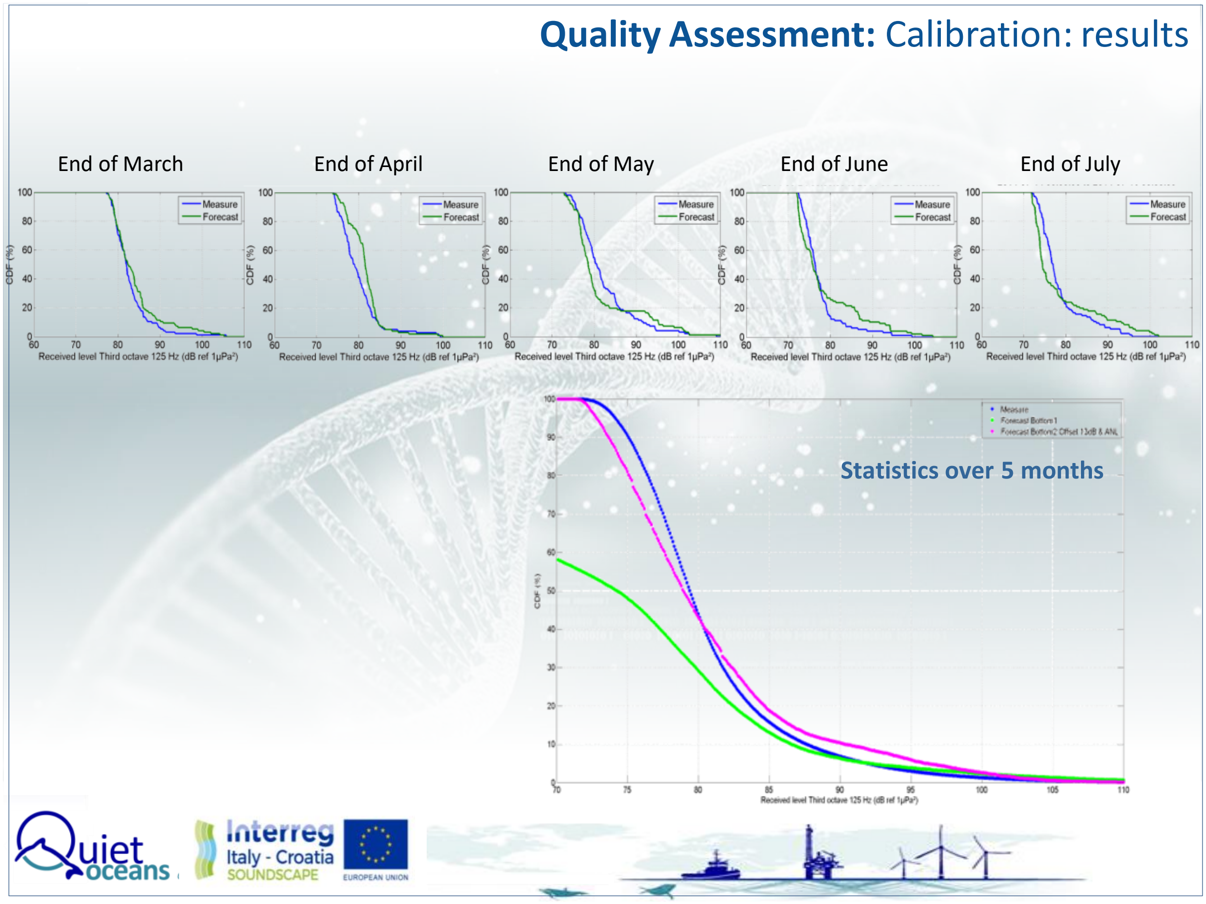
An example of the calibration of model is shown on Figures 2-15 and 2-16. The cumulative distribution of measured and initially predicted noise levels in 125 Hz third octave fits well in March and June but start to differ in May and June (Figure 15). After calibration of the model with the field measured speed of sound profiles, the corrected prediction matches measurement data much better (Figure 16).



