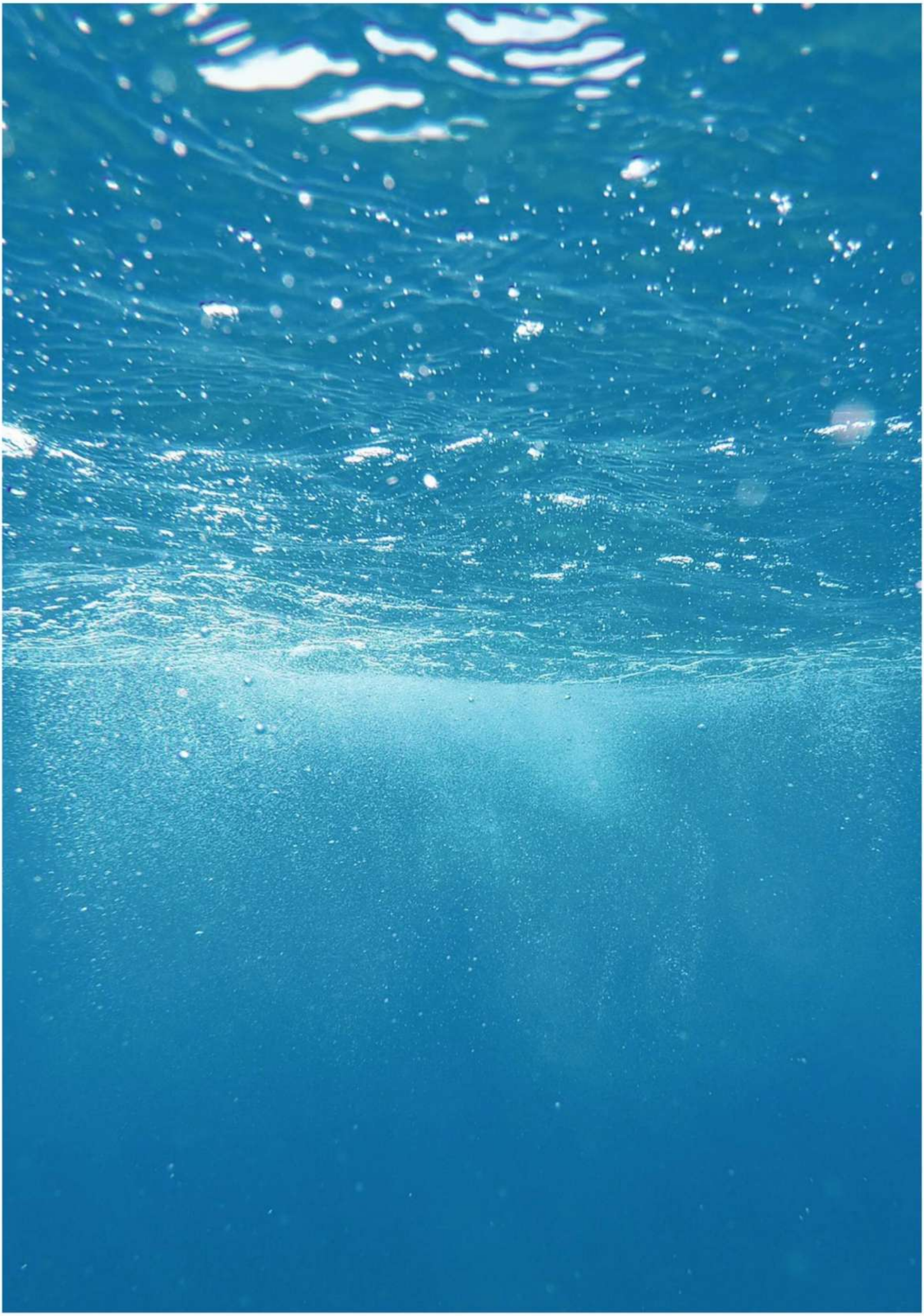
WESE
WAVE ENERGY
IN SOUTHERN EUROPE

DELIVERABLE 2.2
Monitoring of Electromagnetic fields

This project has been funded by the European Commission under the European Maritime and Fisheries Fund (EMFF), Call for Proposals EASME/EMFF/2017/1.2.1.1 – "Environmental monitoring of wave and tidal devices". This communication reflects only the author's view. EASME is not responsible for any use that may be made of the information it contains.



WP 2.4
Deliverable 2.2 Monitoring of Electromagnetic fields

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WESE Wave Energy in the Southern Europe

D2.2 Monitoring of Electromagnetic fields

CONTENTS

1. WESE project synopsis

The Atlantic seaboard offers a vast marine renewable energy (MRE) resource which is still far from being exploited. These resources include offshore wind, wave and tidal. This industrial activity holds considerable potential for enhancing the diversity of energy sources, reducing greenhouse gas emissions, and stimulating and diversifying the economies of coastal communities. Therefore, the ocean energy development is one of the main pillars of the EU Blue Growth strategy. While the technological development of devices is growing fast, their potential environmental effects are not well-known. In a new industry like MRE, and Wave Energy (WE) in particular, there may be interactions between devices and marine organisms or habitats that regulators or stakeholders perceive as risky. In many instances, this perception of risk is due to the high degree of uncertainty that results from a paucity of data collected in the ocean. However, the possibility of real risk to marine organisms or habitats cannot be ignored; the lack of data continues to confound our ability to differentiate between real and perceived risks. Due to the present and future demand for marine resources and space, human activities in the marine environment are expected to increase, which will produce higher pressures on marine ecosystems; as well as competition and conflicts among marine users. This context still continues to present challenges to permitting/consenting of commercial-scale development. Time-consuming procedures linked to uncertainty about project environmental impacts, the need to consult with numerous stakeholders and potential conflicts with other marine users appear to be the main obstacles to consenting WE projects. These are considered as non-technological barriers that could hinder the future development of WE in EU and Spain and Portugal in particular were, for instance, consenting approaches remain fragmented and sequential. Consequently, and in accordance with the Ocean Energy Strategic Roadmap published in November 20161, the main aim of the project consists on overcoming these non-technological barriers through the following specific objectives:

- Development of environmental monitoring around wave energy converters (WECs) operating at sea, to analyse, share and improve the knowledge of the positive and negative environmental pressures and impacts of these technologies and consequently a better knowledge of real risks.
- The resulting data collection will be used to apply and improve existing modelling tools and contribute to the overall understanding of potential cumulative pressures and impacts of larger scale, and future, wave energy deployments.

- Development of efficient guidance for planning and consenting procedures in Spain and Portugal for WE projects, to better inform decision-makers and managers on environmental real risks and reduce environmental consenting uncertainty of ocean WE introducing the Risk Based Approach suggested by the RiCORE, a Horizon 2020 project, which underline the difficulties for developers with an existing fragmented and sequential consenting approaches in these countries;
- Development and implementation of innovative maritime spatial planning (MSP) Decision Support Tools (DSTs) for Portugal and Spain for site selection of WE projects. The final objective of such tools will be the identification and selection of suitable areas for WE development, as well as to support decision makers and developers during the licensing process. These DSTs will consider previous findings (both environmental and legal, found in RiCORE) and the new knowledge acquired in WESE in order to support the development of the risk-based approach mentioned in iii);
- Development of a Data Sharing Platform that will serve data providers, developers, and regulators. This includes the partners of the project. WESE Data Platform will be made of a number of ICT services in order to have: (i) a single web access point to relevant data (either produced within the project or by others); (ii) Generation of OGC compliant requests to access data via command line (advanced users); (iii) a dedicated cloud server to store frequently used data or data that may not fit in existing Data Portals; (iv) synchronized biological data and environmental parameters in order to feed models automatically.

2. Executive summary

As summarized in the Deliverable 2.1 (Vinagre *et al.*, 2019)[1], the Work Package 2 of the WESE project aims to collect, process, analyse and share the environmental data in three areas affected by different types of wave energy projects, i.e.: (1) oscillating water column device deployed offshore – MARMOK-A-5 developed by IDOM – in the Biscay Marine Energy Platform test site (BiMEP) located in Armintza (Spain); (2) oscillating wave surge converter deployed nearshore – WaveRoller developed by AW-Energy – in Peniche (Portugal); and (3) water turbine converter deployed onshore – Mutriku Wave Power Plant – in Mutriku (Spain). The Deliverable 2.1 represented the first phase for the fulfilment of the objectives above, which is the planification of the monitoring plans for noise, electromagnetic fields (EMF) and seafloor integrity for the projects mentioned. The Deliverables 2.2, 2.3 and 2.4 are focused on the results obtained from the monitoring plans executed for EMF, noise, and seafloor integrity, respectively.

This deliverable D2.2 reports the main findings from the electromagnetic fields (EMF) surveys. For the MARMOK-A-5 device installed at BiMEP, a campaign was performed by MAPPEM Geophysics during the 20th and 21st of May 2019. Overall, no EMF signal could be identified as being originated from the cable. The sea conditions were very calm during the survey, and reports from the WEC operation show the power output from the device was small (our estimates account for less than 6kW), with the low emissions possibly being masked by ambient EMF noise (e.g. swell, vessel generator). For the WaveRoller device installed in Peniche, a sequence of events (sensor calibration, Covid19 restrictions and WaveRoller operational status), did not allow for the survey to be conducted at the time of writing this report. Considering that the WaveRoller returns to operation within the timeline of this project, the survey will be conducted, and this report will be updated accordingly.

[1] Vinagre P.A., Cruz E., Chainho P., Ruiz P., Felis I., Muxika I., Bald J., 2019. Deliverable 2.1 Monitoring plans for Noise, Electromagnetic Fields and Seabed Integrity. Corporate deliverable of the Wave Energy in the Southern Europe (WESE) Project funded by the European Commission. Agreement number EASME/EMFF/2017/1.2.1.1/02/SI2.787640. 64 pp.

3. Description of test sites and devices

3.1 Test sites

3.1.1 BiMEP test site

The Biscay Marine Energy Platform (BiMEP, www.bimep.com) is an open-sea facility to support research, technical testing and commercial demonstration of pre-commercial prototype utility-scale floating Marine Renewable Energy Devices (MREDs).

BiMEP occupies a 5.3 km^2 marked area excluded from navigation and maritime traffic. It is located at a minimum distance of 1,700 m from shore, close enough for fast access to deployed devices. The water depth in this area ranges from 50 m to 90 m. The total power of 20 MW is distributed over four offshore connection points of 5 MW each (Figure 1Figure 1).

Each berth is connected to the onshore substation via a dedicated three-phase submarine cable in series with a land three-phase line, both at 13.2 kV. The onshore electricity substation houses electrical protection systems, measurement systems and transformer, allowing the berths to be connected to the national power grid. The berths are fitted with commercial power and fibre optic connectors to enable swift connection and disconnection of MREDs.

Until recently, BiMEP hosted the first floating wave energy device connected to the grid in Spain, the MARMOK-A-5 device.

3.1.2 WaveRoller test site

The concession area of the WaveRoller is located in a mostly sandy bottom off the Almagreira beach in the Peniche municipality (West Coast of Portugal). It is included in the Site of Community Importance (SCI) Peniche/Santa Cruz (PTCON0056) defined in the EC Habitats Directive (HD, 1992) of Rede Natura 2000.

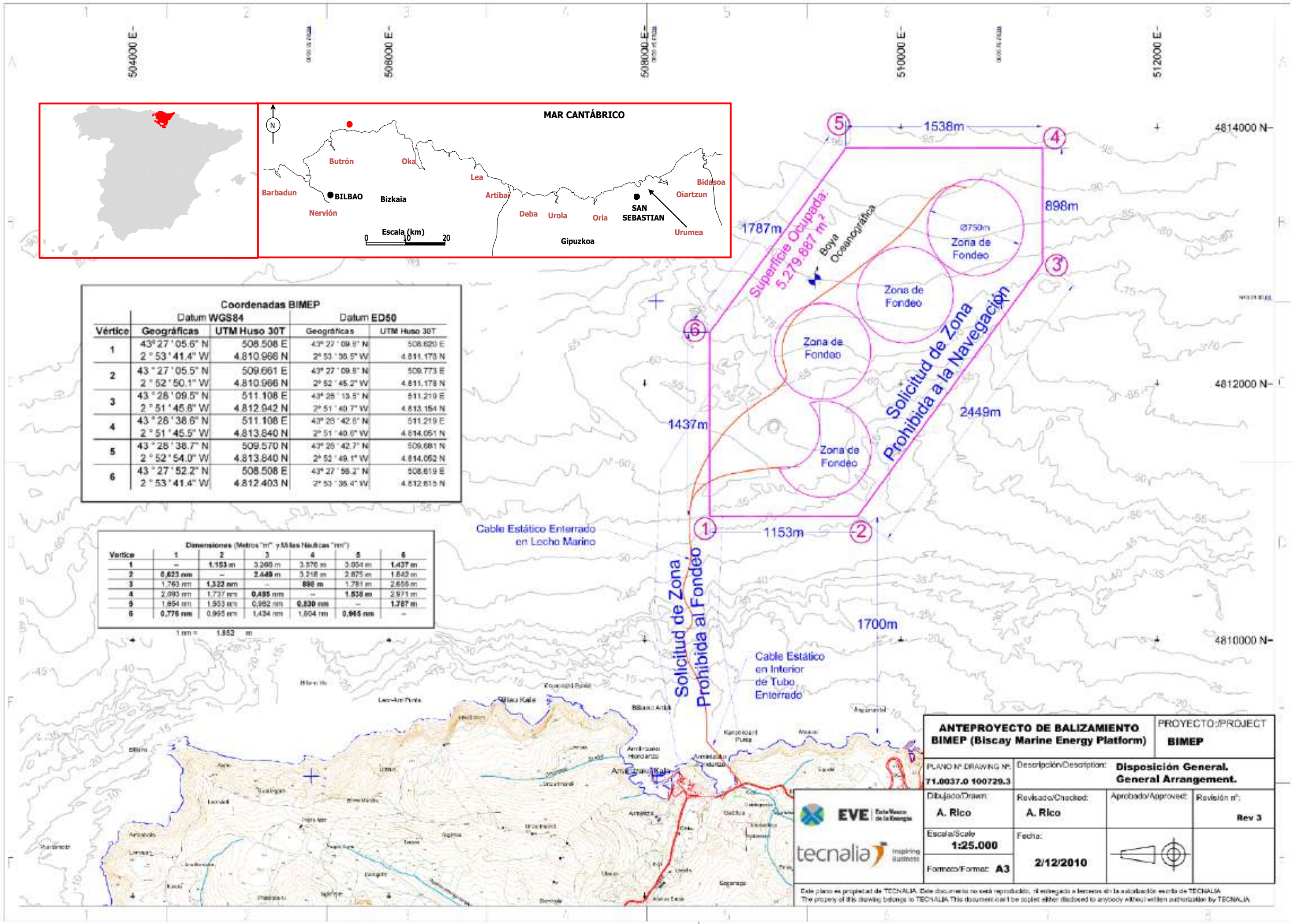


Figure 1. General arrangement of BiMEP.

3.2 Devices

3.2.1 MARMOK-A-5

The MARMOK-A-5, developed by IDOM-Oceantec, is a reduced floating device prototype oscillating water column (OWC), with a point absorber configuration (Figure 2). The device is typically known as SPAR BUOY OWC. It consists of a simple and robust buoy that moves by the action of the waves and is composed of three parts: a float that moves by the effect of waves, a hollow cylinder that contains the water column and a last lower element that provides stability and inertia. The size of the OWC is 42 m length and 5 m diameter, with a power rating of 30 kW. The Marmok-A-5 was deployed in BiMEP (43°28’9.52’’N, 2°52’11.42’’W) in October 2016 at a depth of 80 m and moored to the seafloor trough 4 mooring lines. It was decommissioned in July 2019.

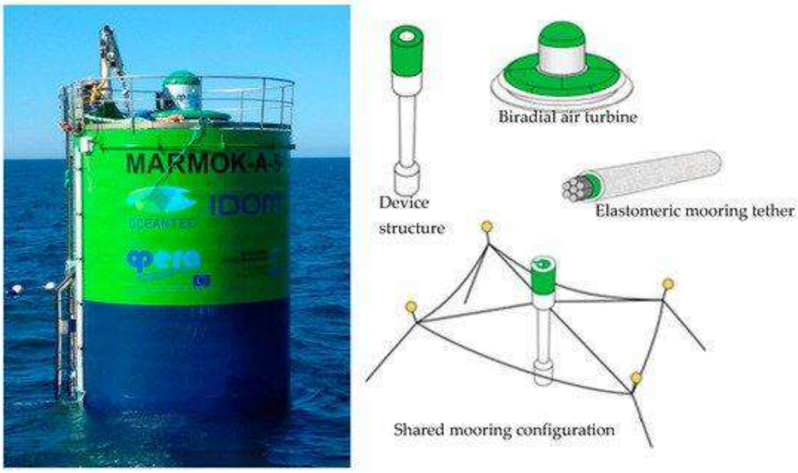


Figure 2. MARMOK-A-5 device. Device deployed at BiMEP (left-side) and device’s main components (right-side) taken from Bloise Thomaz, T.; Crooks, D.; Medina-Lopez, E.; van Velzen, L.; Jeffrey, H.; Lopez Mendia, J.; Rodriguez Arias, R.; Ruiz Minguela, P. O&M Models for Ocean Energy Converters: Calibrating through Real Sea Data. Energies 2019, 12, 2475.

3.2.2 WaveRoller

The WaveRoller system was developed by AW-Energy (https://aw-energy.com/waveroller). The WaveRoller unit (Figure 3) is mounted on a large concrete foundation 42 m long and 18 m wide and consists of an oscillating bottom hinged WEC with a steel flap 18 m wide and 10 m high, representing a total area of 860 m^2 of which 756 m^2 integrate the maritime public domain.

The WaveRoller unit was deployed in the end of October 2019, positioned at about 850 m of the shoreline (39°23.374'N, 9°18.500'W) between the -15 m and the -

20 m bathymetries. It was to be removed from water for maintenance in October 2020; however, the foundation and WEC were in the same day (October 17th) lifted from the seafloor and again set in place, and the decommissioning was cancelled.

Figure 3. Representation of the WaveRoller unit. Source: AW-Energy (https://aw-energy.com/waveroller).

4. Monitoring activities

4.1 BiMEP test site EMF survey

The EMF survey at the BiMEP site was subcontracted to MAPPEM Geophysics (http://www.mappem-geophysics.com/). This company is specialized in marine electromagnetic measurements, using static or towed devices, and has developed the proprietary PASSEM towed instrument to measure marine electromagnetic fields with high precision and resolution. The survey took place on the 20th and 21st of May 2019. This section mostly feeds from MAPPEM post-survey report, which describes the survey routes, presents the measured data, and provides an analysis of the results.

4.1.1 Equipment

As specified in Deliverable 2.1 of this project, the equipment used for the monitoring activities is the proprietary PASSEM system, developed by MAPPEM Geophysics.

The PASSEM instrument (Figure 4) is a towed system to be deployed from a vessel, that integrates sensors capable of measuring electromagnetic fields along survey routes. It is composed of a main fish, where the electronics and data logger are located (including the 3-axis magnetometer), followed by a cable composed of electrodes forming electric field measurement dipoles (potential differences between 2 electrodes). The system records data on each of the 4 measurement dipoles, with different length and position on the cable 19m,17m and two 4m dipoles. The 4 dipoles allow redundancy of the data and helps identifying some signal source depending on the signals power on each dipole. Electric fields are measured with AgCl non polarisable electrodes and a very low noise preamplifier with strong gain to obtain the highest sensitivity (Figure 4). It is also equipped with a 3-axis fluxgate magnetometer (Bartington Mag-03 low noise).

All signals are recorded simultaneously with a sampling frequency of 2 kHz. The main fish attitude (pith, roll, heave) and navigation (GPS position, depth, altitude to the seafloor) are logged in order to calculate the position of the equipment and locate the data. The sensitivity of the sensors is very high, and the intrinsic noise of the system is far below the general electromagnetic signals recorded in coastal environment.

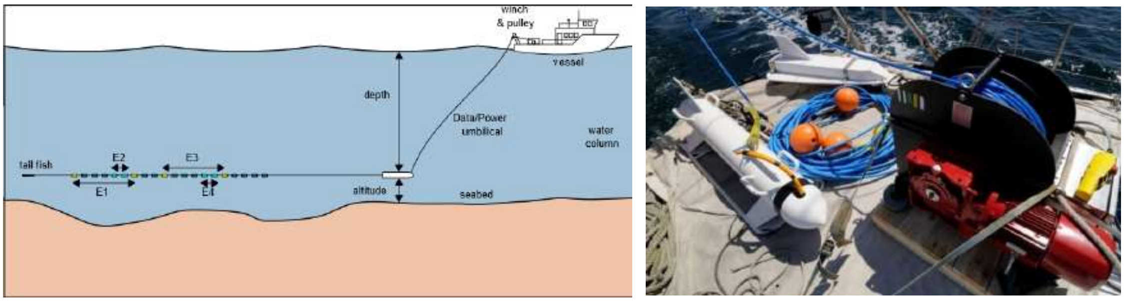


Figure 4. The PASSEM instrument.

4.1.2 Survey

The EMF survey was led by team members of MAPPEM Geophysics: Fabien Gaspari (Electronics Engineer) and Alexis Lepot (Electromagnetic data processing), with support from Juan Bald (from AZTI) and the vessel crew from Ekocean. The survey vessel was the EKOCEAN EXPLORER, a 11.95m long catamaran (Figure 5). A crane was available to deploy and retrieve the equipment. The mobilization took place in Getxo harbour, Bilbao, Spain.

Figure 5. Survey boat -> EKOCEAN EXPLORER.

The survey was conducted for two days from 20/05/2019 to 21/05/2019 at the BiMEP area, with the following route lines:

- 23 lines have been made during the first day, among which eighteen cross the BiMEP connecting cables (Figure 7- DAY1).
- 11 lines have been made the second day, among which six cross the BiMEP connecting cables and 4 go all the way around the wave system (Figure 7- DAY2).

Figure 6. Photos from the EMF campaign at BiMEP.

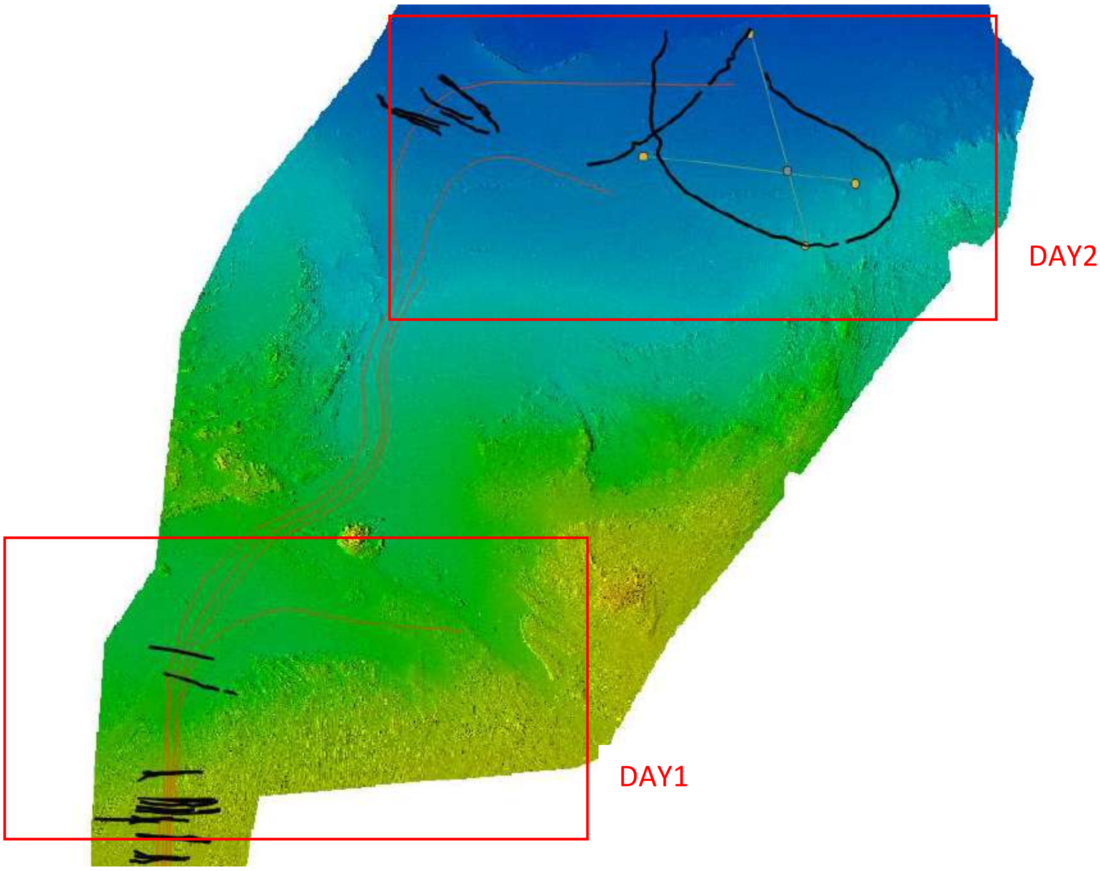


Figure 7. Survey area and PASSEM profiles.

The table below (Table 1) lists all the PASSEM route lines that are crossing at least one connecting cable, associated with the mean height (from seabed) of the EMF sensors during the profile.

Table 1. Table listing the profiles made during the survey.

PASSEM line, day1	mean height (m)	PASSEM line, day2	mean height (m)
passem_20_05_2019_11_55_41	11.9	passem_21_05_2019_10_38_01	38
passem_20_05_2019_12_39_02	12.6	passem_21_05_2019_10_55_16	28
passem_20_05_2019_12_46_10	11.2	Height<15m	
passem_20_05_2019_13_12_23	19.4	passem_21_05_2019_11_26_11	5.5
passem_20_05_2019_13_34_25	13.3	passem_21_05_2019_11_15_43	11.2
passem_20_05_2019_14_26_40	12	passem_21_05_2019_11_04_10	11.4
passem_20_05_2019_15_48_35	31	passem_21_05_2019_10_45_29	13.2
passem_20_05_2019_15_59_59	12.4		
Height<10m			
passem_20_05_2019_13_23_45	4.8		
passem_20_05_2019_14_43_32	4.9		
passem_20_05_2019_12_31_25	6.1		
passem_20_05_2019_13_02_37	6.2		
passem_20_05_2019_12_10_39	8		
passem_20_05_2019_12_54_29	8.1		
passem_20_05_2019_12_02_38	8.7		
passem_20_05_2019_12_21_46	8.7		
passem_20_05_2019_14_53_52	9.5		
passem_20_05_2019_14_34_20	9.8		

The survey took place under good weather conditions. However, the survey area is quite challenging, with rather deep waters (down to about -70m), local currents, and difficult local bathymetry for navigation. Indeed, the cables have been installed in a deep area, making it more difficult to tow the equipment close to the seafloor.

In the first day, in the shallow area, navigation was easier than during the second day, closer to MARMOK-A-5 device, where various holding lines and moorings were present. Indeed, during the second day, the PASSEM system got trapped on a mooring line of a wave buoy while being at over -50m depth, due to navigation too close to the mooring. The instrument was not lost but it damaged some of the equipment (mainly the towing cable), forcing the crew to end the survey.

4.2 WaveRoller test site EMF survey

At the time of writing this report, no EMF survey was able to be performed at the WaveRoller test site. As mentioned in section 3.2.2, the WaveRoller was deployed in the end of October 2019, and from there we initiated campaign preparations. During this exercise, it was found the calibration certificate of our Bartington Mag690 sensor had expired. After requesting several quotes for the calibration service, the sensor was sent to the UK for calibration around mid-February and was ready around mid-March. However, this coincided with the dates of the declaration of state of emergency in Portugal due to Covid19. Minding the international/national restrictions, our calibrated sensor was only shipped to Portugal at early July, when we were informed the WaveRoller was not operational. This status did not change until October 2020 when the device was to be removed from water for maintenance.

If the WaveRoller returns to operation within the timeline of this project, the survey will be conducted, and this section will be updated accordingly.

5. Monitoring Results

5.1 BiMEP test site EMF survey results

5.1.1 WEC Operation

A proper analysis of the EMF data requires correlation with the EMF source, in this case the energized subsea power cables. Hence, an essential parameter consists of some measure of the power generated by the WECs. The following Table 2 presents normalized[2] power output data of the MARMOK-A-5 device device, for the time periods matching the EMF survey campaign. The power output is discretized in 5 even split levels (where 0 means the WEC was stopped, and 5 the maximum power output measured). Also, for information, the table includes the wave conditions measured by the nearby Triaxys Buoy.

Table 2. Normalized operational data of MARMOK-A-5 device for the time periods matching the EMF survey campaign. Cable Current is an estimate.

Timestamp_ini	Timestamp_fin	Hs [m]	Te [s]	Normalized WEC Power Output [0-5]	Cable Current [A]
20/05/2019 11:34:07	20/05/2019 11:44:07	0.84	6.39	1	0.26
20/05/2019 12:34:07	20/05/2019 12:44:07	0.79	6.33	1	0.26
20/05/2019 13:34:07	20/05/2019 13:44:07	0.84	6.65	1	0.26
20/05/2019 14:34:07	20/05/2019 14:44:07	0.81	6.69	1	0.26
20/05/2019 15:34:07	20/05/2019 15:44:07	0.89	6.82	1	0.26
20/05/2019 16:34:07	20/05/2019 16:44:07	0.9	6.85	1	0.26
21/05/2019 10:34:07	21/05/2019 10:44:07	0.51	6.15	1	0.26
21/05/2019 11:34:07	21/05/2019 11:44:07	0.54	6.06	1	0.26
21/05/2019 12:34:07	21/05/2019 12:44:07	0.53	6.12	1	0.26
21/05/2019 13:34:07	21/05/2019 13:44:07	0.5	5.97	1	0.26
21/05/2019 14:34:07	21/05/2019 14:44:07	0.52	5.78	1	0.26
21/05/2019 15:34:07	21/05/2019 15:44:07	0.49	5.39	1	0.26

[2] Required due to confidentiality reasons.

As an exercise to estimate the current flowing in the cable, the rated power output of the WEC device (30kW) is evenly split over the 5 levels, and the phase current (variable of interest) computed using the formula $P = \sqrt{3}.V_{LL}.I.pf$, where the V_{LL} is 13.2kV and the pf assumed as one.

As expected, the calm sea state at the time of the survey, only allowed for low power output from the WEC, which resulted in extremely low phase currents inside the cable. As previously done in Deliverable 2.1 of this project, E and B normalized curves[3] are here used for quick assessment of the order of magnitude of the EMFs expected, which for a 0.26A three-phase current, at an average distance of 10m from the cable axis, returns a peak magnetic field of $\mathrm{B} = 0.15\mathrm{nT}$ and a peak electric field of $\mathrm{E} = 0.04\mu\mathrm{V/m}$. These are very small values difficult to detect, with high probability of being masked by ambient EMF noise (e.g. swell, vessel generator…).

5.1.2 EMF measured at the MARMOK-A-5 area

First, a detailed study of two profiles with a low distance from the seafloor is presented to show the process for the visualisation and the interpretation of the measured signals. These route lines were conducted during the first day and are crossing all the cables (although only one should be energized). The results of all survey routes made both days are then presented in the Appendix 7.1.

The route lines "passem_20_05_2019_13_23_45" and "passem_20_05_2019 _14_43_32" are chosen as a reference for this analysis. The first line was logged in the first day and crosses the connecting cable at a mean height of 4.8m and thus is interesting in terms of signals.

Figure 8 is divided into 4 sub-figures:

- The first sub-figure shows the position of the connecting cables (in red) as well as the main fish position (in black). The green cross indicates the beginning and the direction of the profile. This segment is just an indication of the survey line position. It is naturally distorted and is not intended to be used as a map of the area.

[3] Slater M., Schultz A., Jones R., 2010. Estimated ambient electromagnetic field strength in Oregon's coastal environment. Report prepared to Oregon Wave Energy Trust, 26 pp.

- The second sub-figure shows the bathymetry without tide correction (in black) and the depth of the main fish (in green). It allows to verify that the navigation was normal and steady during the line.
- The third and fourth sub-figures shows the normal magnetic field (nT) and the electric fields measured with the four dipoles normalized by each dipole length (V/m) (dipole 1 in red, dipole 2 in green, dipole 3 in black and dipole 4 in blue). Oscillations in the magnetic field as seen on figure 5 are due to the residual swell present in the area.

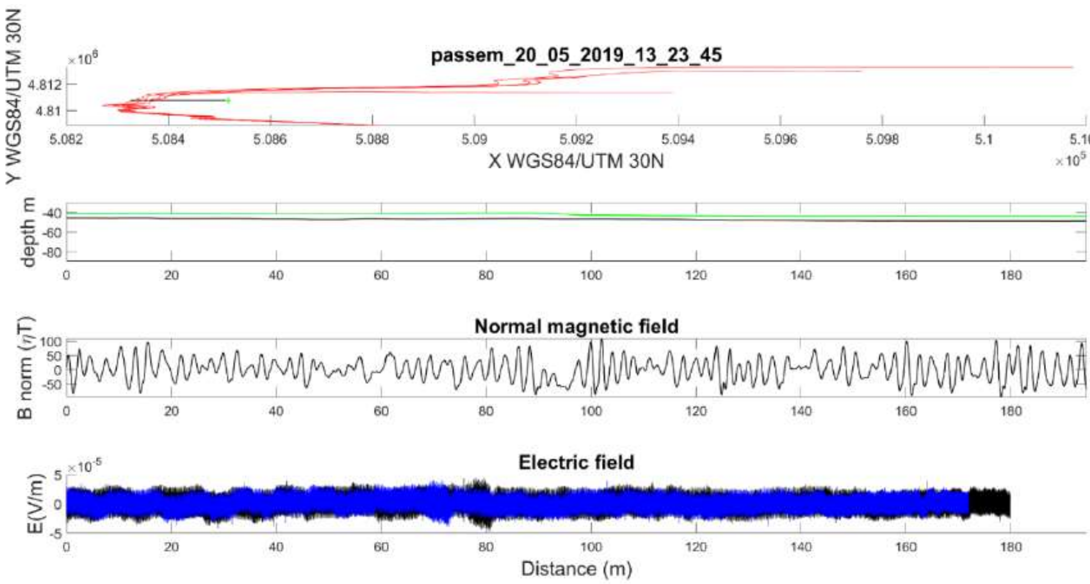


Figure 8. Raw data of line 13_23_45.

On this route line the bathymetry shows no obstruction. There is no evidence of any magnetic anomaly on the signal (no signature visible in the third subplot). The cable should show a magnetic anomaly, due to the phase currents, but also from the magnetisation of the cable. Indeed, the cables are "shielded" by steel armouring, that usually show some magnetic signature. This cable does not seem to show such magnetic signature. There is no significant variation on the continuous part of the electric field neither. The cables are not visible despite the 4.8m distance to the seafloor, which is relatively small.

A spectral analysis can be done to refine the interpretation and have a better view on the signals (including noise measured). On Figure 9, the electric field frequency components are observed for the four electric dipoles, corrected of the dipole length. This visualisation does not give direct indication on the presence of the cables but shows the main frequencies and amplitudes that are present in the signals. The electric field is in V/m and its frequency components for each dipole are plotted.

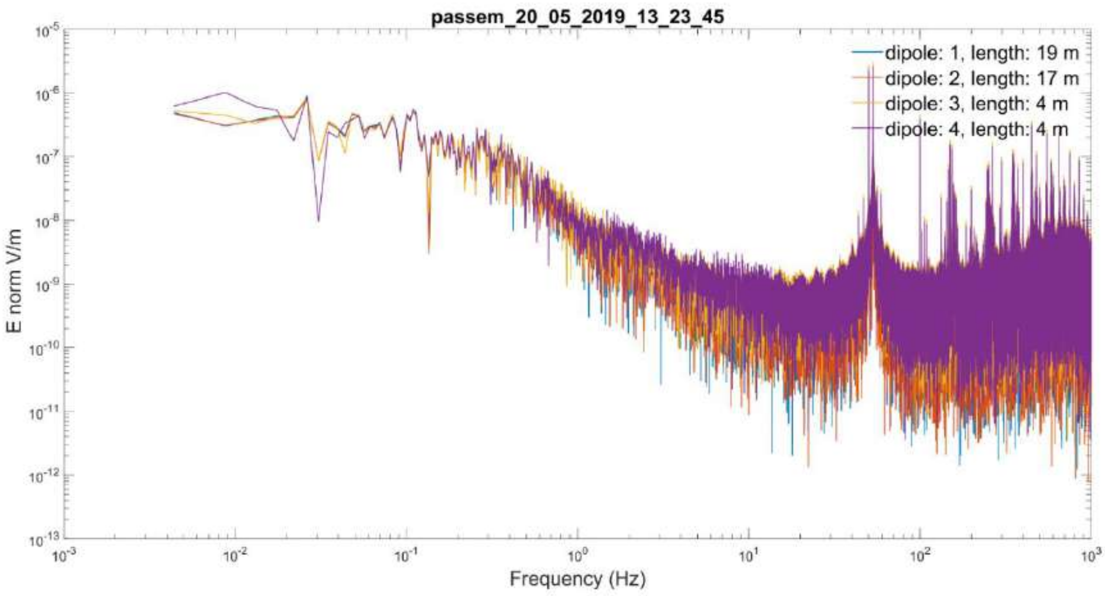


Figure 9. Spectral analysis of line 13_23_45.

The frequency spectrum shows the presence of 50 Hz and its harmonics (Figure 10). These signals are usually observed nearshore, as land powerlines are creating electromagnetic signals. However, one can observe that several picks are present around 50hz. This is unusual as land signals are all synchronized at 50 Hz with normally a rather precise frequency.

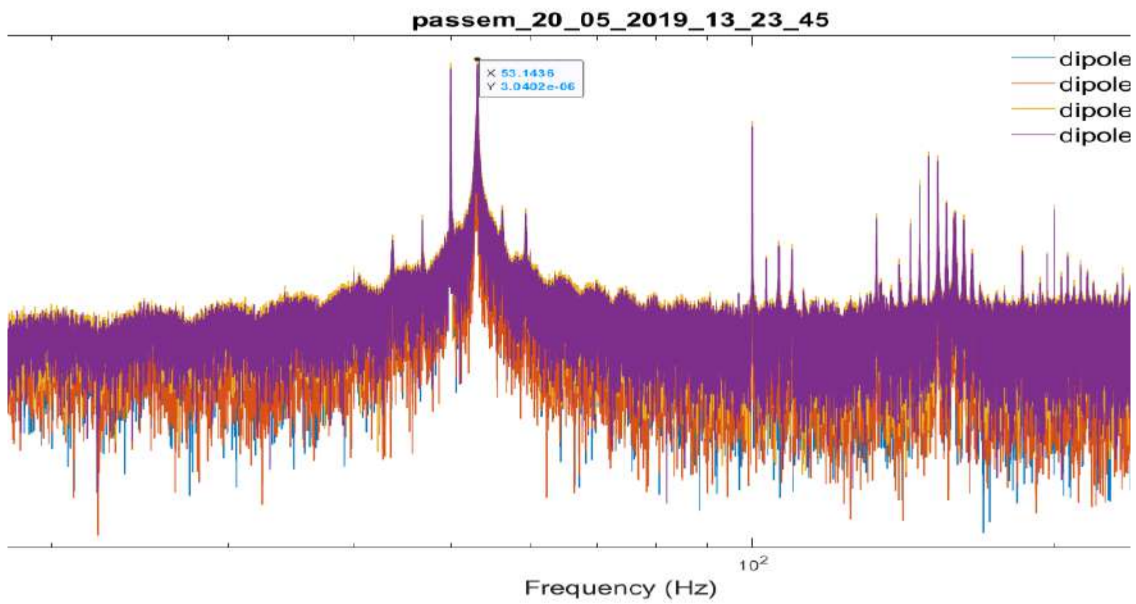


Figure 10. Detail of spectral analysis of line 13_23_45 around 50Hz.

Figure 10 shows a zoom of the spectrum around 50Hz. One can observe that the strongest signal is at 53.1Hz. This cannot be a signal from the subsea cable, nor land power lines. It is highly suspected that this signal is from another source, namely the towing vessel, as the amplitude of this signal measured on each dipole is different, which shows a more local origin. Indeed, signals with a distant origin, like the land power lines, have the same amplitude on all dipoles. This signal might be the sign of a badly set power generator, with a shifted frequency. Moreover, these noisy signals are of larger amplitude that what is usually observed in similar situations. Nevertheless, the strength of this signal is very unusual, and might be the sign of an electrical problem on the vessel.

To correlate the signals with frequency ranges a spectrogram is then calculated on the electric field for the four dipoles. It allows to see the evolution of the signal along the profile in the frequency domain. The spectrogram is presented on Figure 11:

- The first subplot represents the bathymetry and the instrument height in red.
- The second subplot represents de normal magnetic field in nT
- The third subplot shows the spectrogram of the magnetic field
- The other subplot are the spectrograms of the electric dipoles (e1e20, e2e19, e5e9, e13e17)

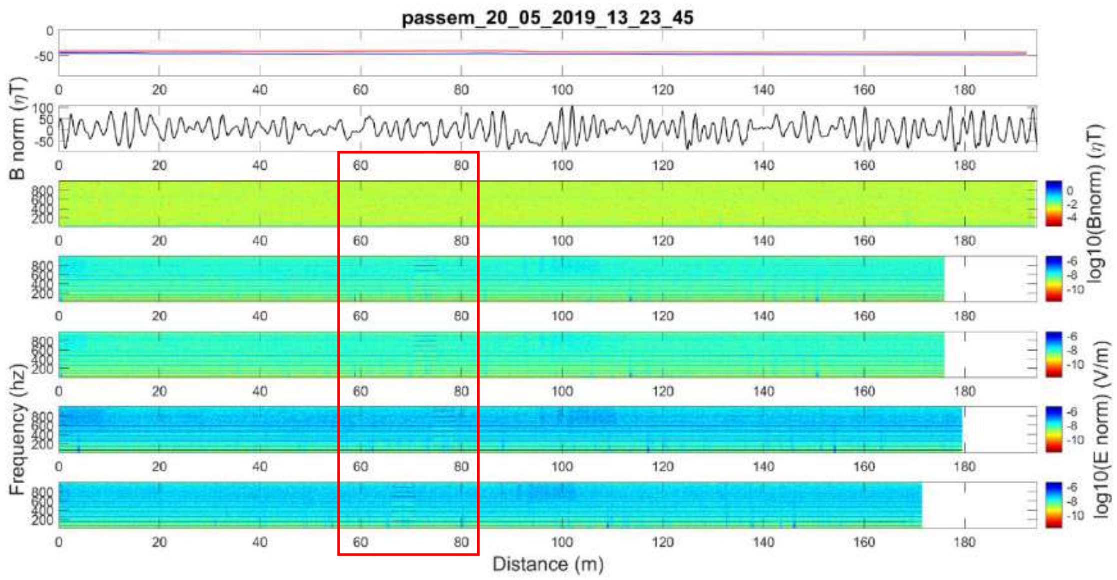


Figure 11. Spectrograms of the electric and magnetic fields.

An anomaly seems to appear on the spectrogram of each electric dipole (in red square), but no significant anomaly is detected on the magnetic field which could indicate that it is more likely to be noise rather than a cable signature. The oscillations on the magnetic field are normal and due to the swell in the area inducing some movement to the equipment. In order to check whether the signals variations seen in the electric fields is from the cables or not, we locate the spectrogram of the first dipole in longitude and latitude and we plot it on QGIS along with the cables (Figure 12).

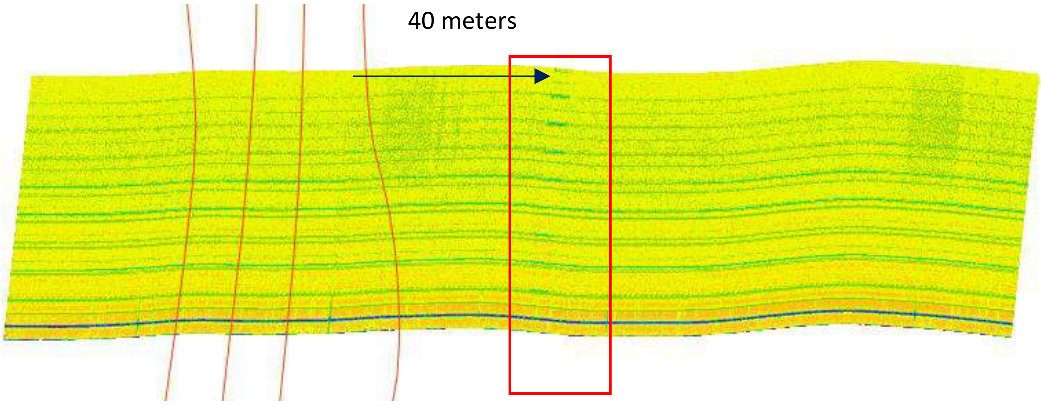


Figure 12. Zoom on the spectrogram of dipole1 of line 13_23_45.

It appears that the anomaly is not correlated with the known cable position. The spectrogram analysis confirms the strong presence of 50 Hz signal with stripes every 50Hz multiples, but also strong signals at 53Hz and its harmonics. The anomalous signal on Figure 12 is actually linked to the spurious 53Hz signal.

Despite the small distance of the instrument to the seabed (less than 5m) no significant signatures have been detected for this profile. We can make the same observation on the other profiles.

The second suspicious line is the line "passem_20_05_2019_14_43_32" with a mean height of 4.9m (Figure 13).

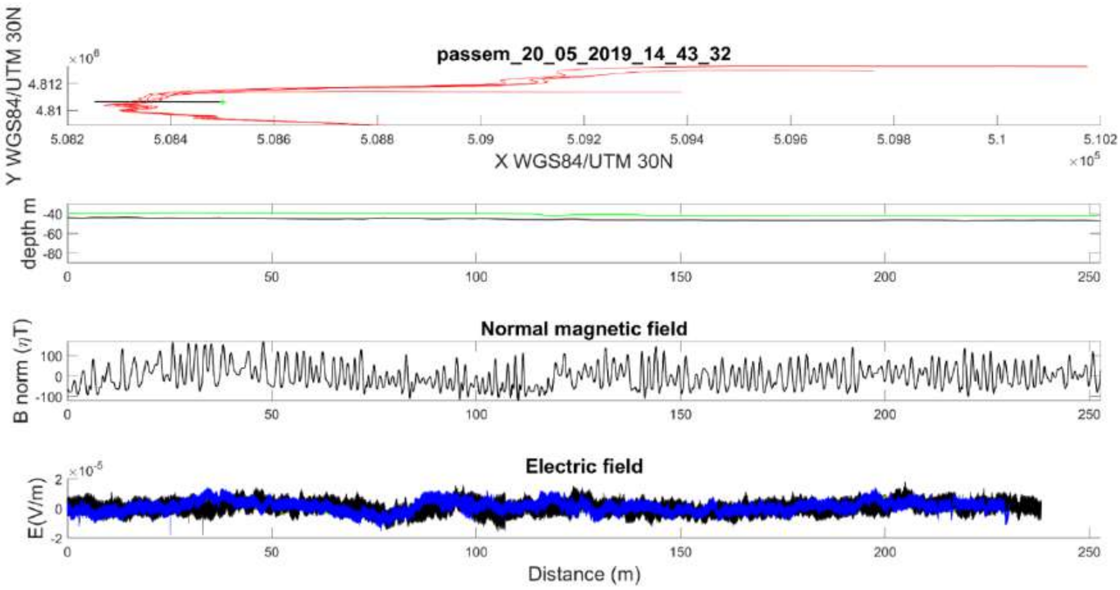


Figure 13. Raw data of route line 14_43_32.

Once again, the first visualisation (Figure 13) shows that nothing significant is seen in the continuous part of the signals. Normal magnetic field presents no anomalies neither electric dipoles. The magnetic data is quite affected by the movements of the vessel. These movements are hard to correct numerically.

Looking at the frequency domains (Figure 14) on each electric dipole, 50Hz signals and its multiples are once again present, but also the spurious 53Hz signal, with a strong intensity.