Quality Assessment: Measurement vs. prediction

Implementation on OBSEA (UPC, Barcelona):
Initial (raw) assessment

Figure 15



Quality Assessment: Calibration: results

End of March

End of April

End of May

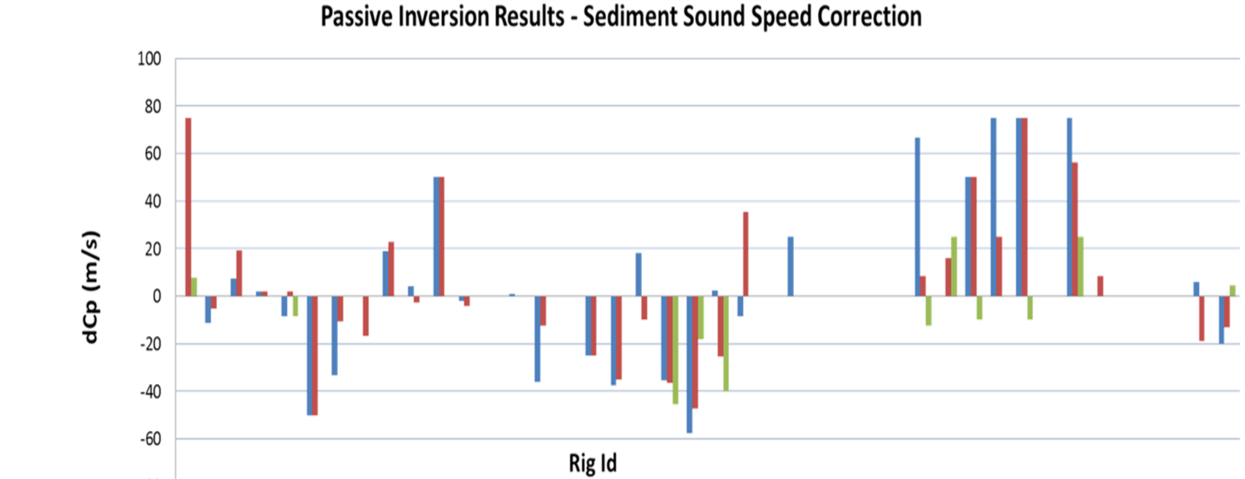
End of June

End of July

Statistics over 5 months

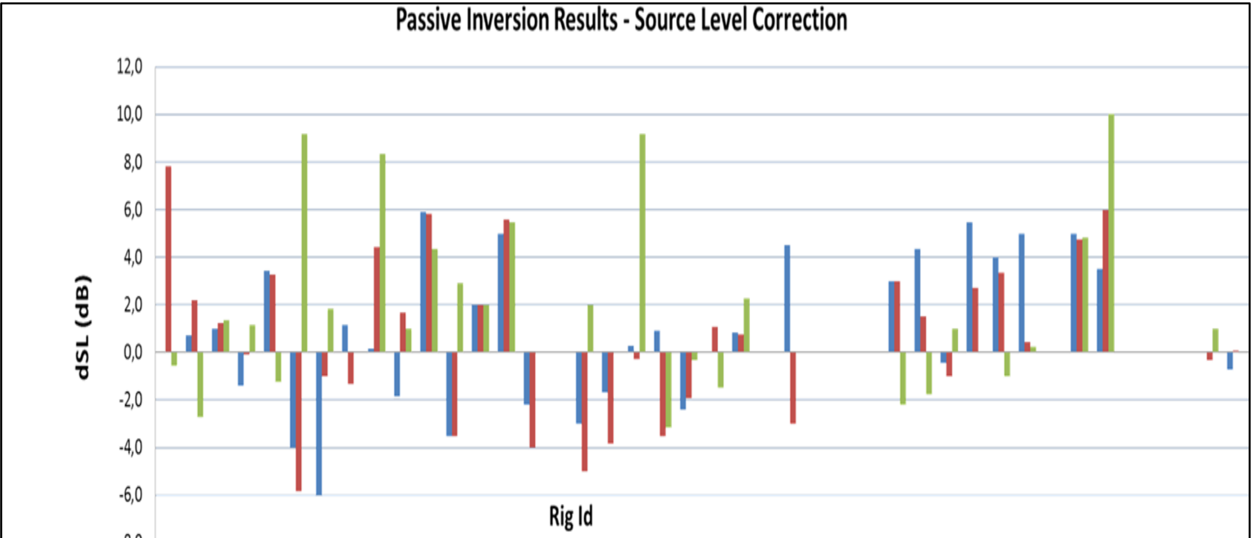
Figure 16

Another example of the calibration of the model to decrease uncertainty is shown on Figure 17 and 18. The calibration method was to calculate monthly percentiles on all measurement data and than apply corrections to the initial sediment (bottom) compressional sound speed and initial source level model to decrease differences between modeled and measured values. These have been done for all positions (measurement rigs) in the area of modeling.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	101	102
■ 63 Hz third octave band	0	-11	8	2	-8	-50	-33	0	19	4	50	-2	0	1	-36	0	-25	-38	18	-35	-58	2	-8	0	25	0	0	0	0	67	0	50	75	75	0	75	0	0	0	0	6	-20
■ 125Hz third octave band	75	-5	19	2	2	-50	-10	-17	23	-3	50	-4	0	0	-13	0	-25	-35	-10	-36	-47	-25	35	0	0	0	0	0	0	8	16	50	25	75	0	56	8	0	0	0	-19	-13