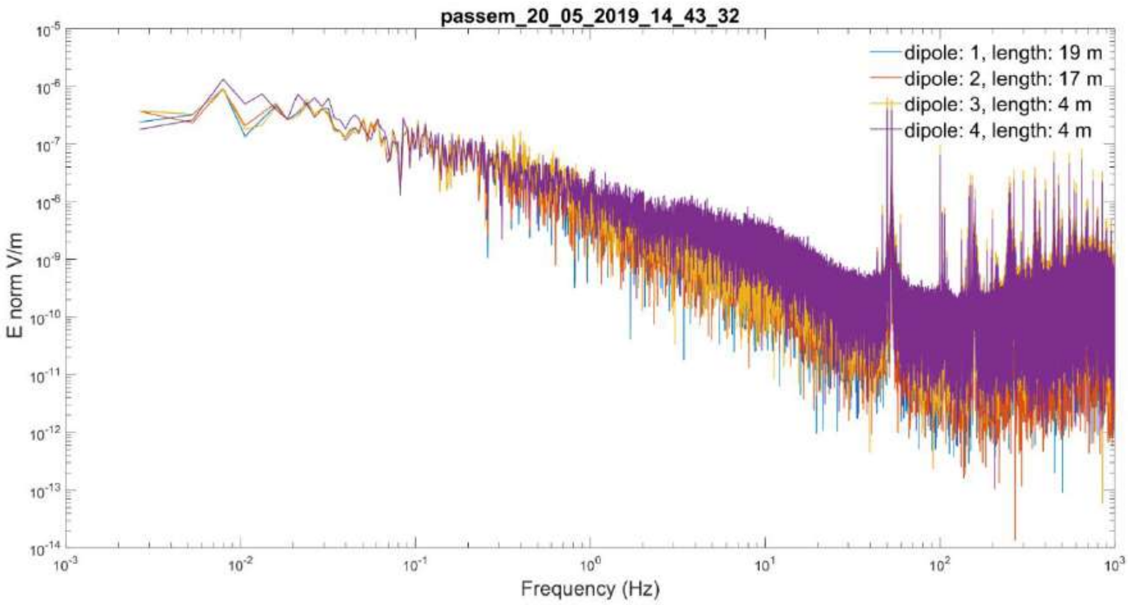


Figure 14. Spectral analysis of line 14_43_32.

If we plot the spectrogram to have the evolution of the frequency domain along the profile (Figure 15) we can observe anomalous signals on the electric field. Once again, no signal is observed on the magnetic field (Figure 16).

These three anomalous signals are suspicious and could be correlated with the cables. However, no signal is observed on the magnetic field and all cables are not detected whereas there are all in the same configuration. These signals could be some spurious signals, due to the towing vessel.

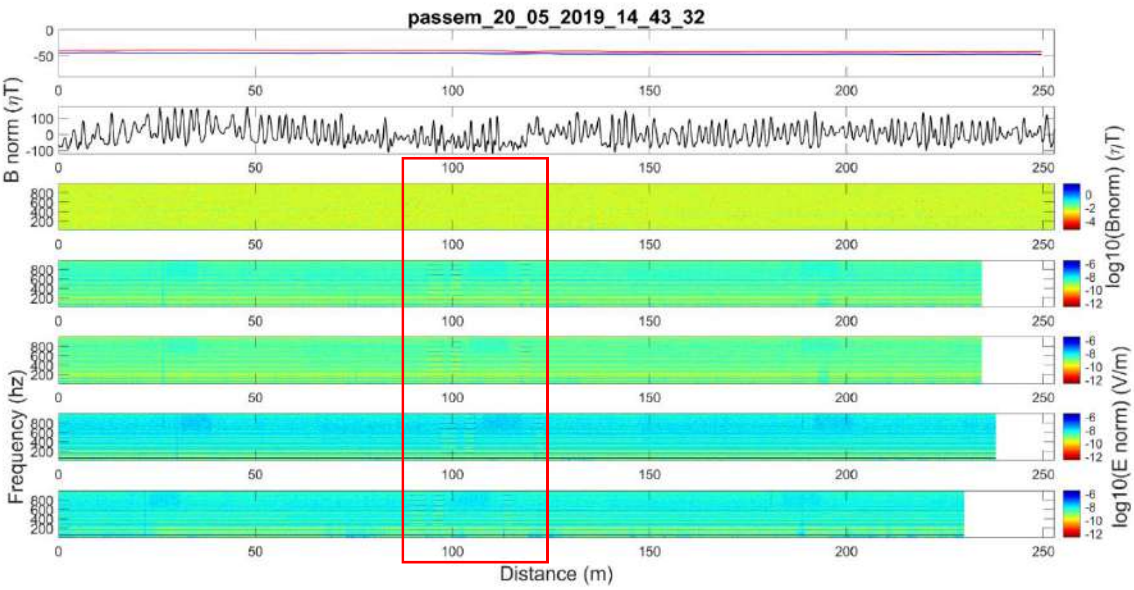


Figure 15. Spectrogram of line 14_43_32.

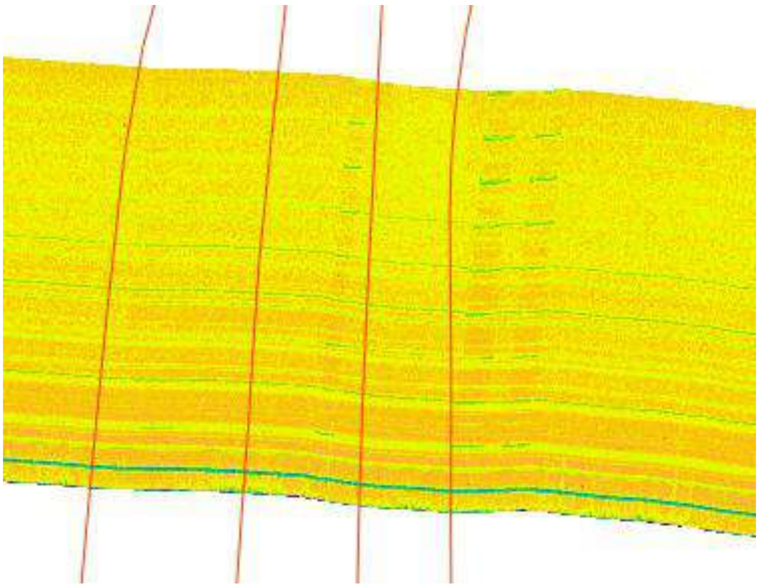


Figure 16. Zoom on the spectrogram of dipole 1 of line 14_43_32.

The data captured for all remaining profiles are presented in Appendix 7.1, with non-significant results, from the ones here analysed.

It is to be noted that on some of the route lines, the electric signals appear to have a sudden decrease or increase of the noise. These noise variations are variations of the 53Hz noise signal. It is likely that a bad connexion is suddenly increasing the noise on the data, which is very unfortunate, could not be detected before (theses are still small signals).

Relevant to note that the same equipment has been successfully used in similar conditions less than one month after this survey, which eliminates the internal origin of the noise.

5.2 WaveRoller test site EMF survey results

No survey was conducted by the time of writing, more details in the previous section 4.2. As mentioned, minding the WaveRoller returns to operation within the timeline of this project, the survey will be conducted, and this section will be updated accordingly.

6. Conclusions

6.1 Marmok-A-5

Passive electromagnetic measurements have been made with the PASSEM instrument in the BIMEP area in order to evaluate the electromagnetic noise from the WEC system. This campaign was performed by MAPPEM Geophysics during the 20th and 21st of May 2019.

Various route lines have been recorded crossing the cable positions, from the nearshore to the test area, up to 70m water depth. On these, no signal identified as the cables electromagnetic signatures could be isolated. The sea conditions were very calm during the survey, and reports from the WEC operation show the power output from the device was small (our estimates account for less than 6kW), and consequently the phase currents responsible potential electromagnetic signals outside of the cable were very small (here our estimates account for less than 0.26A).

However, the analysis of the electromagnetic signals, shows the classical 50Hz and harmonics signals from power lines, together with a strong 53.1Hz (an harmonics) unusual signal. This 53.1Hz signal might have masked the signals from the cables themselves.

This 53.1 Hz has been identified to be the vessel's electric generator with quite high probability. The generator is probably faulty and inducing strong signals in the water, then detected by the instrument (the PASSEM itself is powered through an UPS set to 50Hz output). Strong noise variations are due to this spurious signal.

6.2 WaveRoller

A sequence of events (sensor calibration, Covid19 restrictions and Waveroller operational status), did not allow for the survey to be conducted at the time of writing this report. As mentioned before, minding the Waveroller returns to operation within the timeline of this project, the survey will be conducted, and this section will be updated accordingly.

7. Annexes

7.1 BIMEP EMF survey – Post Processed Data

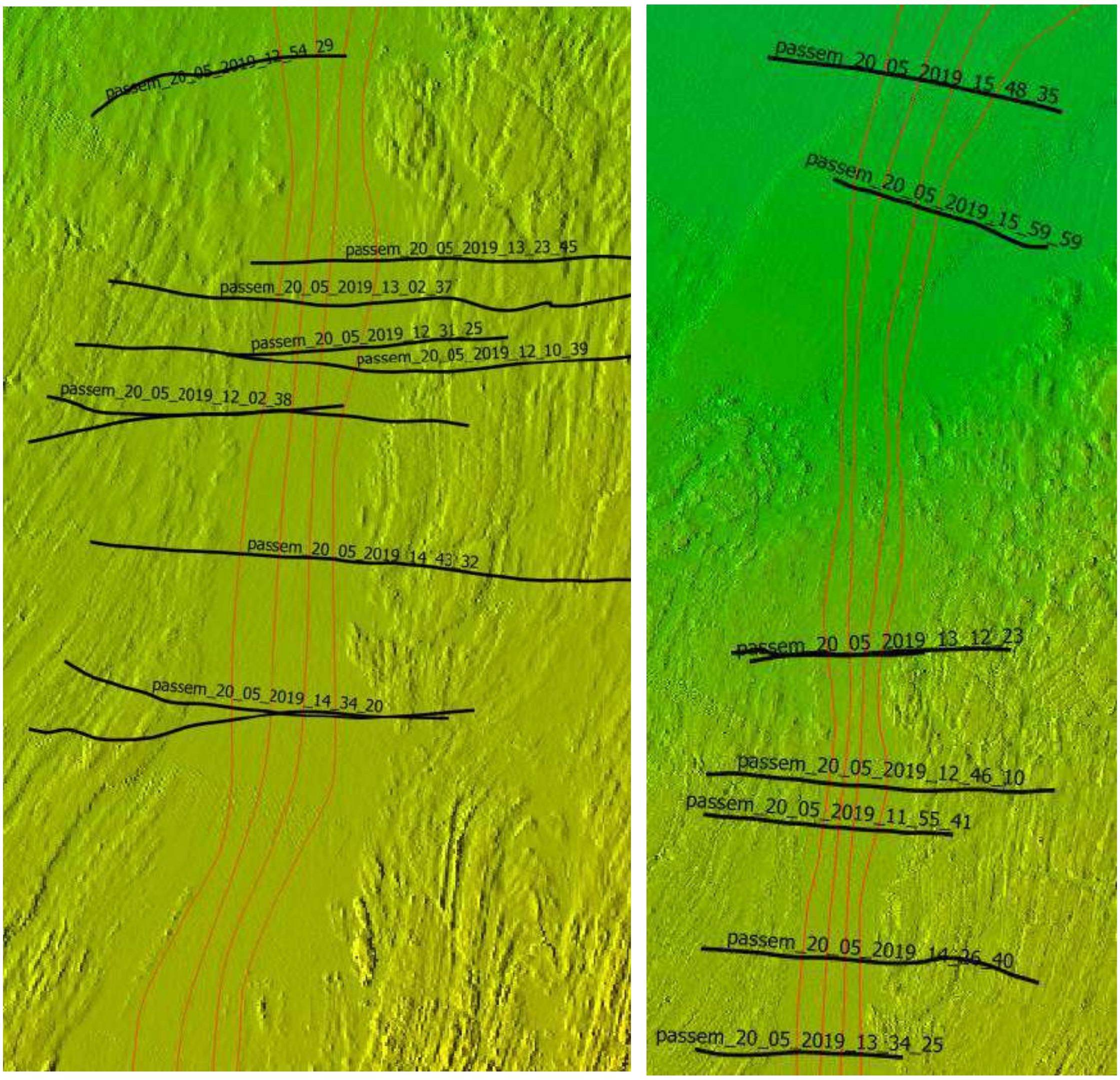
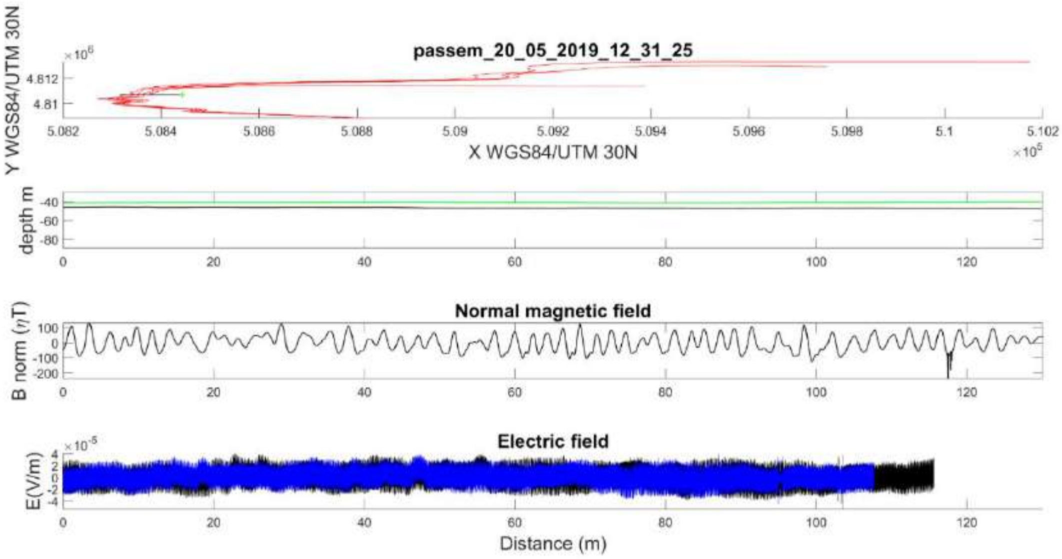
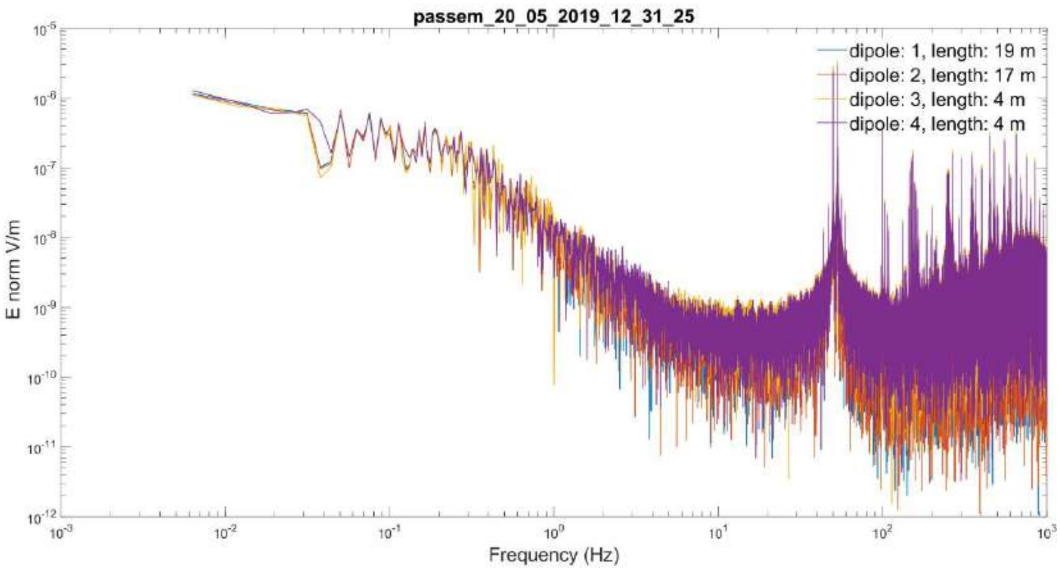
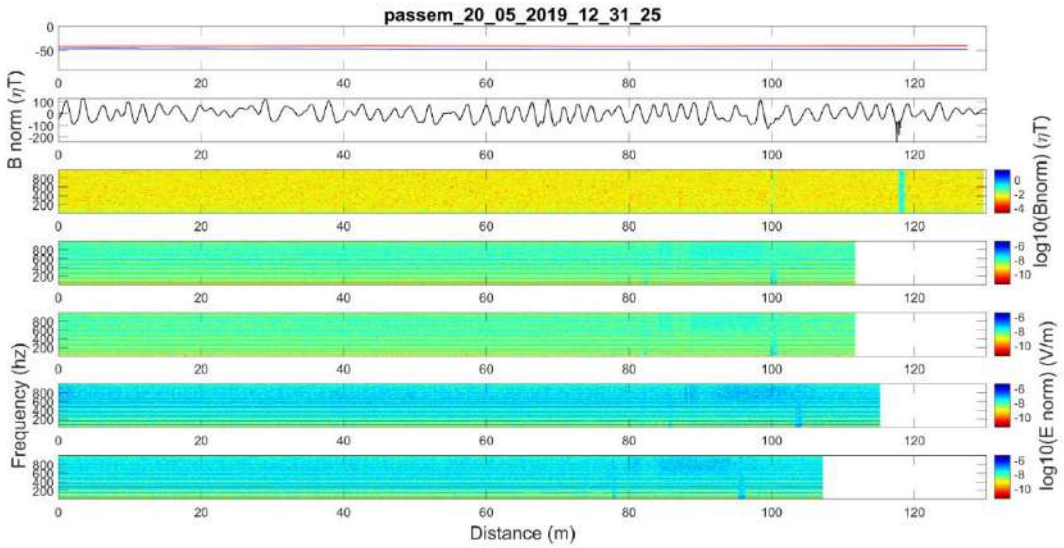


Figure 17. Profiles made during the day1: with a mean height < 10 m (left figure) with a mean height > 10 m (right figure)