■ 2kHz third octave band	8	0	0	0	-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-45	-18	-40	0	0	0	0	0	0	0	-13	25	-10	0	-10	0	25	0	0	0	0	0	5

Figure 17



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	101	102
■ 63 Hz third octave band	0,0	0,7	1,0	-1,4	3,4	-4,0	-6,0	1,2	0,2	-1,8	5,9	-3,5	2,0	5,0	-2,2	0,0	-3,0	-1,7	0,3	0,9	-2,4	0,0	0,8	0,0	4,5	0,0	0,0	0,0	3,0	4,3	-0,4	5,5	4,0	5,0	0,0	5,0	3,5	0,0	0,0	0,0	0,0	-0,7
■ 125 Hz third octace band	7,8	2,2	1,3	-0,1	3,3	-5,8	-1,0	-1,3	4,4	1,7	5,8	-3,5	2,0	5,6	-4,0	0,0	-5,0	-3,8	-0,3	-3,5	-1,9	1,1	0,8	0,0	-3,0	0,0	0,0	0,0	3,0	1,5	-1,0	2,7	3,3	0,4	0,0	4,8	6,0	0,0	0,0	0,0	-0,3	0,1
■ 2kHz third octave band	-0,5	-2,7	1,3	1,2	-1,3	9,2	1,8	0,0	8,3	1,0	4,3	2,9	2,0	5,5	0,0	0,0	2,0	0,0	9,2	-3,2	-0,3	-1,5	2,3	0,0	0,0	0,0	0,0	0,0	-2,2	-1,8	1,0	0,0	-1,0	0,3	0,0	4,8	10,0	0,0	0,0	0,0	1,0	0,0

Figure 18

The quality of the modeling and noise maps is assessed by quantifying the remaining differences between the measured acoustic data and the modeled sound pressure levels at percentiles for each period of interest and each rig after applying the calibration procedure. The examples for one-month period for 90% and 10% percentiles are shown on Figures 19 and 20.