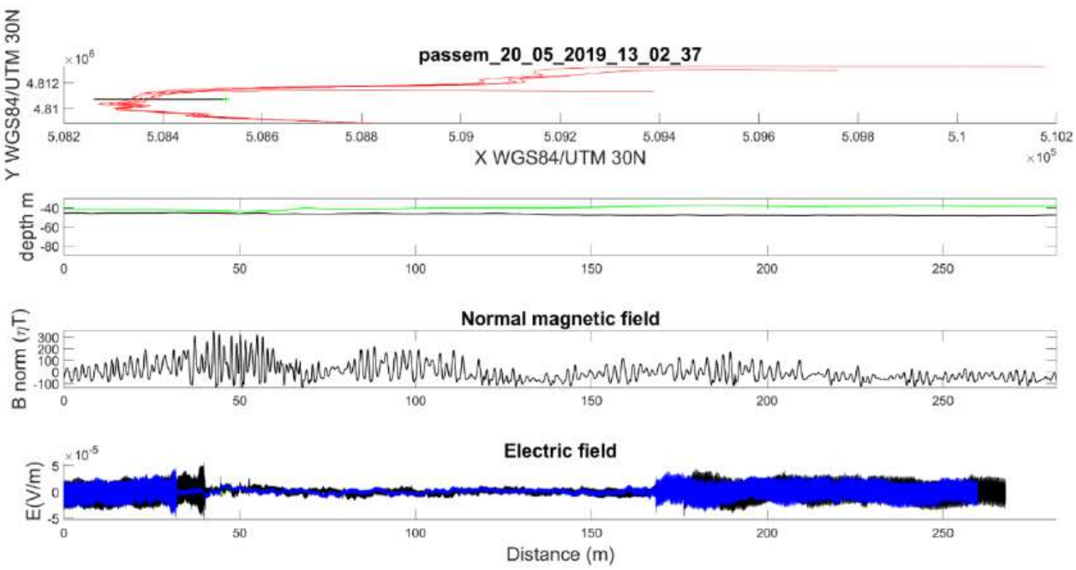
- ***Profile 20_05_2019_12_31_25:***

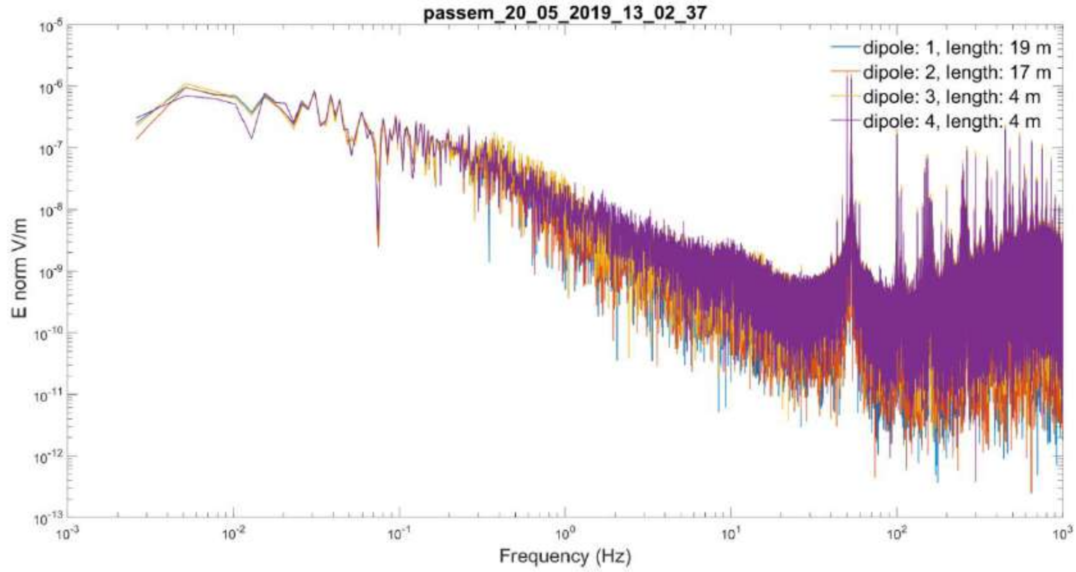


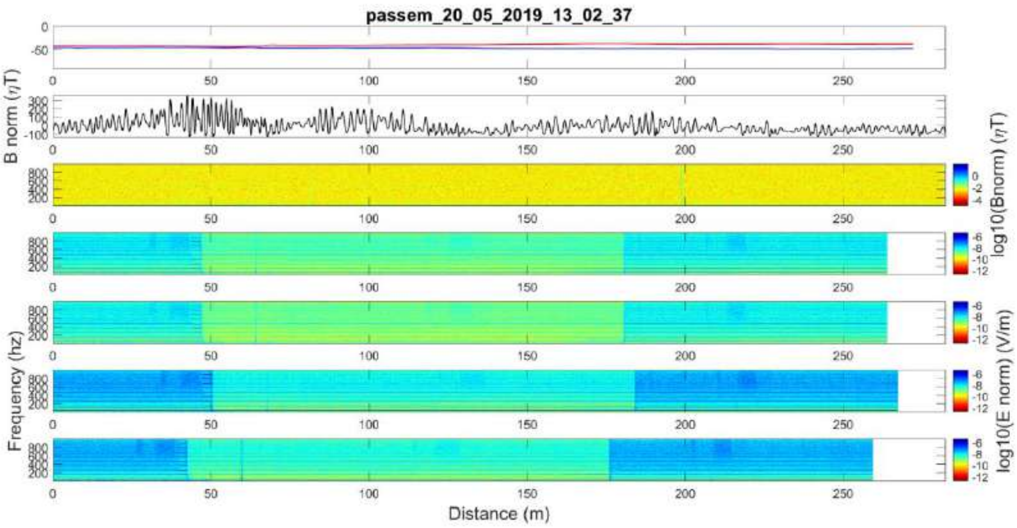




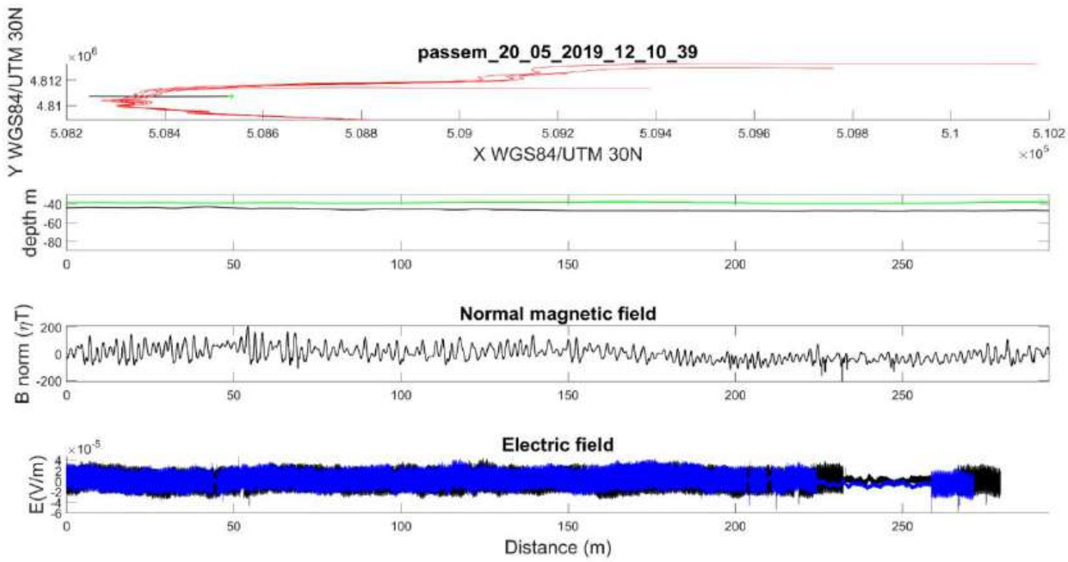
- ***20_05_2019_13_02_37:***

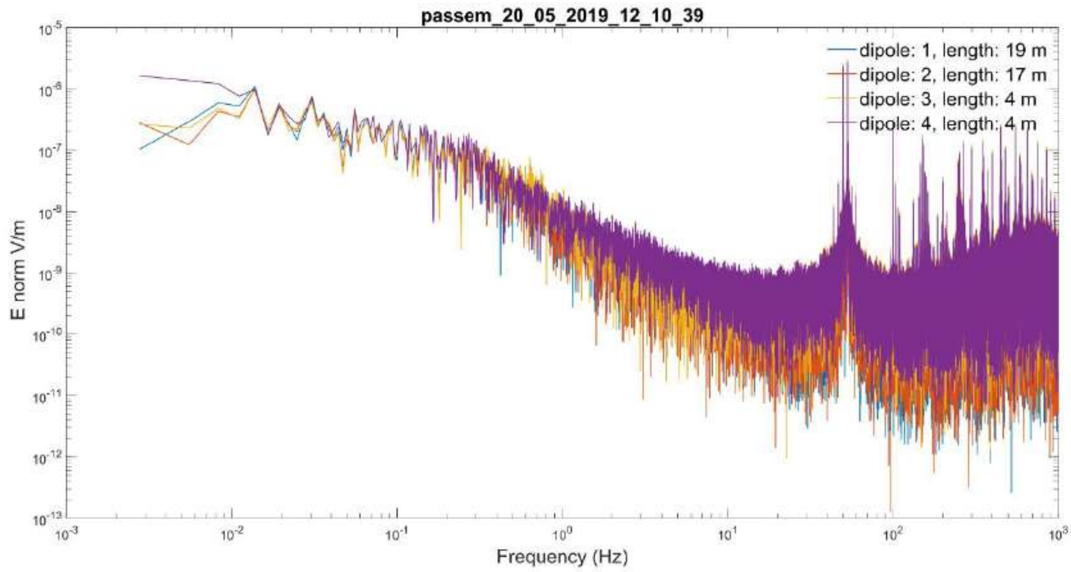


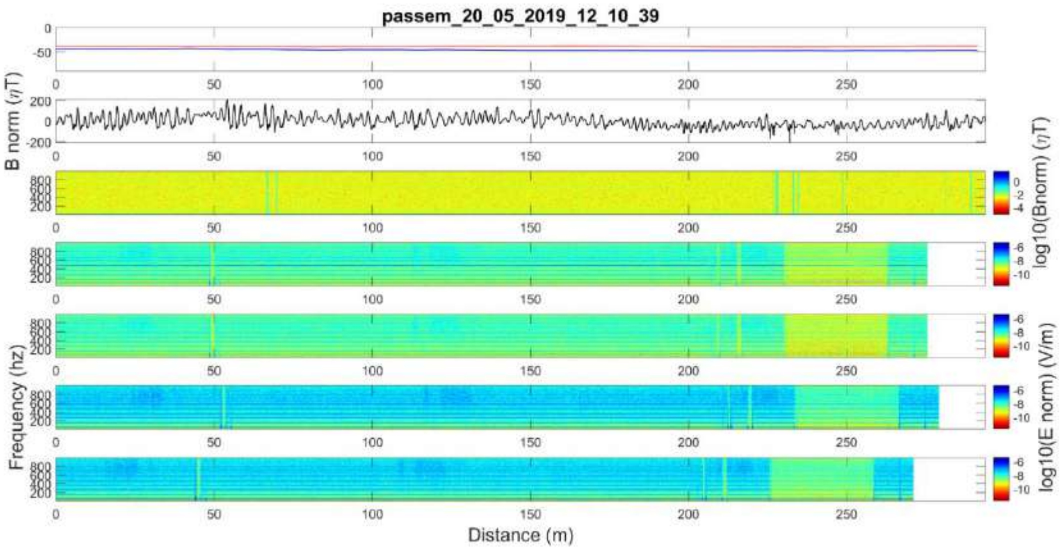




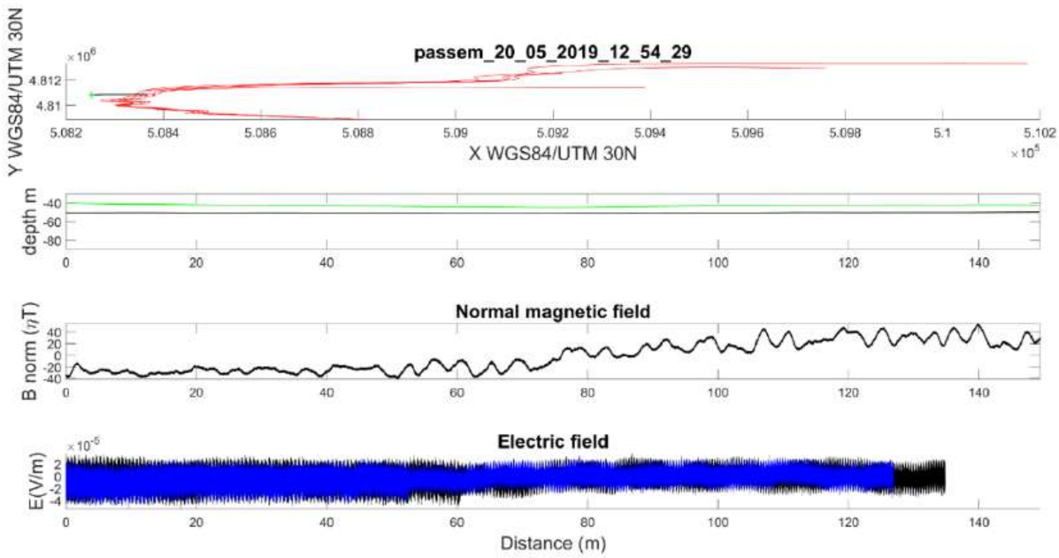
- **20_05_2019_12_10_39:**

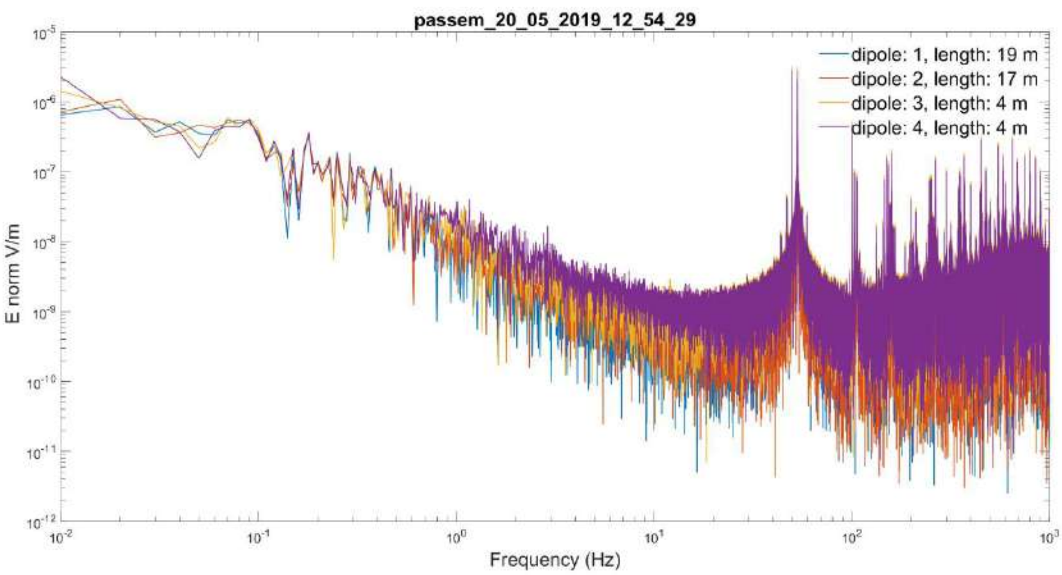


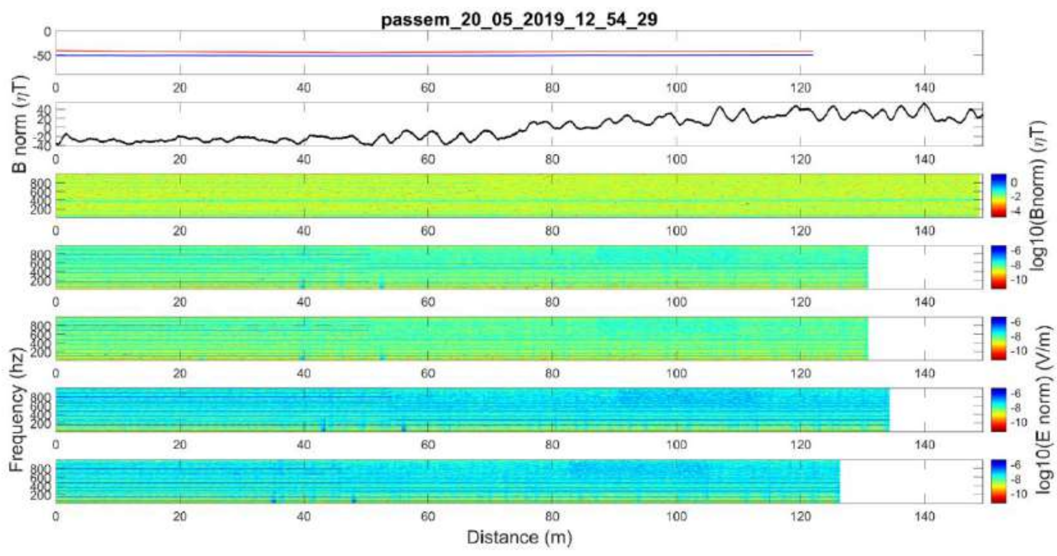




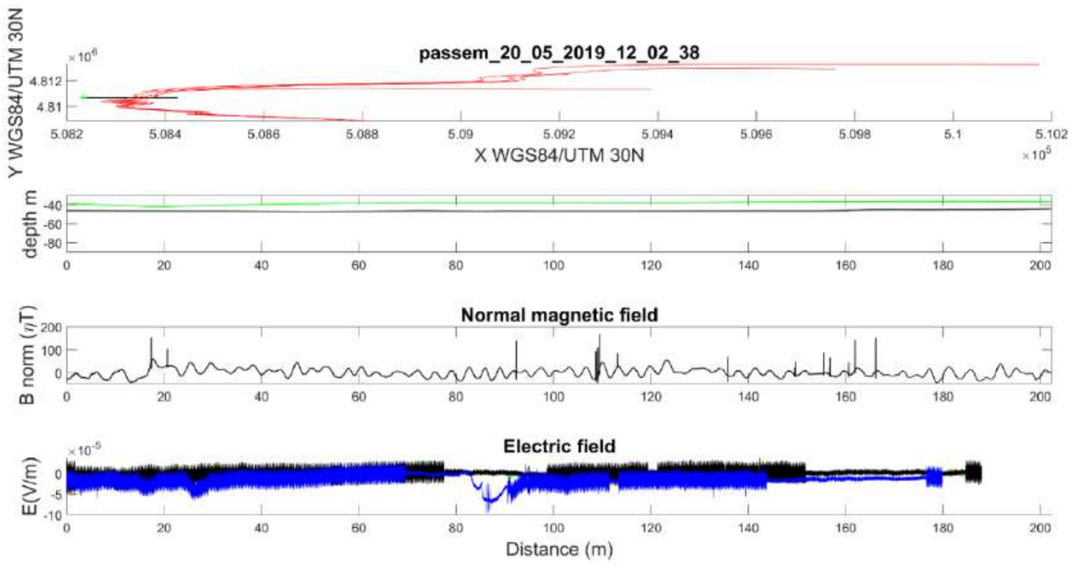
- ***20_05_2019_12_54_29:***

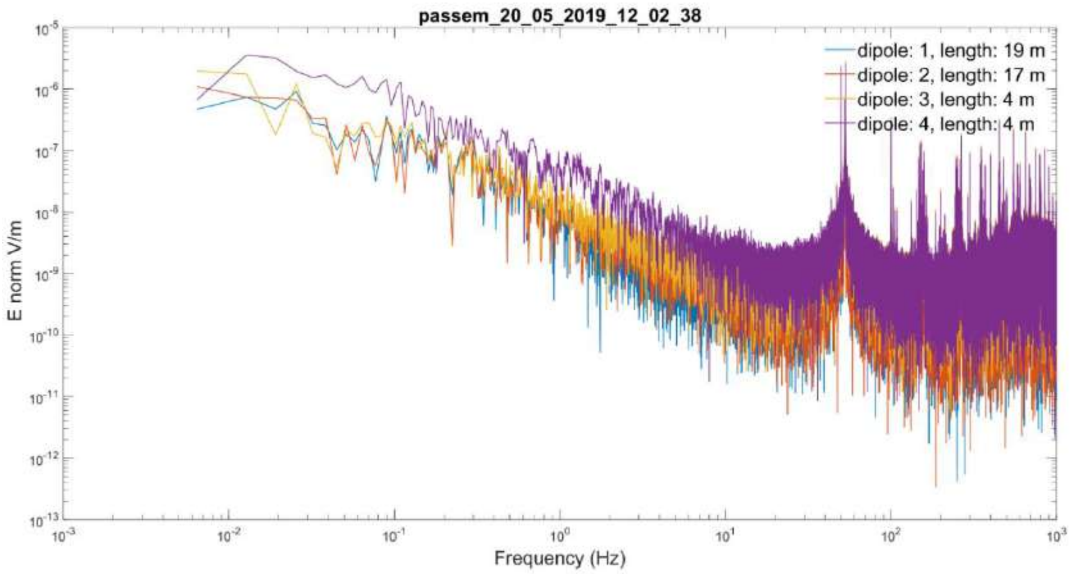


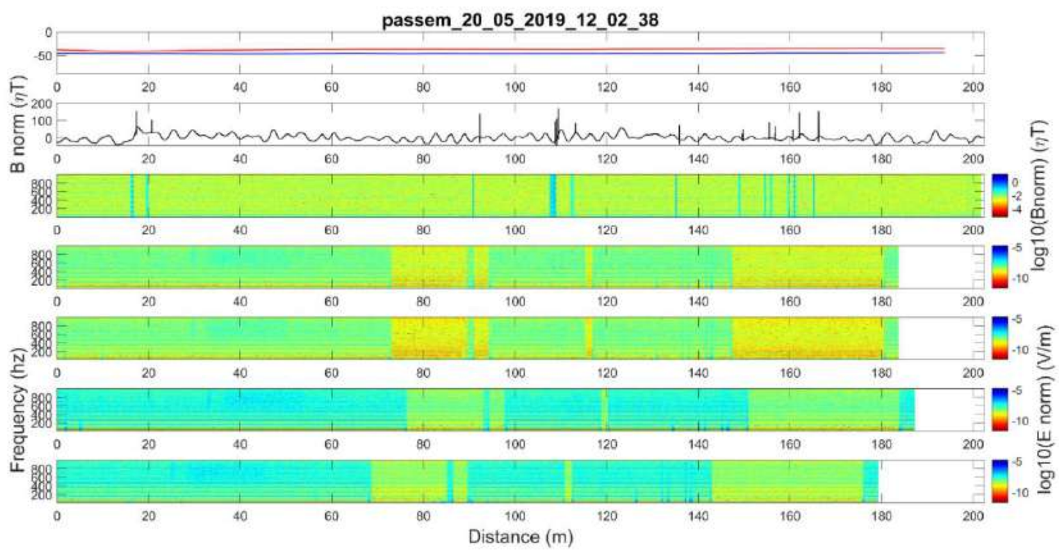




- ***20_05_2019_12_02_38:***







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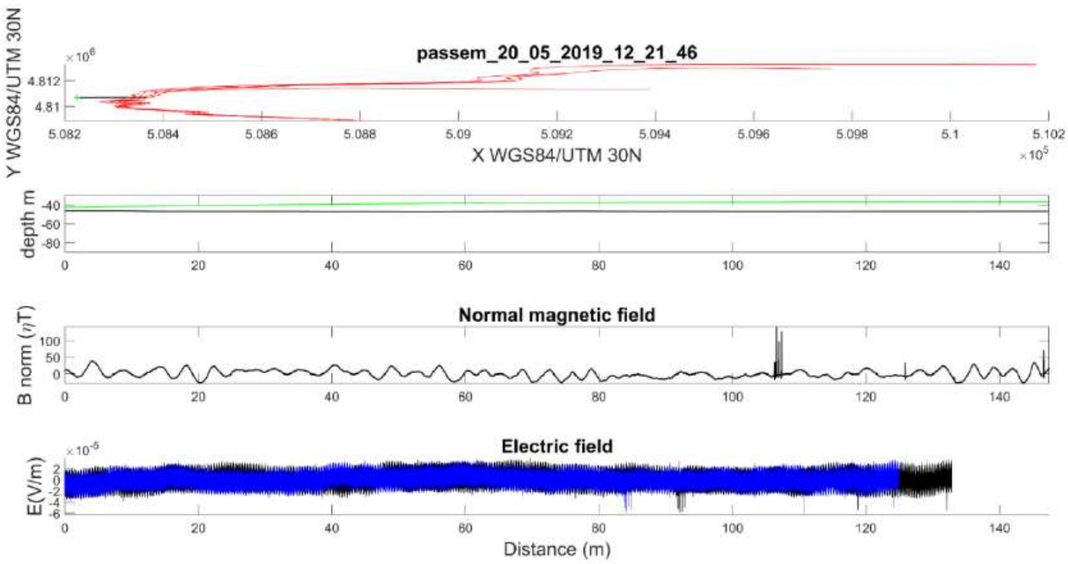
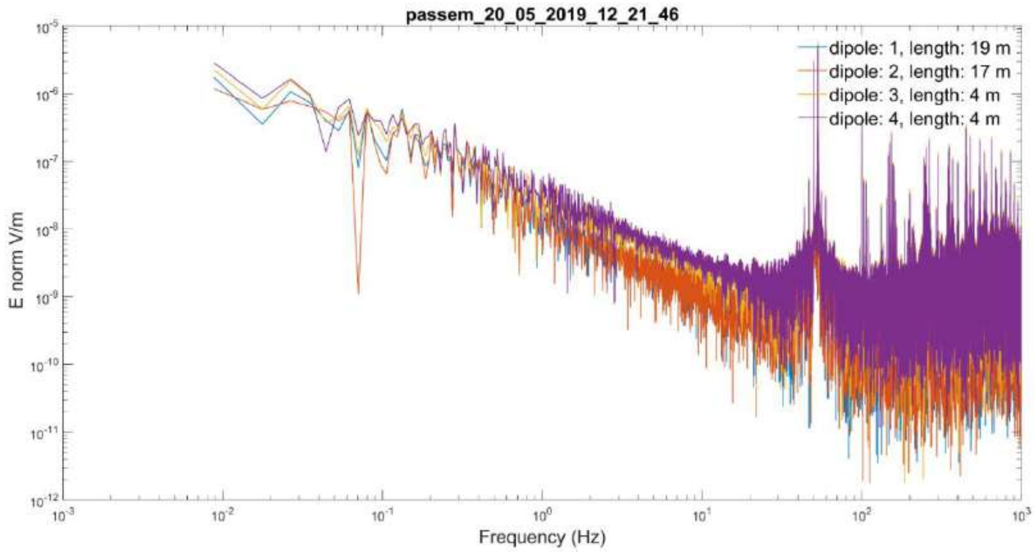
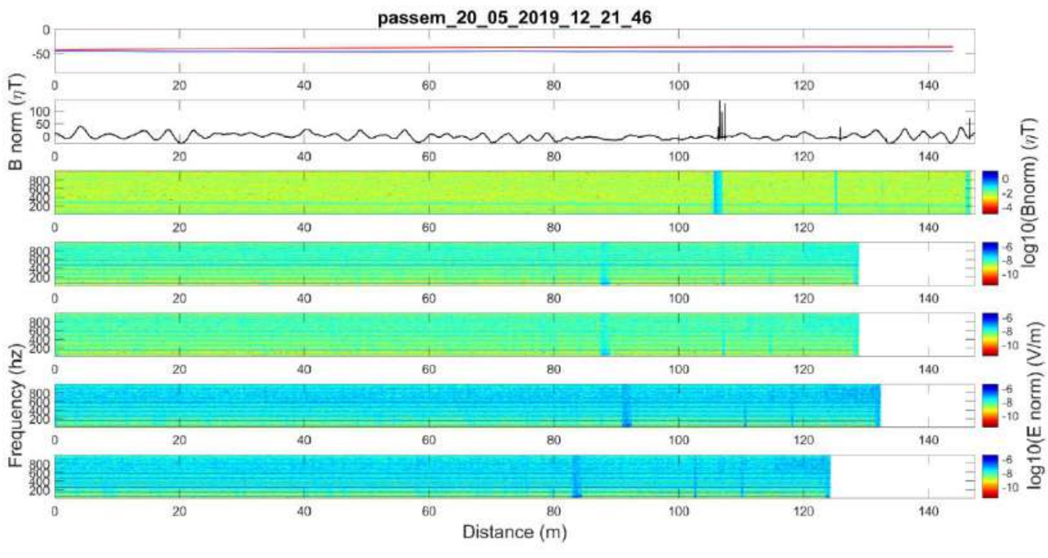
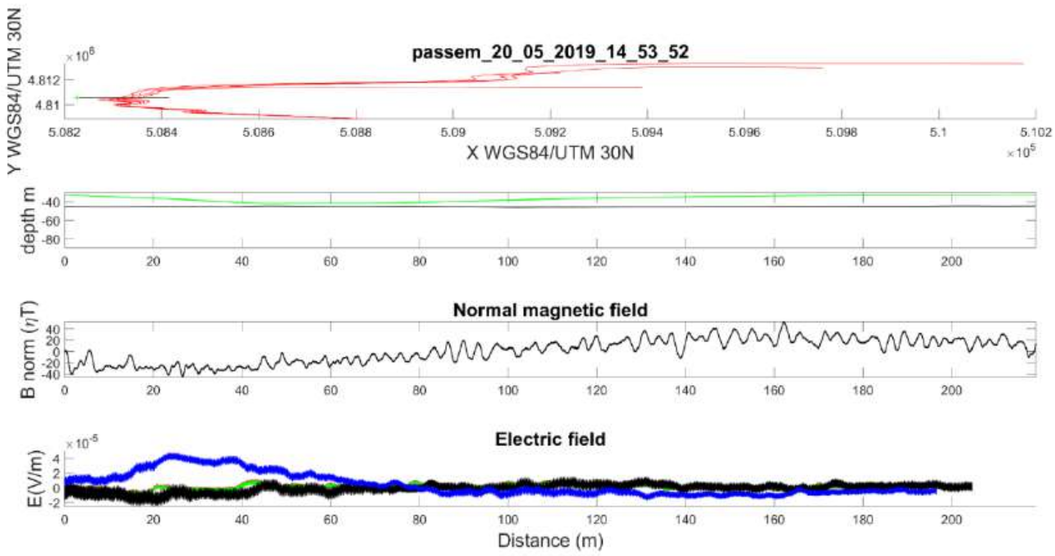
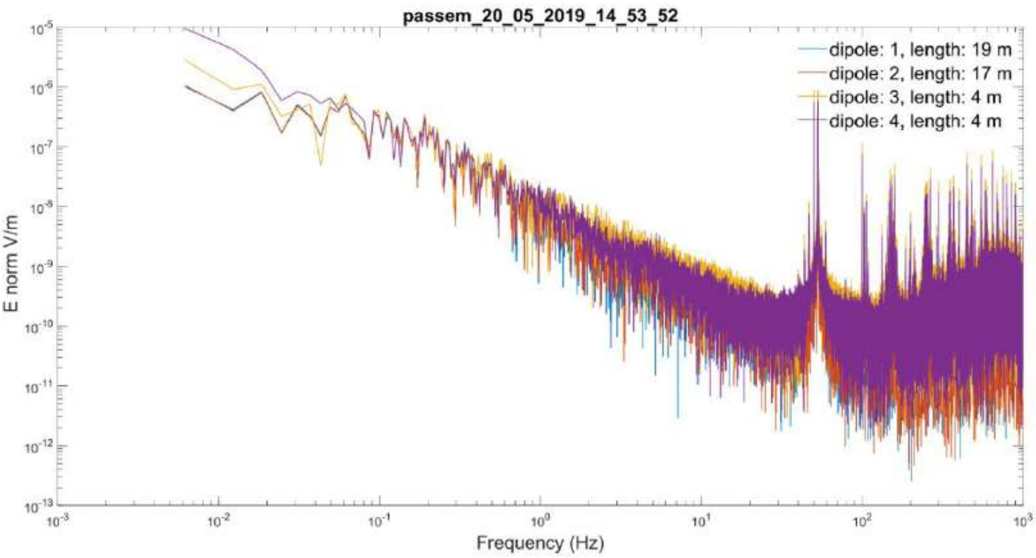