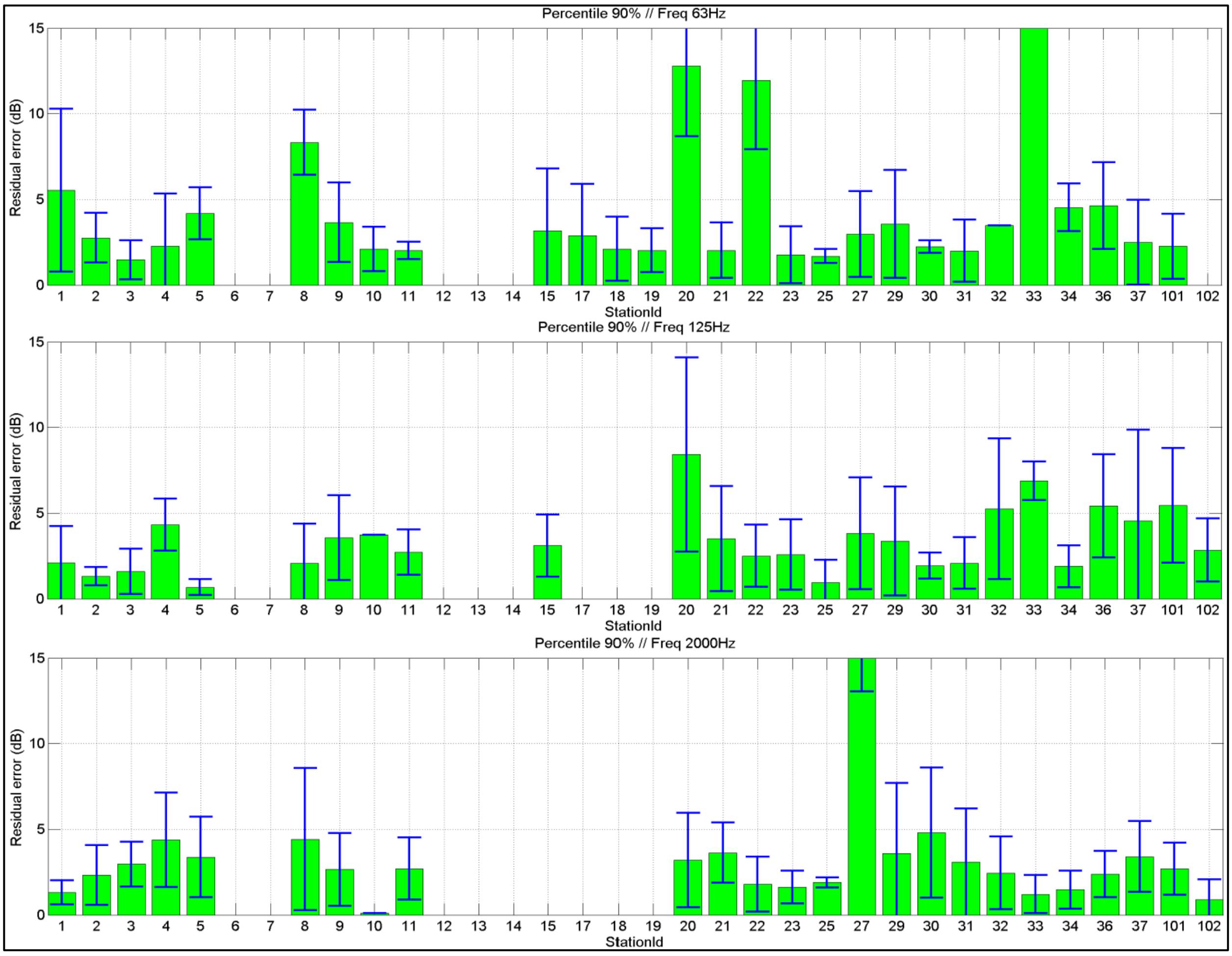


Figure 19 The remaining (residual) differences between the measured and the modeled sound pressure levels at 90% percentiles for each rig after applying the calibration procedure.