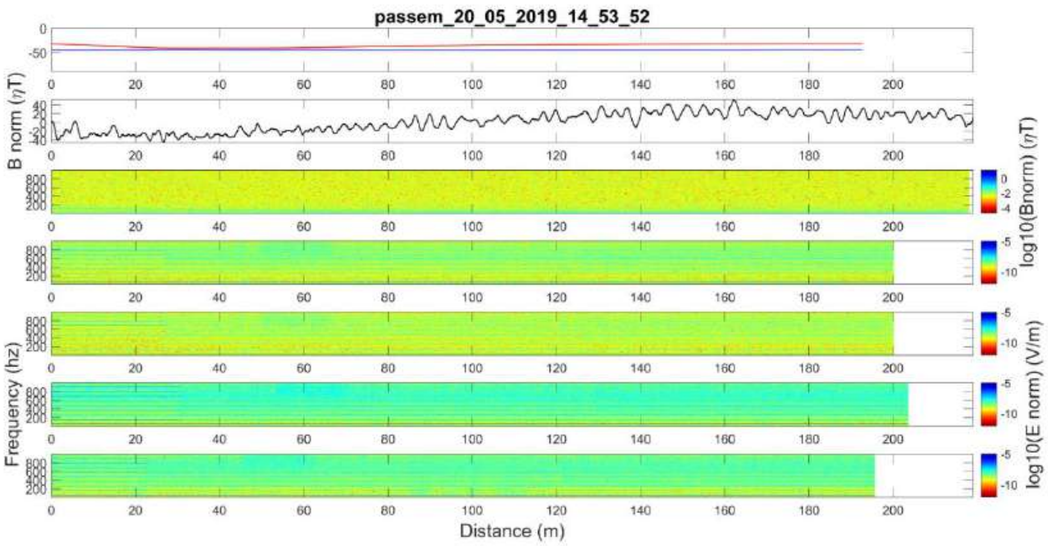




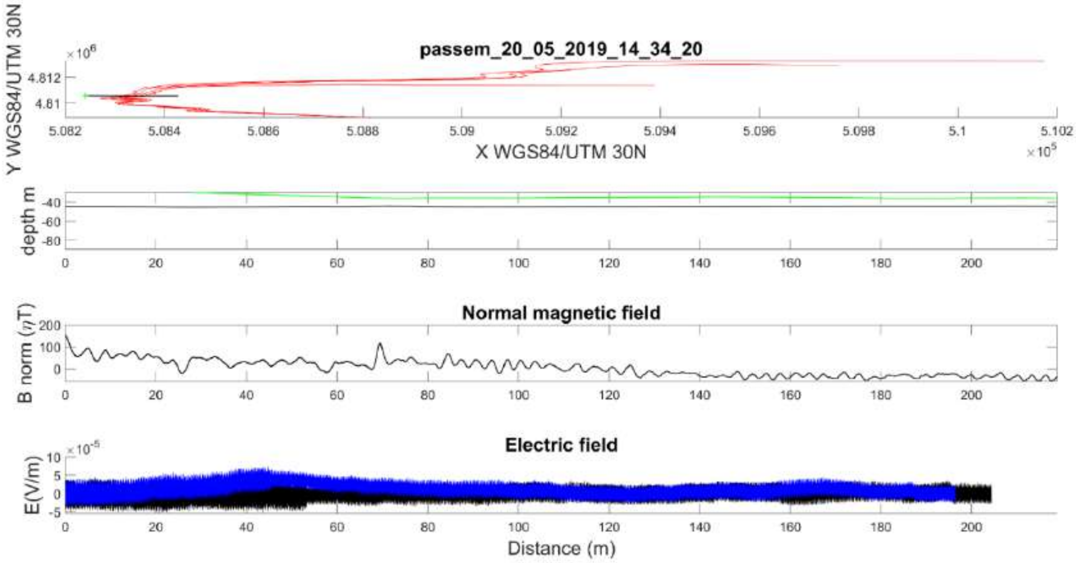
- ***20_05_2019_14_53_52:***

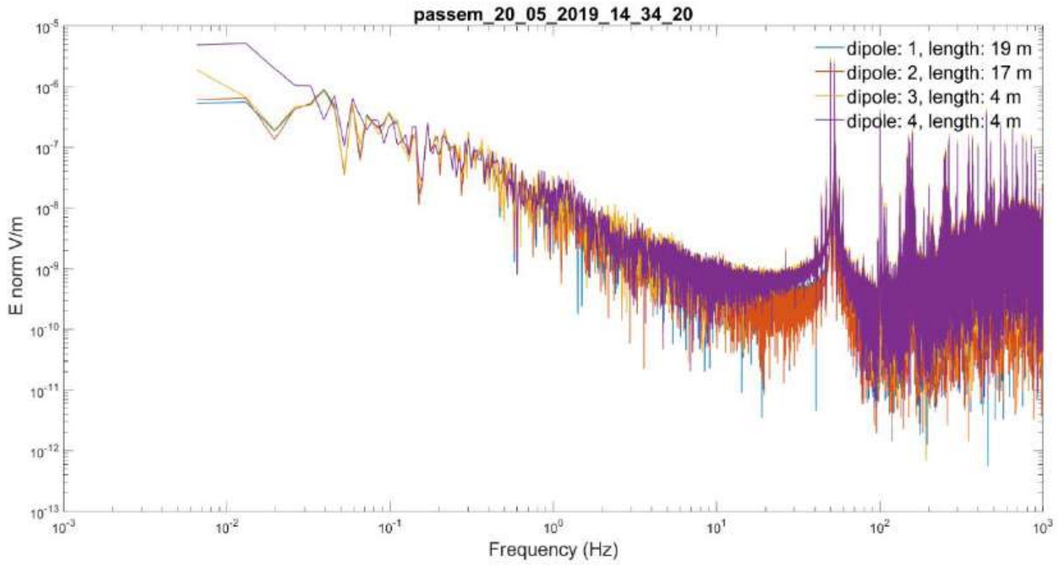


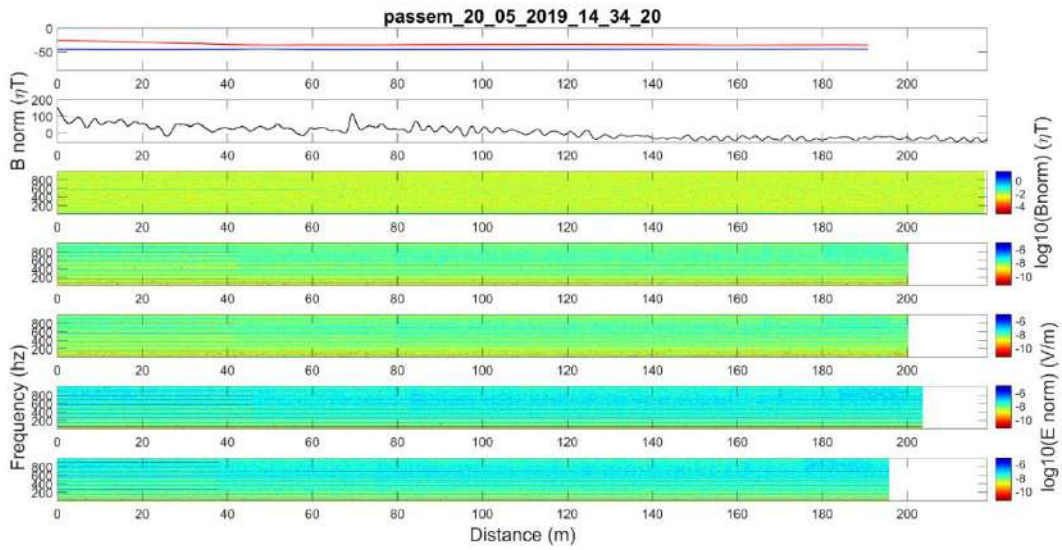




- ***20_05_2019_14_34_20:***







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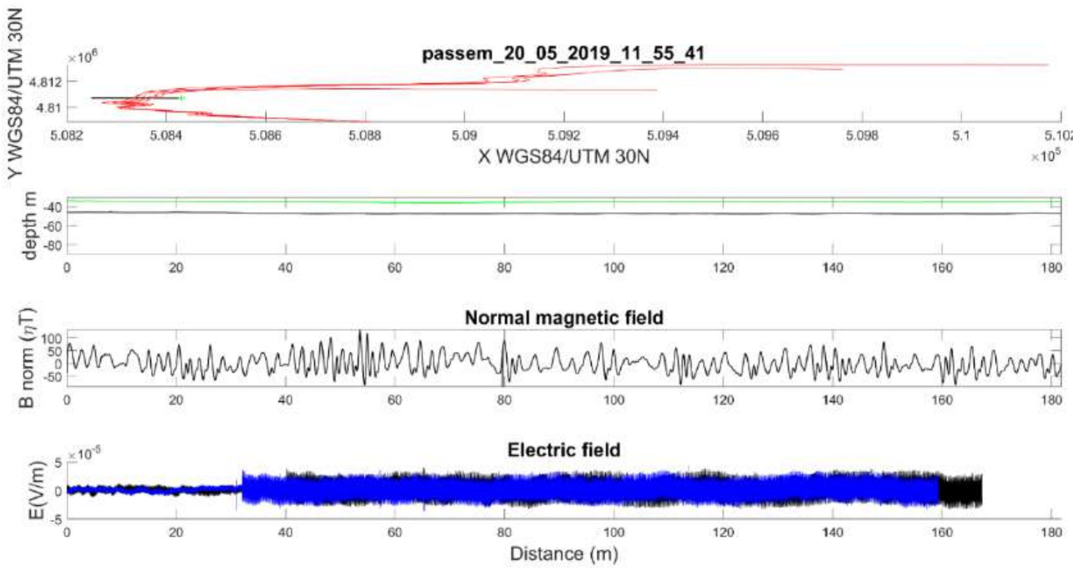
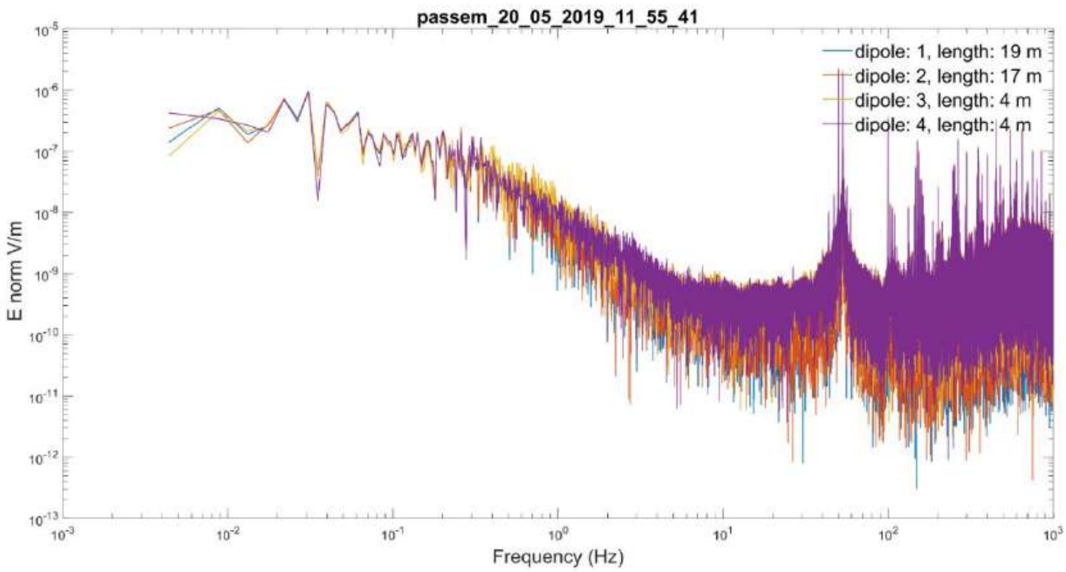
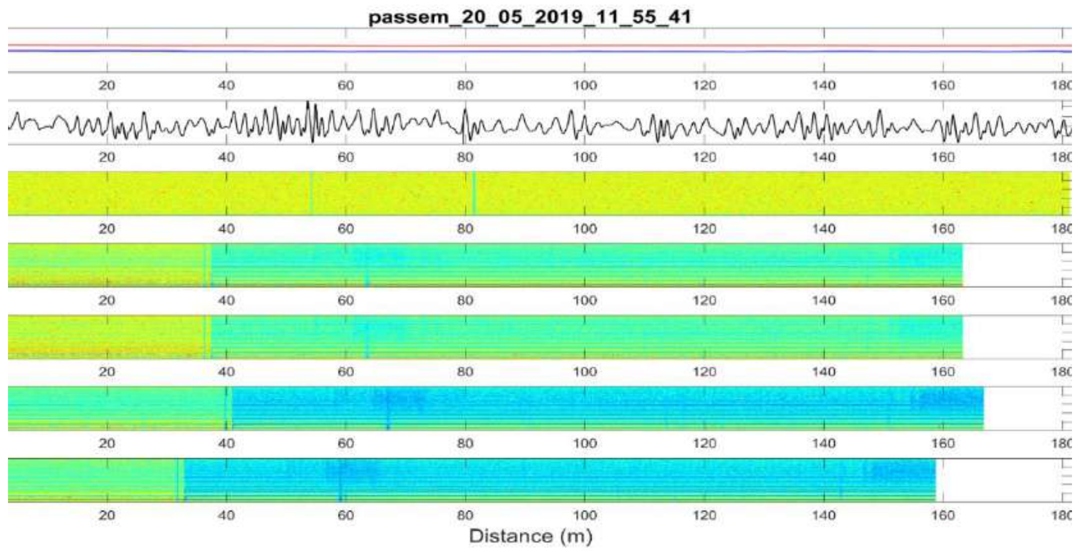
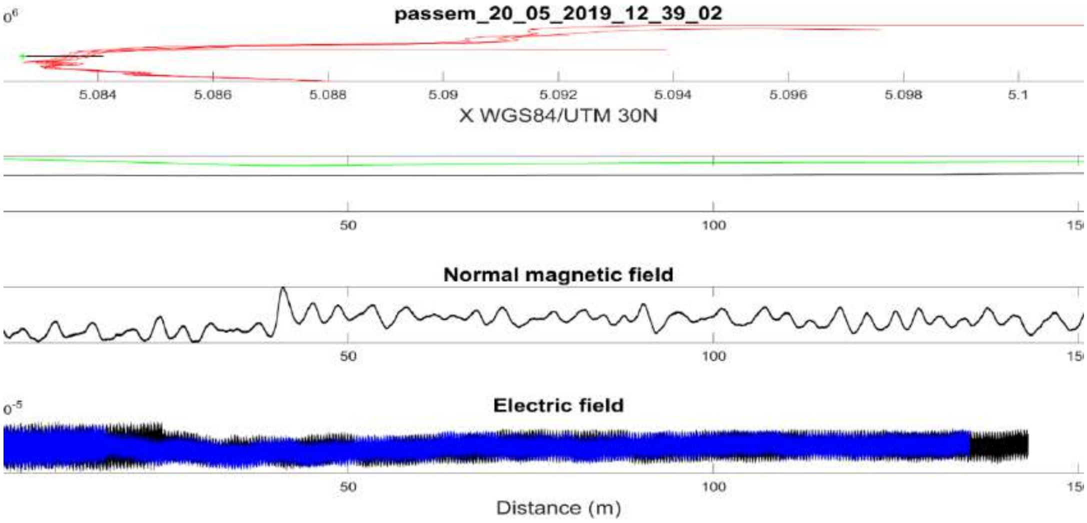
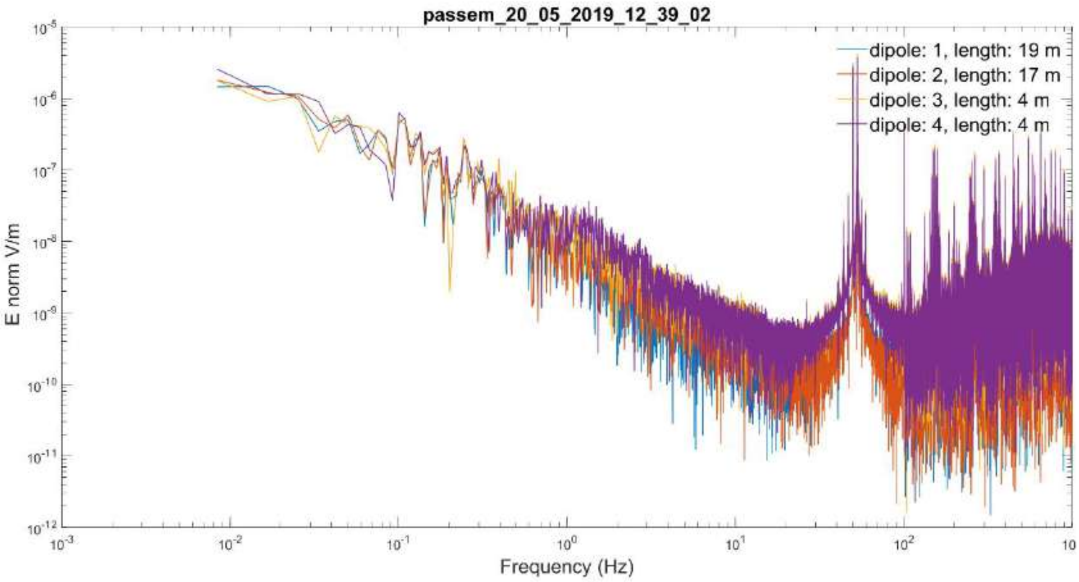


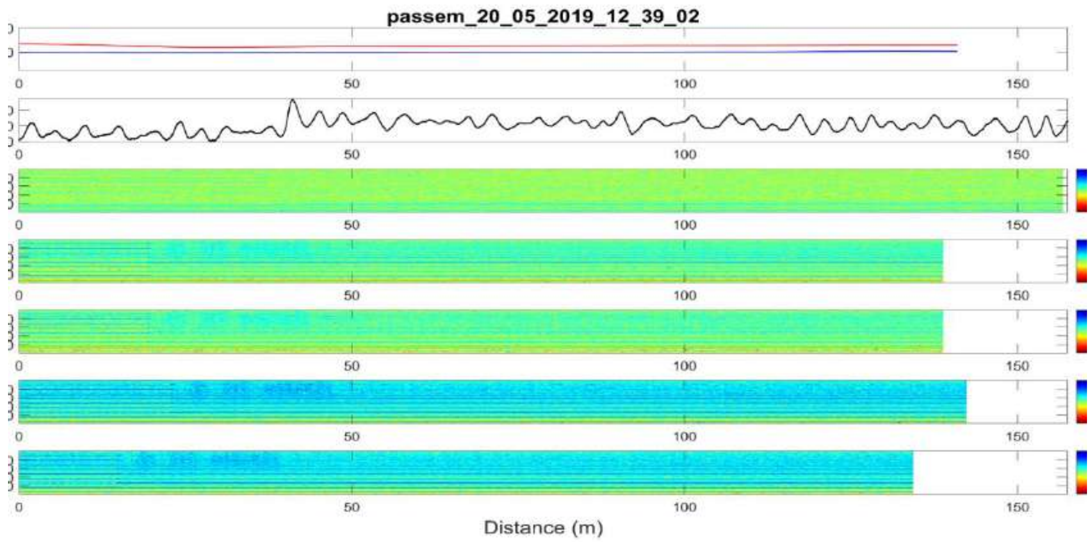




- ***20_05_2019_12_39_02:***


passem_20_05_2019_12_39_02
X WGS84/UTM 30N
Normal magnetic field
Electric field
Distance (m)


passem_20_05_2019_12_39_02
dipole: 1, length: 19 m
dipole: 2, length: 17 m
dipole: 3, length: 4 m
dipole: 4, length: 4 m
E norm V/m
Frequency (Hz)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Distance (m)

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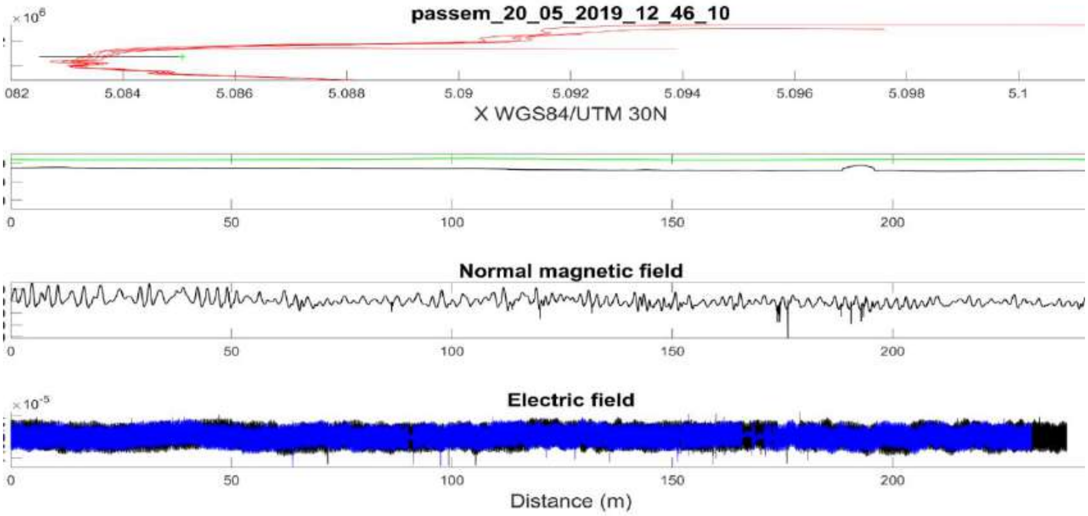

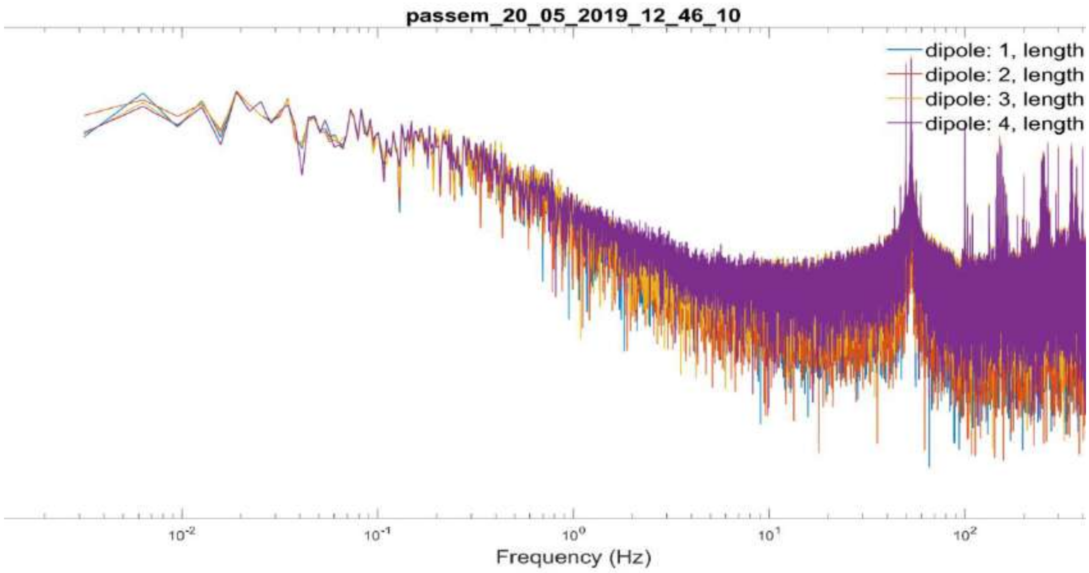

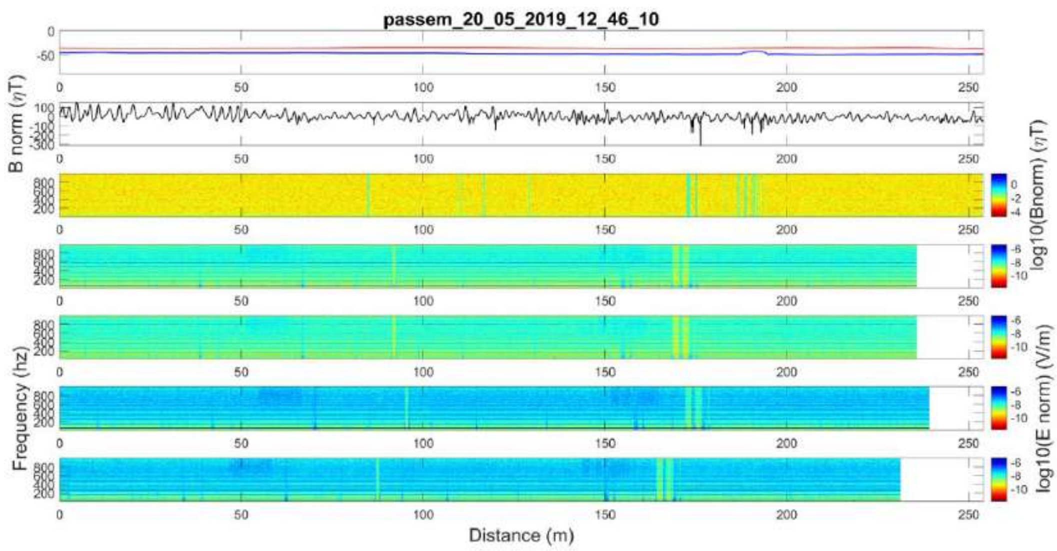

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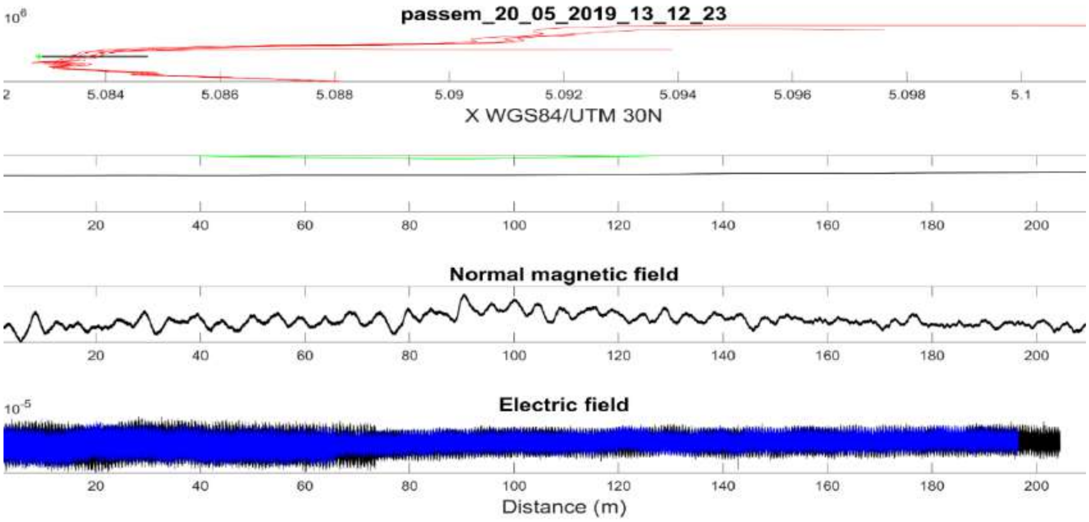

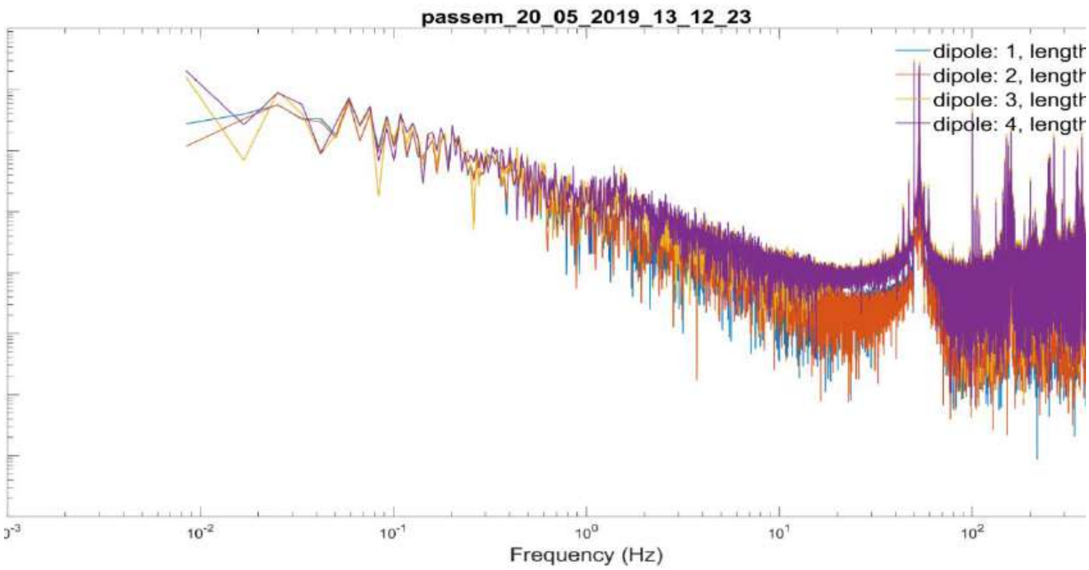

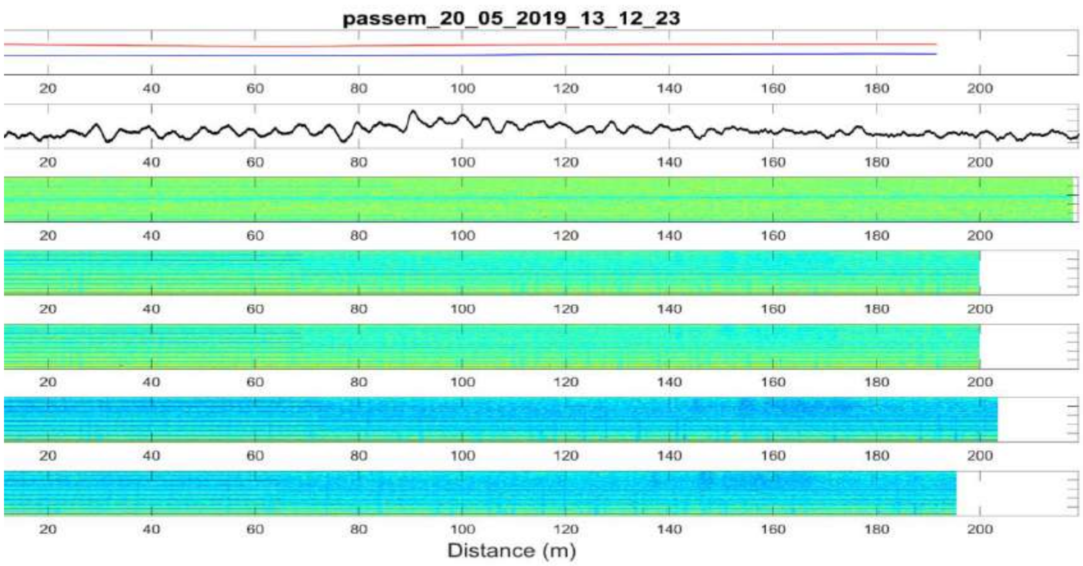

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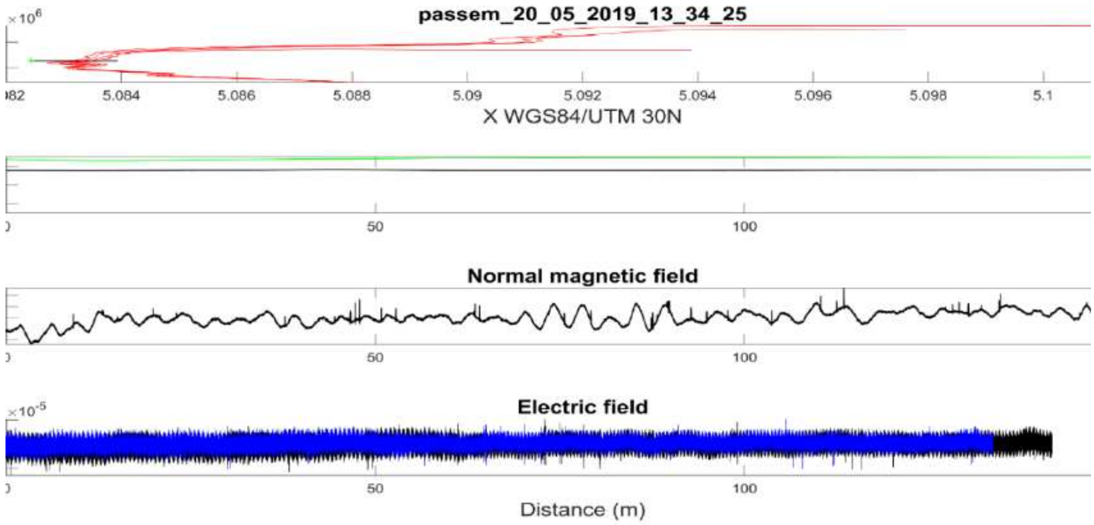
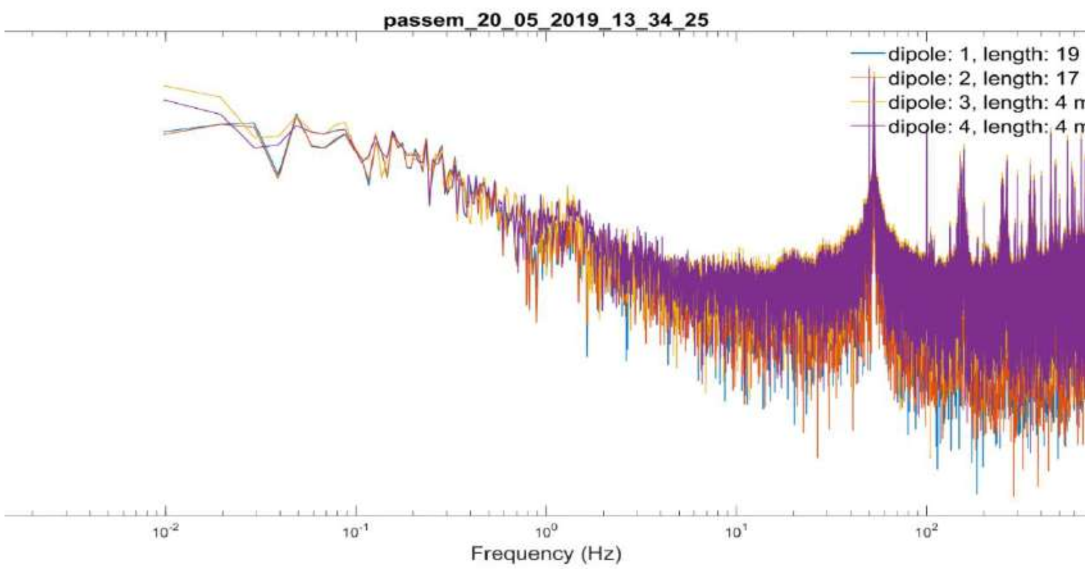
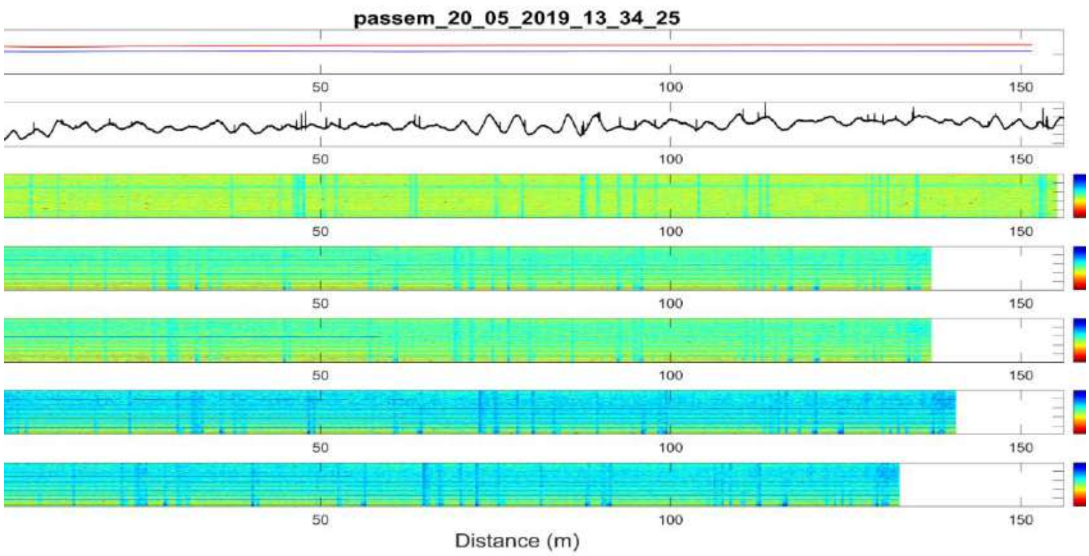
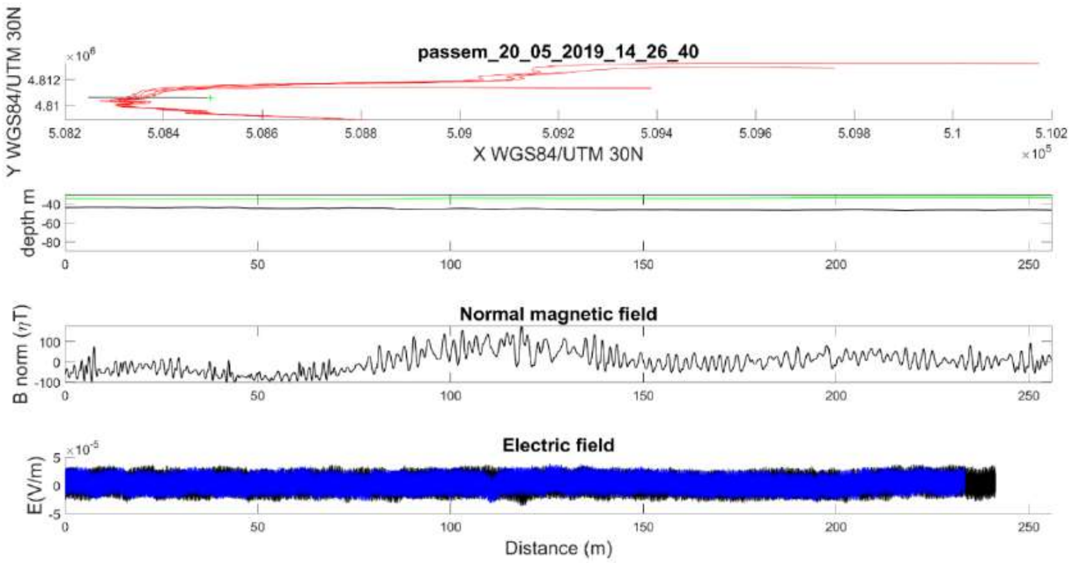
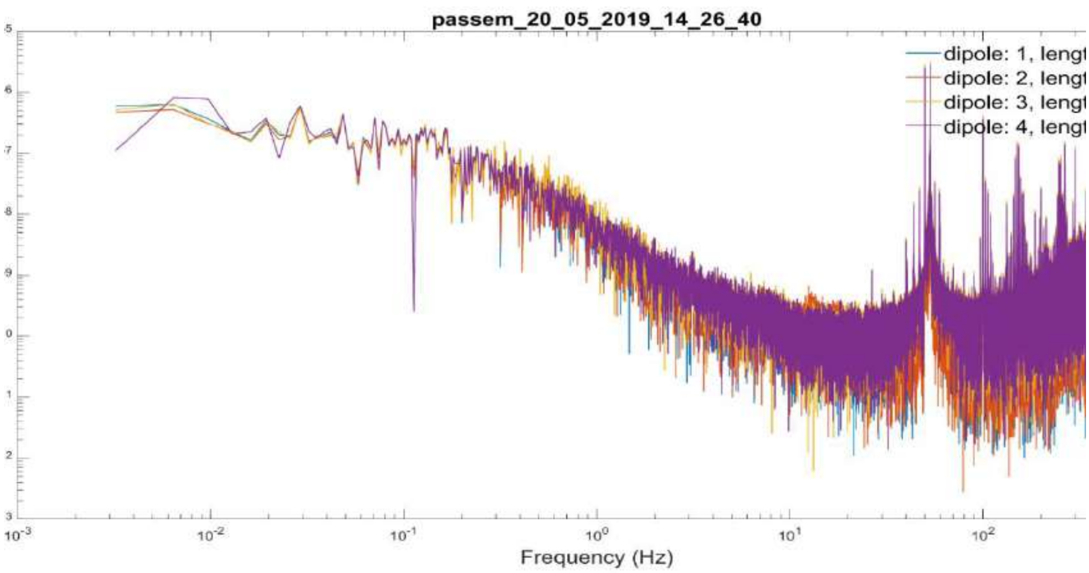