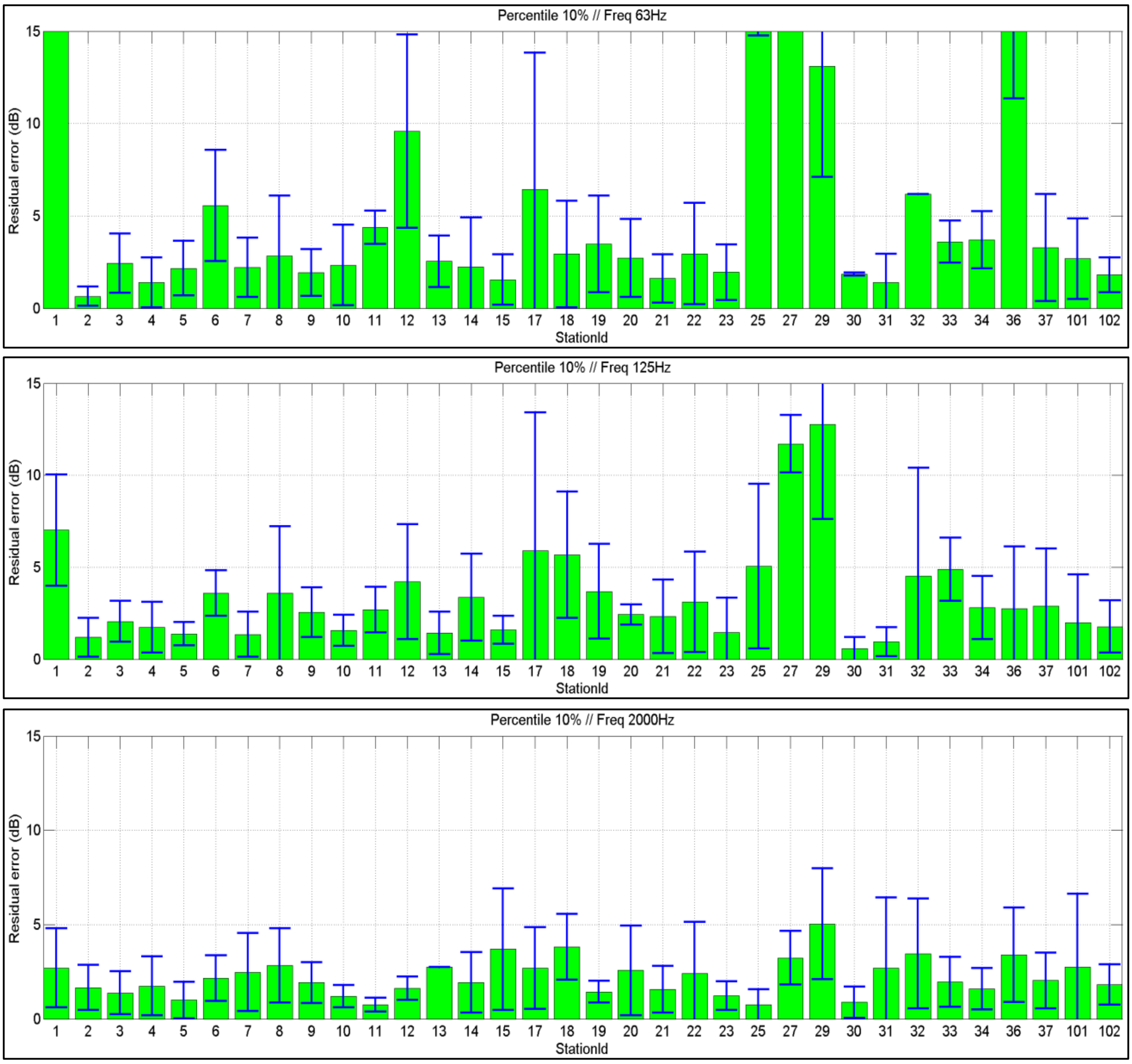


Figure 20 The remaining (residual) differences between the measured and the modeled sound pressure levels at 10% percentiles for each rig after applying the calibration procedure.

Limitations & recommendations for the modeling

- ✓ **Modeling of the noise from sources we don't know about is not possible**
    - o Biological noise
    - o Noise from rain

- ✓ **There no easy way (for now) to quantify a uncertainty of modeling at large scale**
  - ○ Can only be done at the exact position and depth of a measurement station by direct comparison
  - ○ Use of the best input data available
  - ○ From our experience, uncertainty is the smallest in busy areas
  - ○ The more hydrophone measurements, the smaller is the uncertainty

- ✓ **Recommendation for measurement in the prospective of modeling**
  - ○ Avoid any noise from the mooring itself (no metal-metal connection)
  - ○ Avoid any noise from other moorings or instruments (ADCP for example)
  - ○ Measure CTD at deployment and at recovery to cross check the oceanographic data
  - ○ Investigate if unexpected maritime activities will or have occurred during the whole measurement period. If there are, get as much information as possible about the activity(type of activity, start, end, description, etc.
  - ○ Use a minimum of ~30% duty-cycle
  - ○ Pistonphone test before deployment and after recovery
  - ○ Check the gain twice and report it
  - ○ Take into consideration the ADC input tension
  - ○ Use the same processing tool for each processed dataset across the region
  - ○ Use the same format for each processed dataset across the region
  - ○ Do not average long period of time

3.4 Discussion on monitoring uncertainty, conclusions for the further work and wrap up

The topic of the workshop was well received and raised much interest among participants and all partners. Some of participants being marine biologists and environmentalists have never been involved in the measurement and/or modeling of physical fields and quantities. That is why they have been very interested in the details of the methodology and especially details of the modeling procedures.

As a consequence, a great deal of time was spent on explaining and clarifying measurement and modeling methodology to enable all participants to fully understand possible components of the overall uncertainty. The other very important part of the discussion was the possibilities of bridging the knowledge gap in definition and quantification of the uncertainty components of continuous underwater noise monitoring. As the presenters presented all knowledge that they were aware of and that there were no experts on the subject among participants, it was concluded that all involved would invest their best efforts to share experience gained through the project.

Conclusion of the workshop was that all available measures for the mitigation of monitoring uncertainties should be applied to render monitoring results valid and reliable. Without it further workpackage concerning planning of impact and mitigation measures and scenarios for the underwater noise could be faulty and inadequate. The main recommendations include:

- Follow the procedure for the measurement of the continuous underwater noise as agreed upon and documented, especially quality assurance procedures. These include proper accurate calibration, valid equipment set-up, documentation of all set-up parameters and metadata and valid deployment set-up.
- Follow the instructions and requirements for the quality assurance of the data needed for the underwater noise modeling (e.g. environmental data).