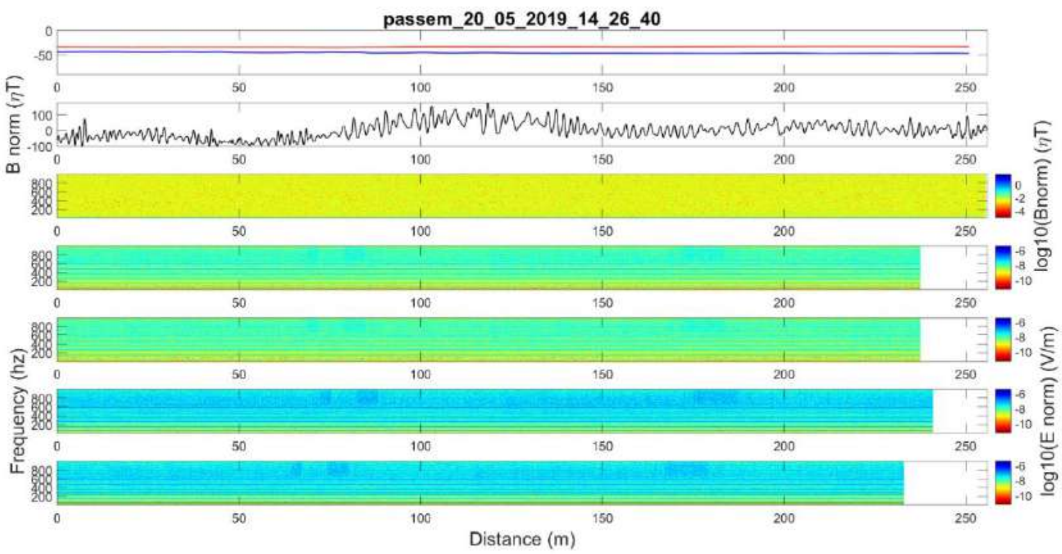




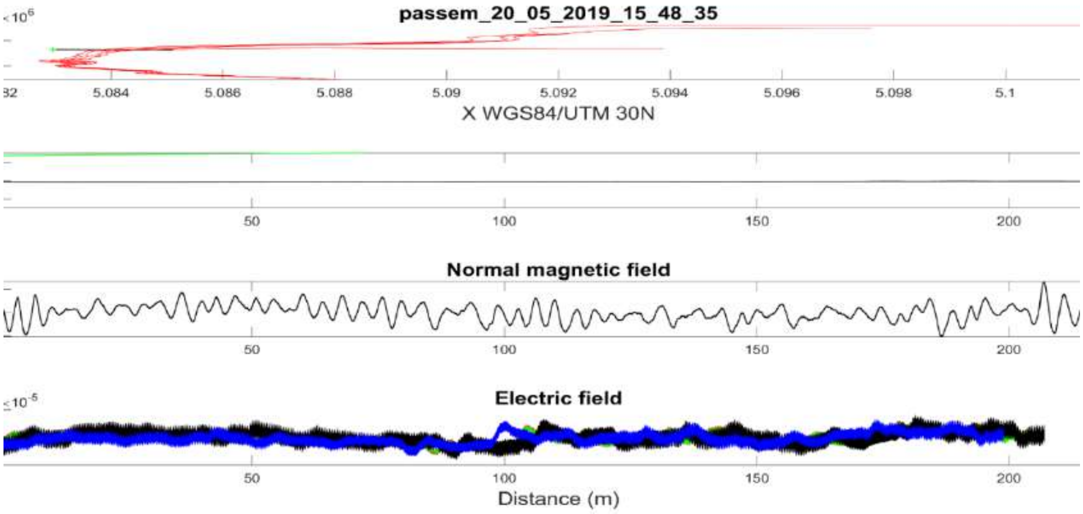
- ***20_05_2019_14_26_40:***

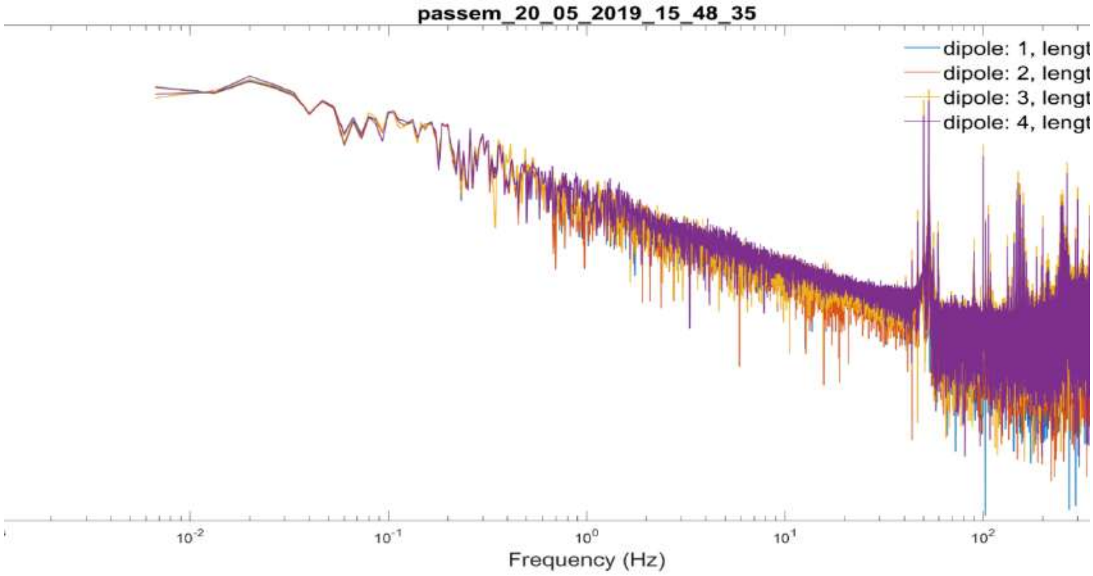


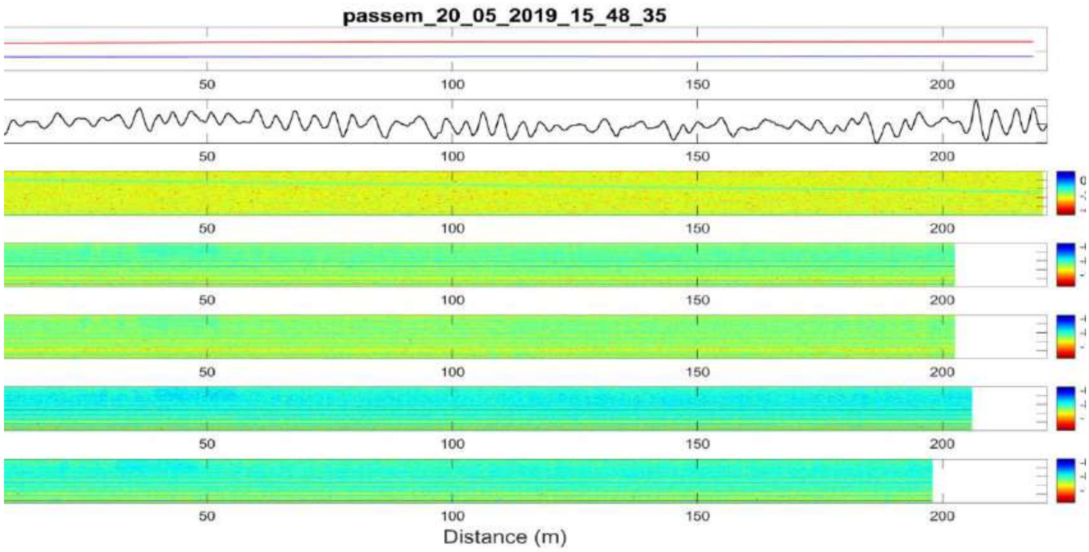




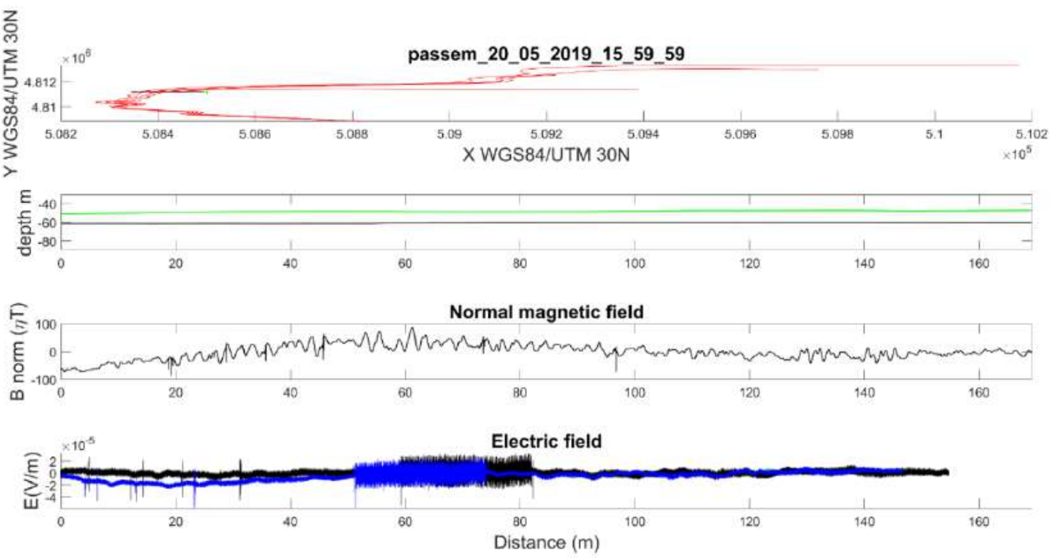
- ***20_05_2019_15_48_35:***

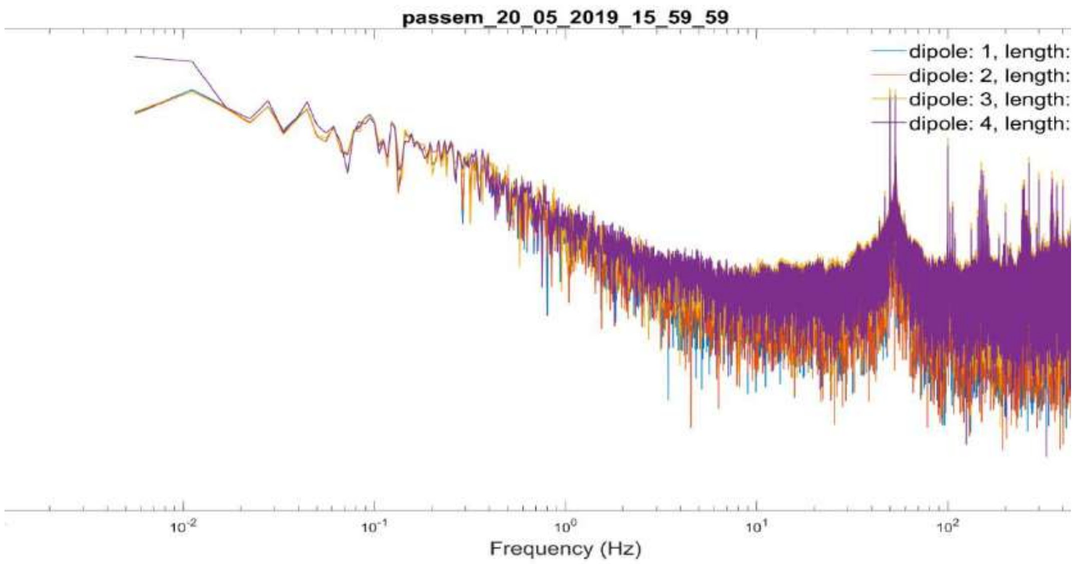


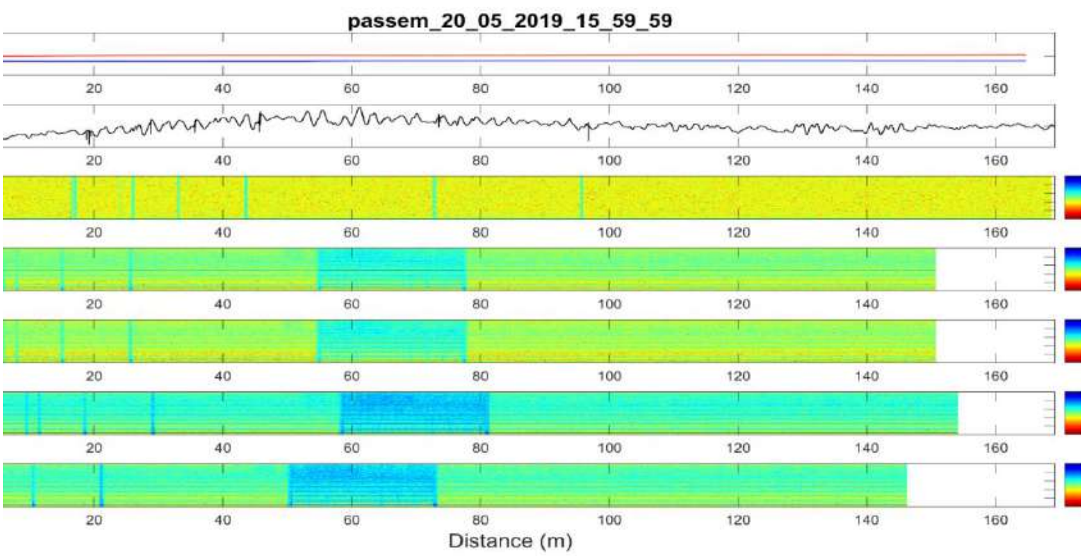




- ***20_05_2019_15_59_59:***







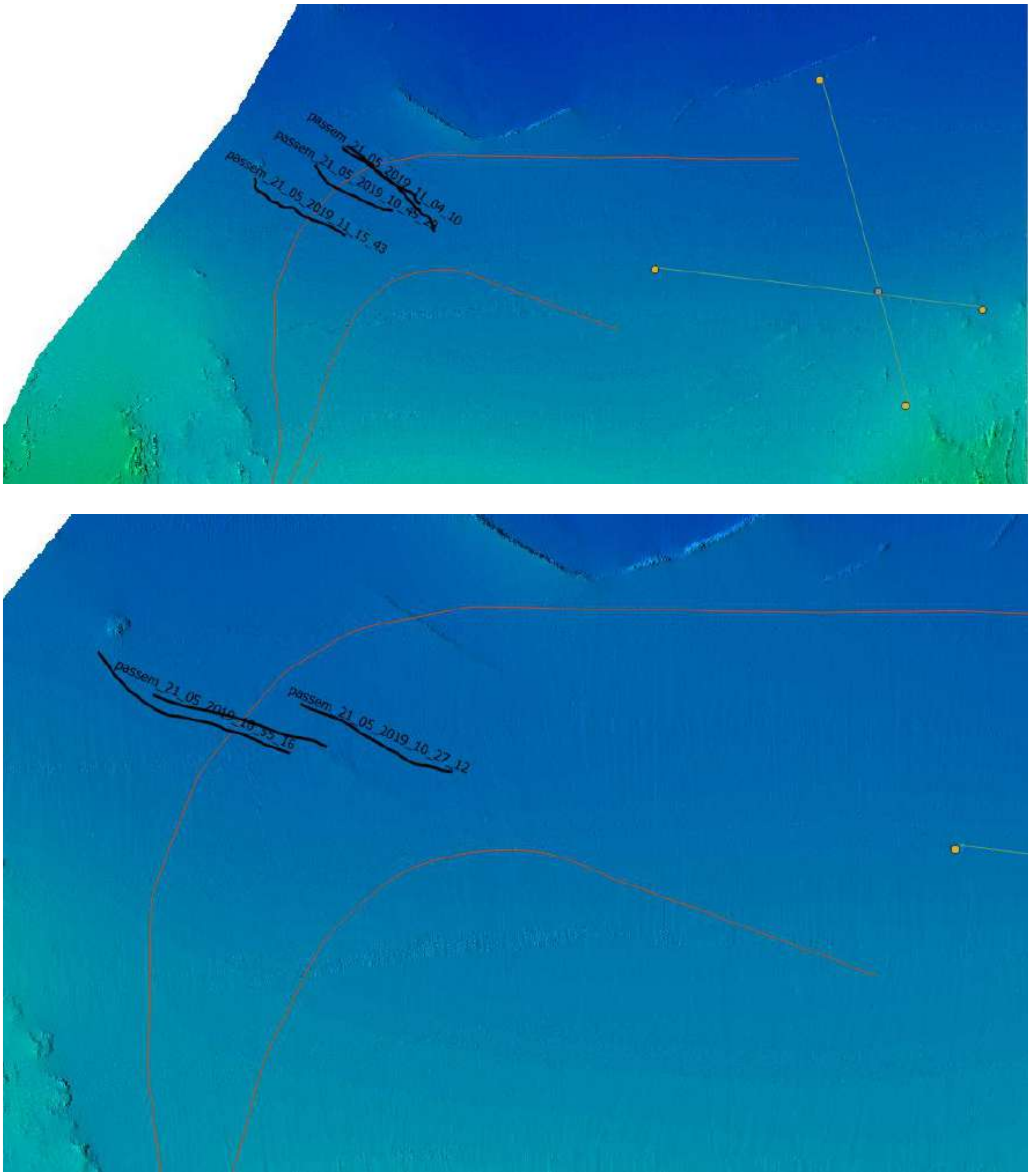
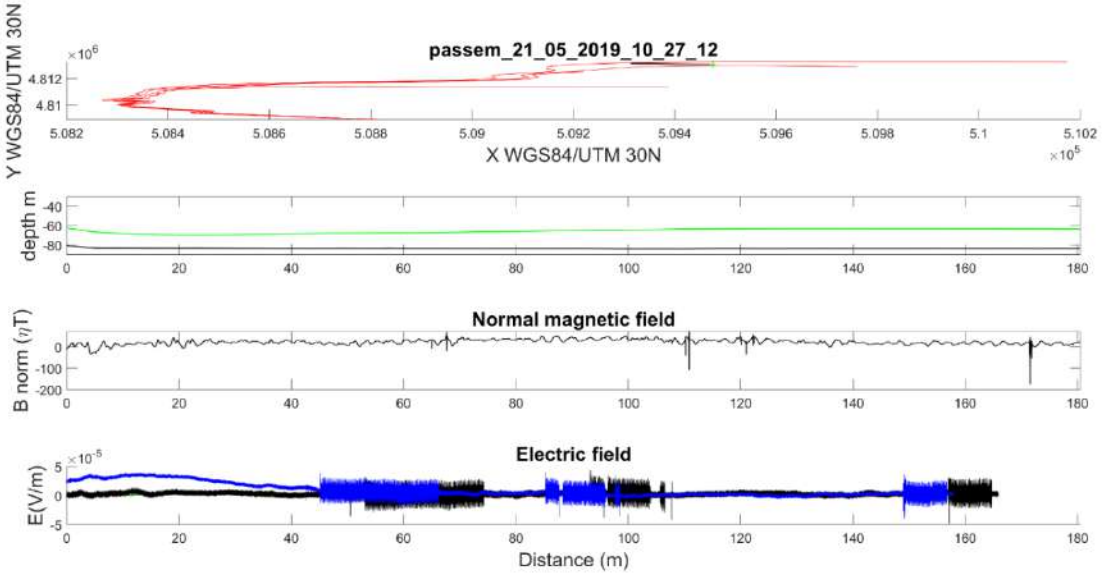
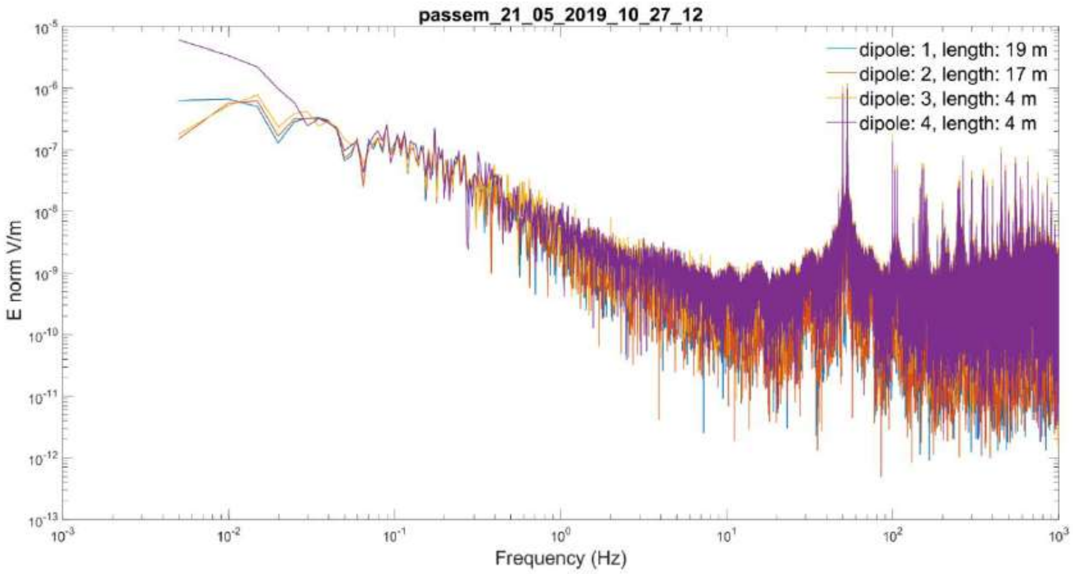
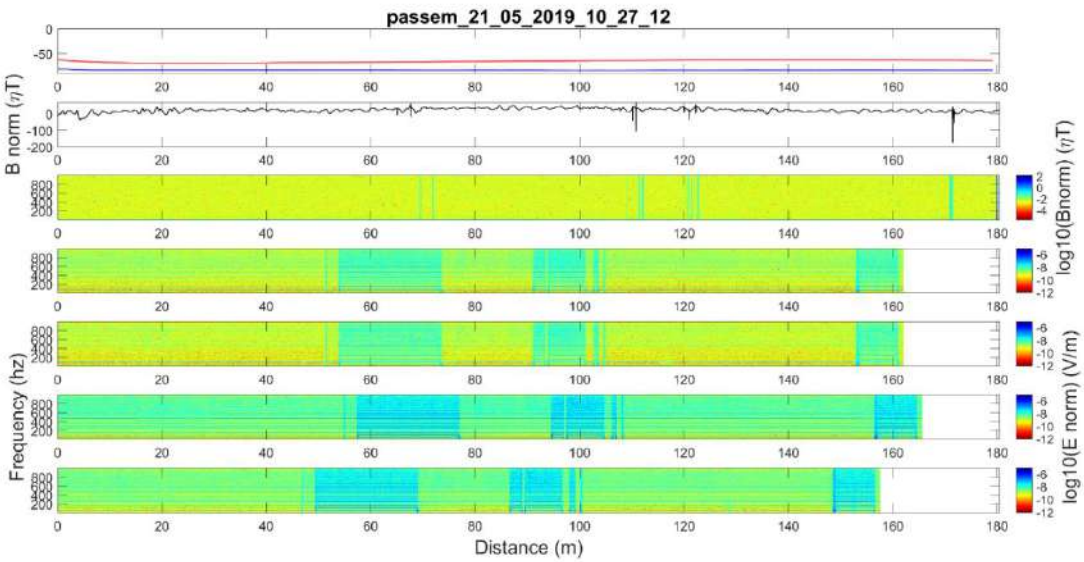


Figure 1: Profiles made during Day2: with a mean height < 15 m (upper figure) with a mean height > 15 m (bottom figure)

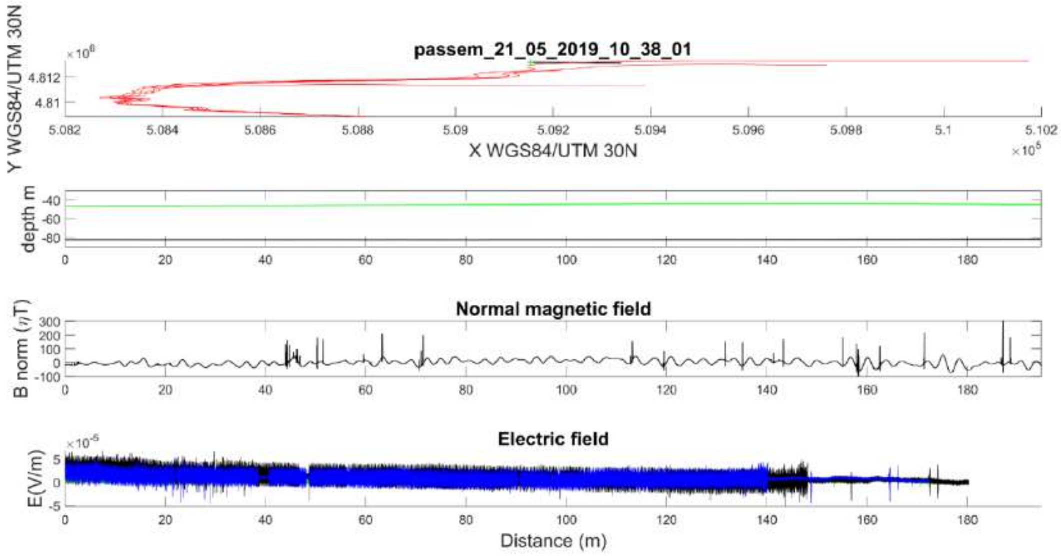
-21_05_2019_10_27_12:

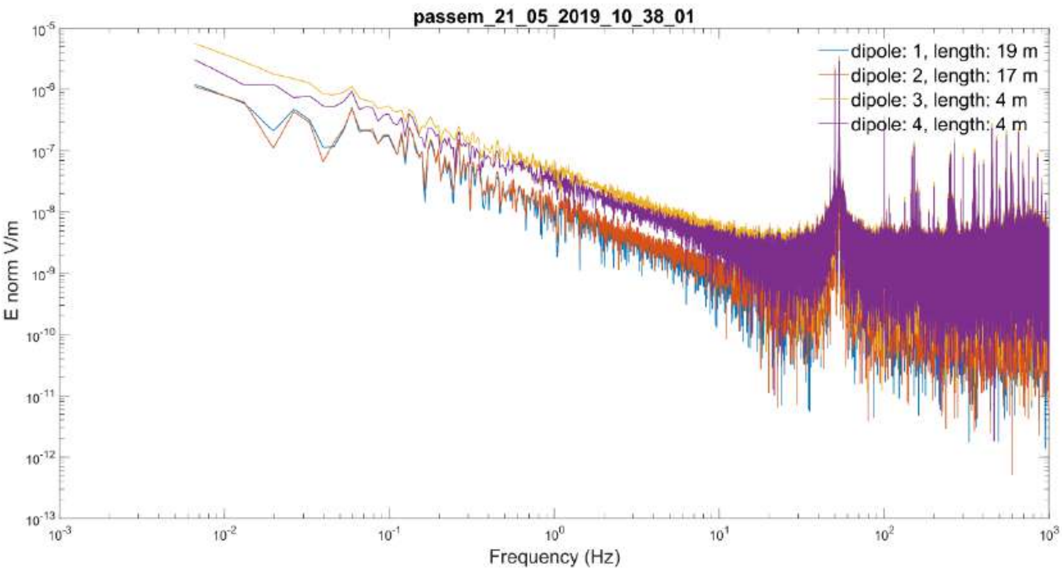


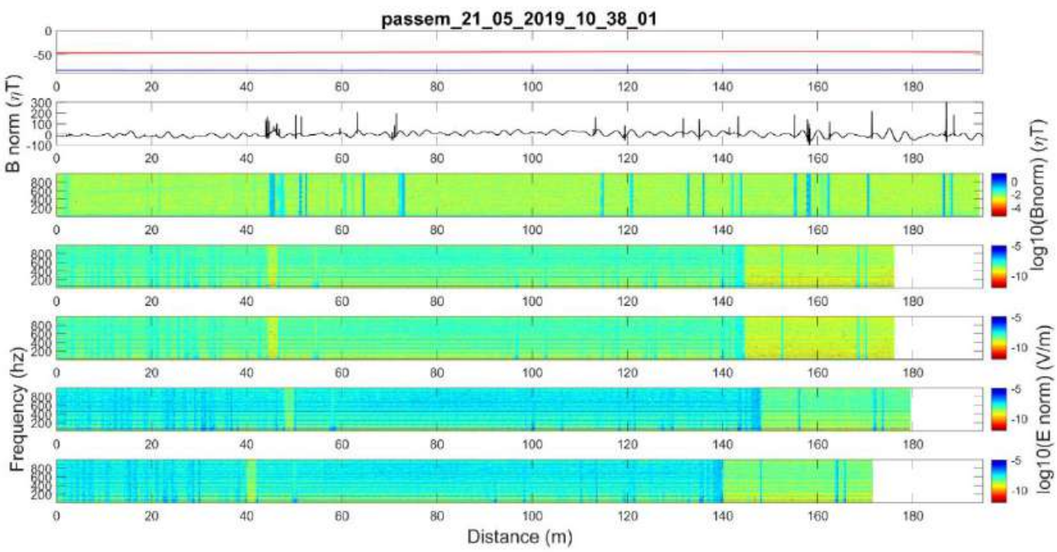




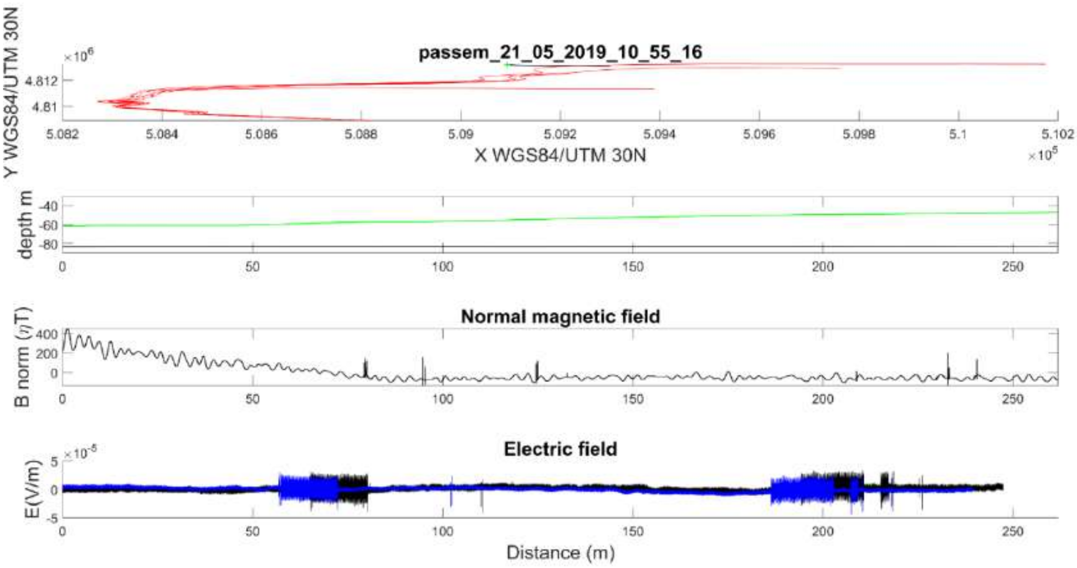
- ***21_05_2019_10_38_01:***

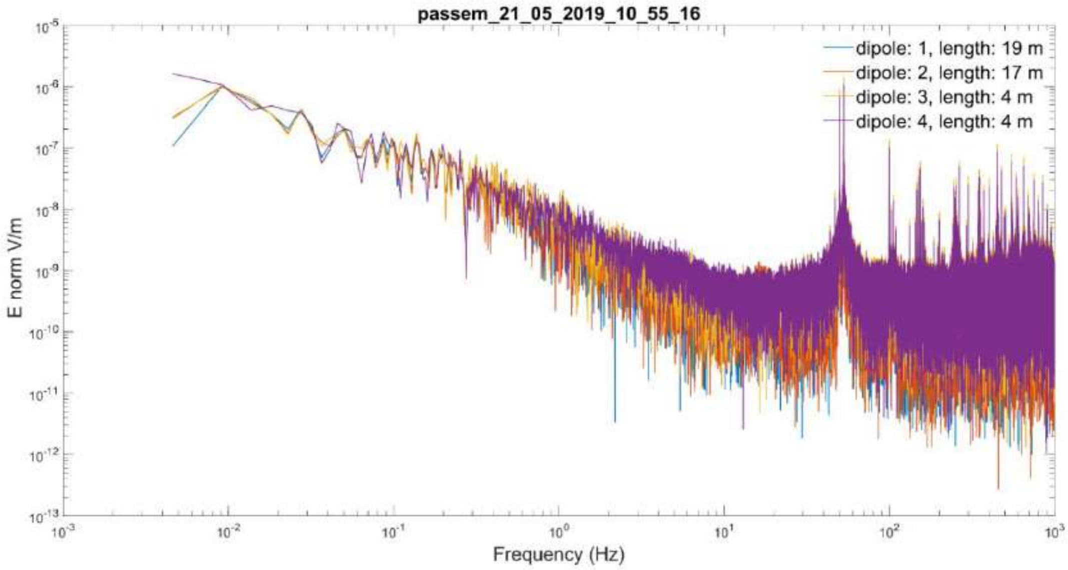






- ***21_05_2019_10_55_16:***





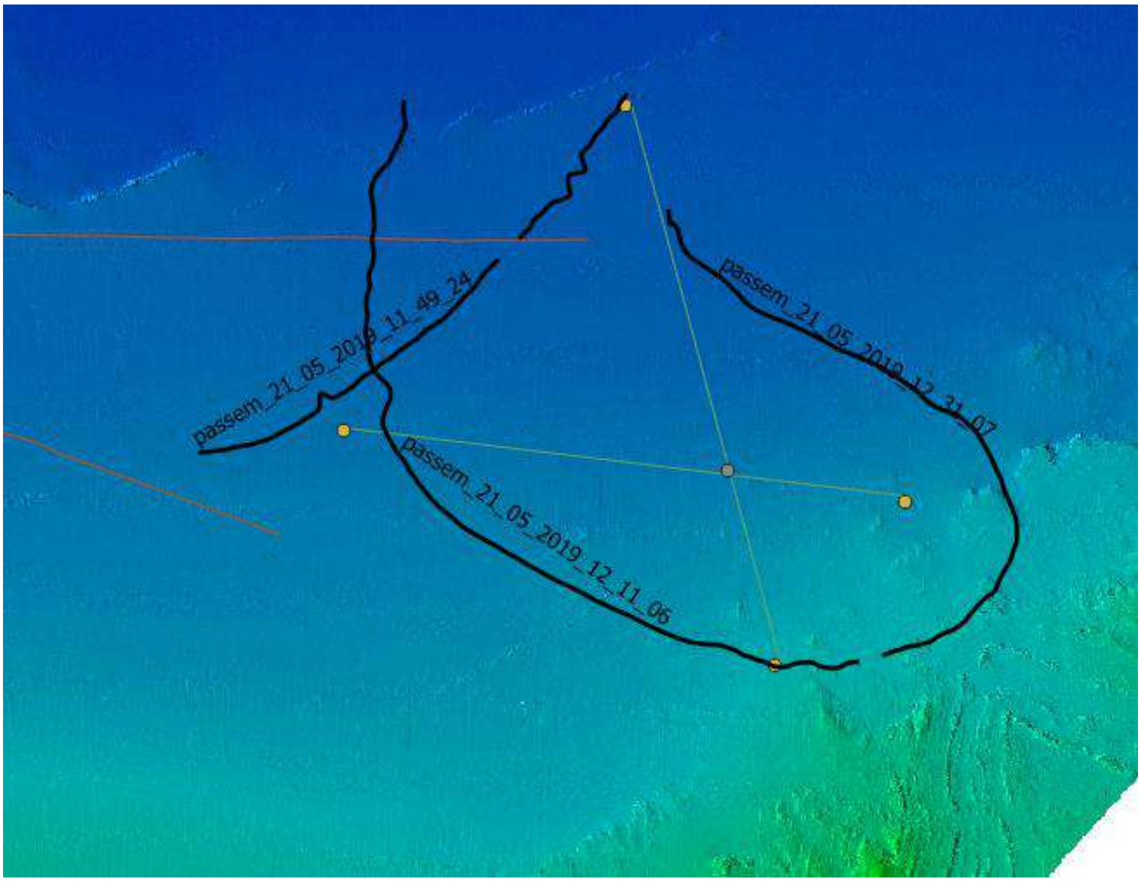
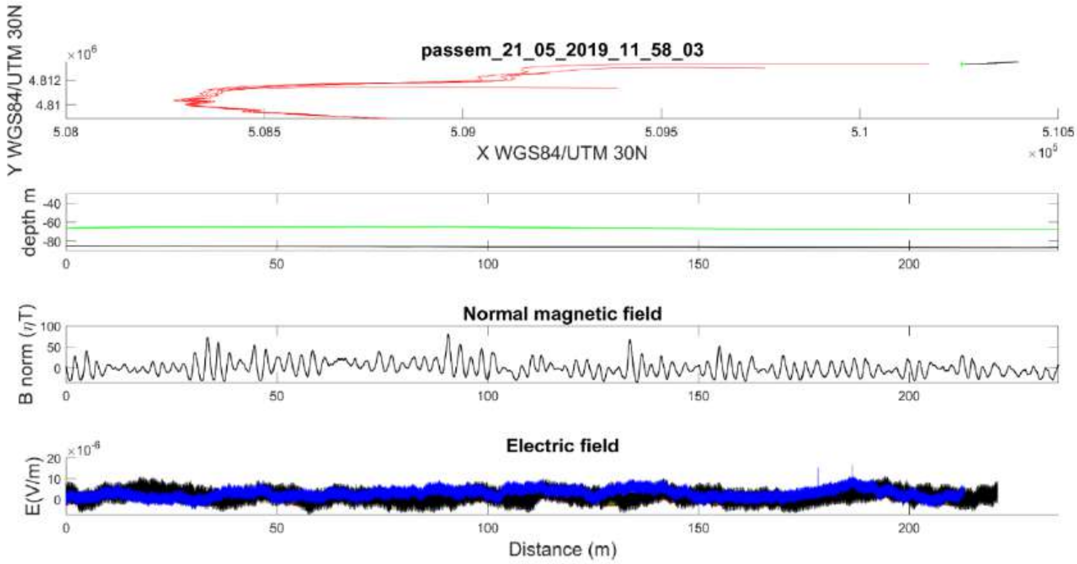
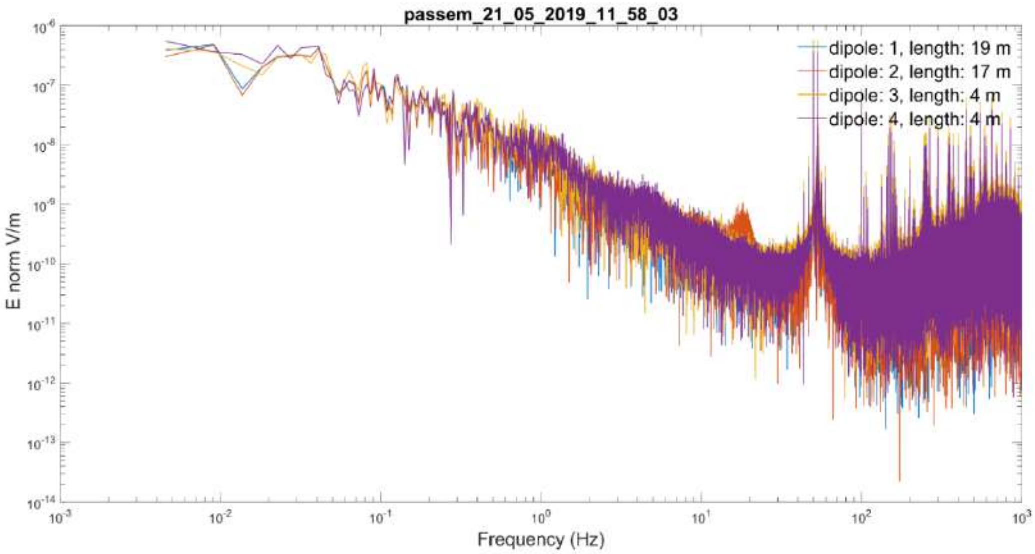
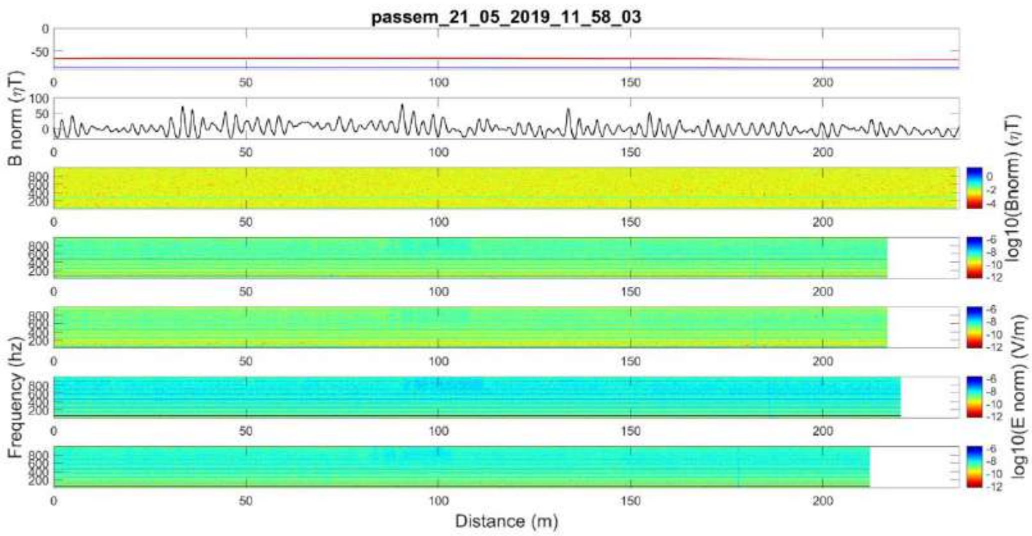


Figure 18. Profiles made during Day2: around the MARMOK WEC system.

- ***21_05_2019_11_58_03:***







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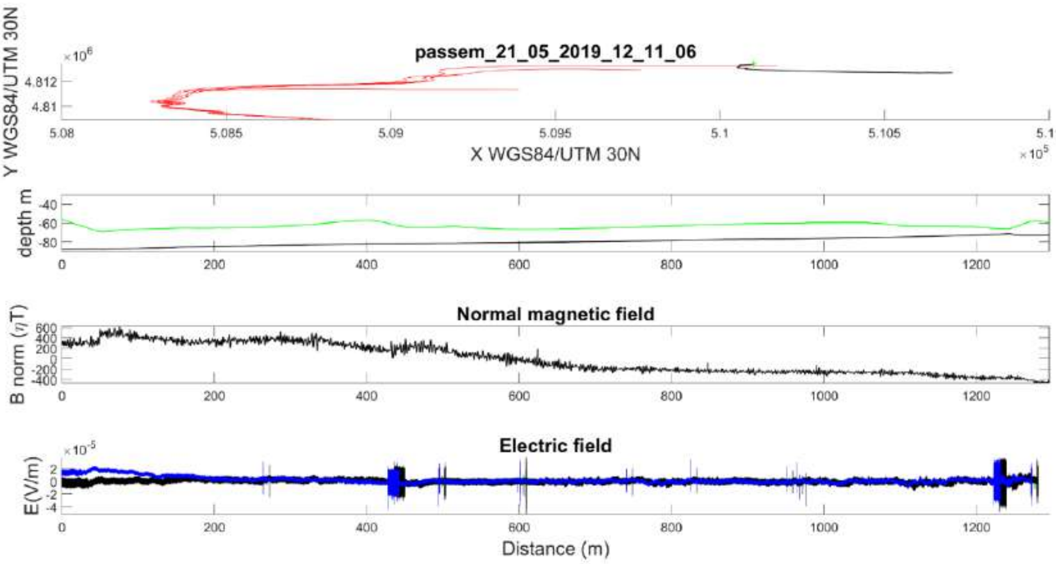

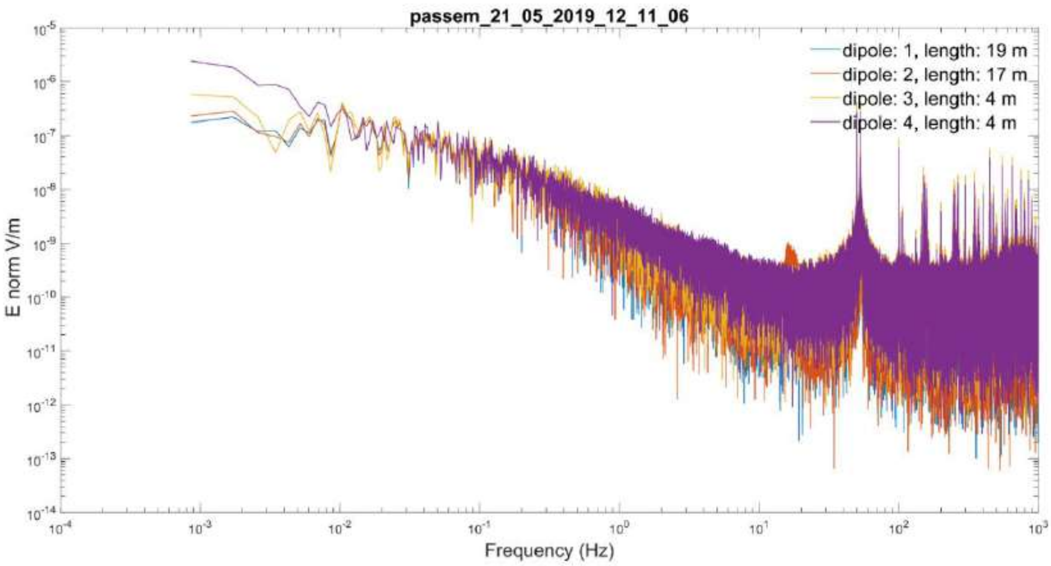

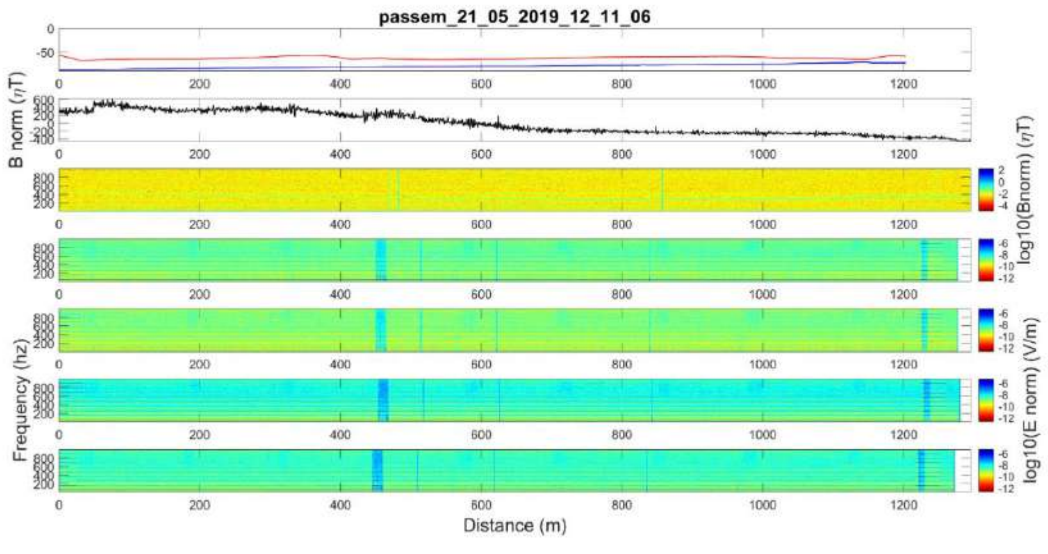

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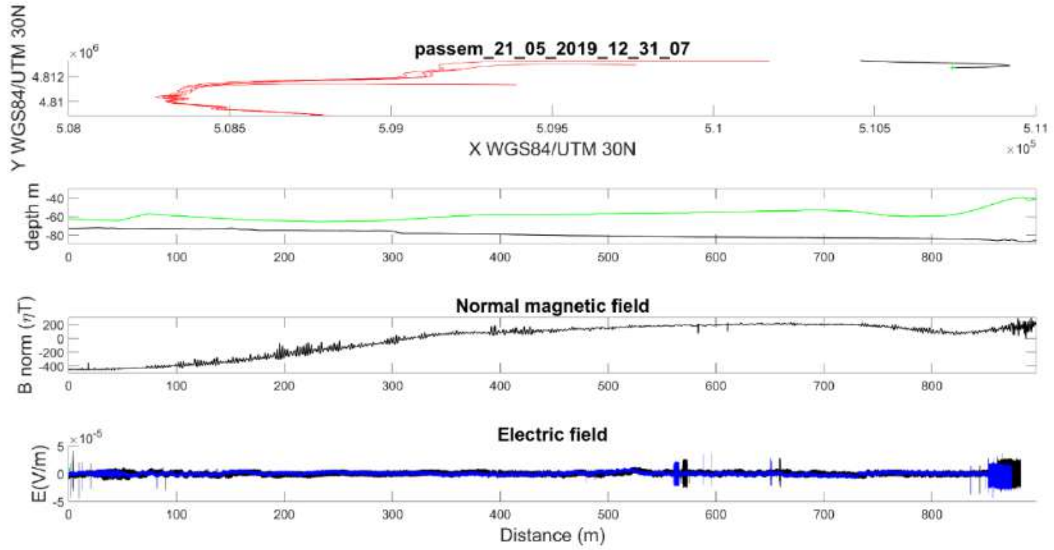

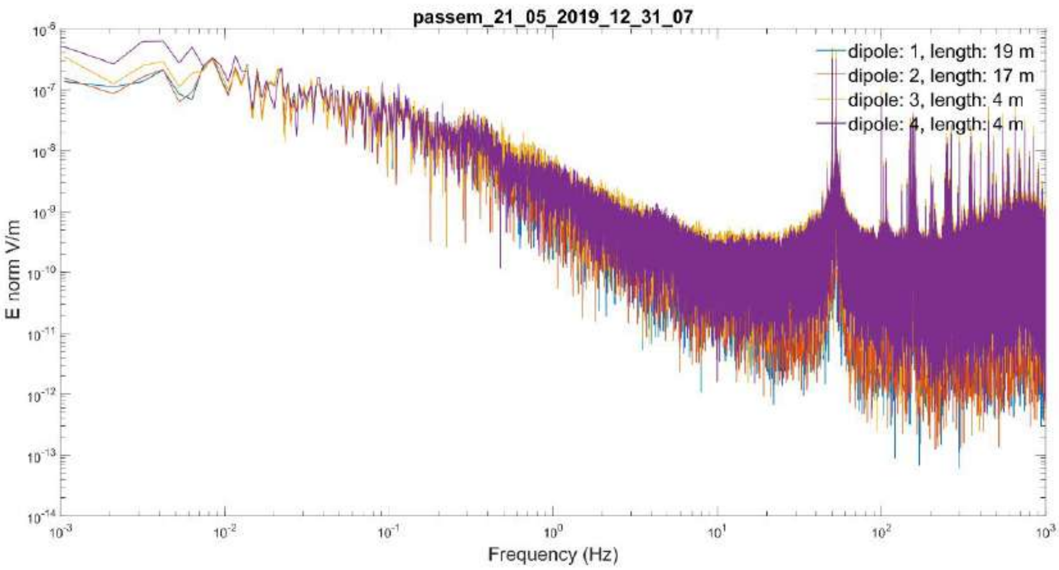

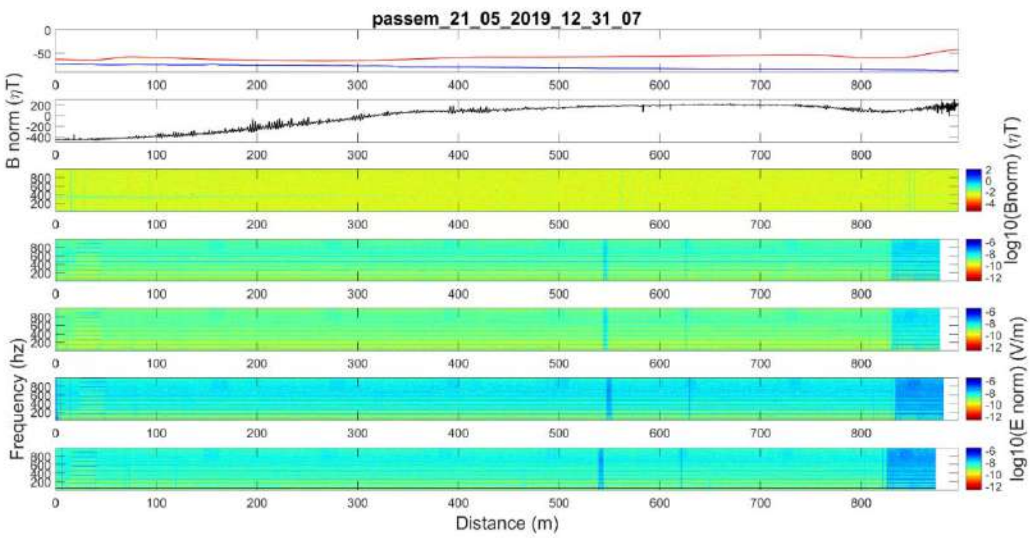

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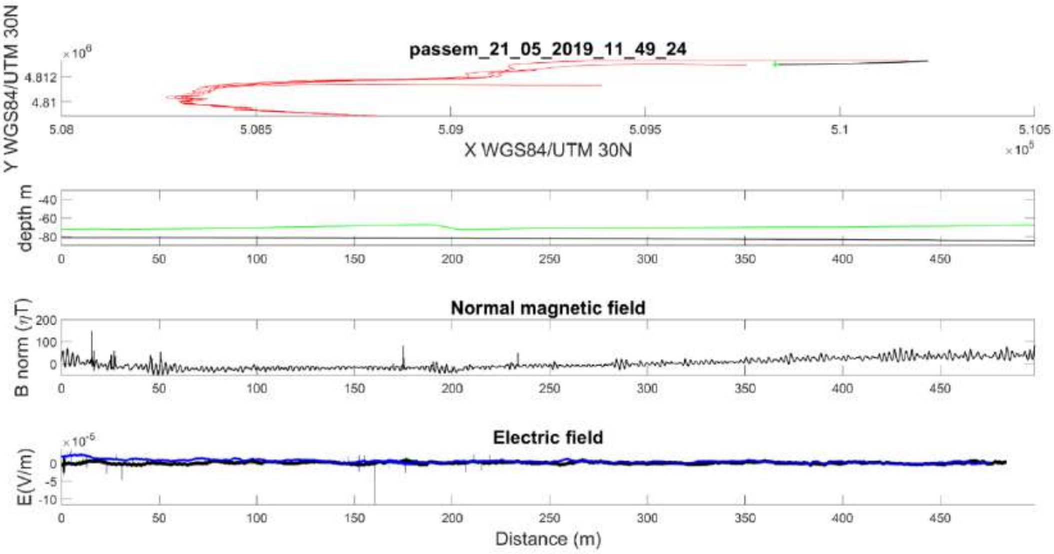

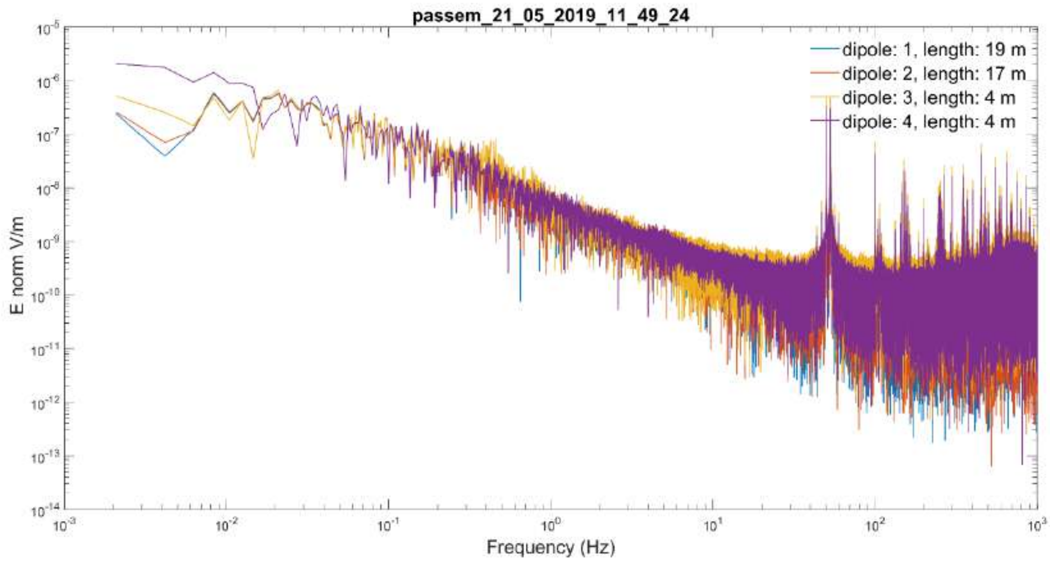

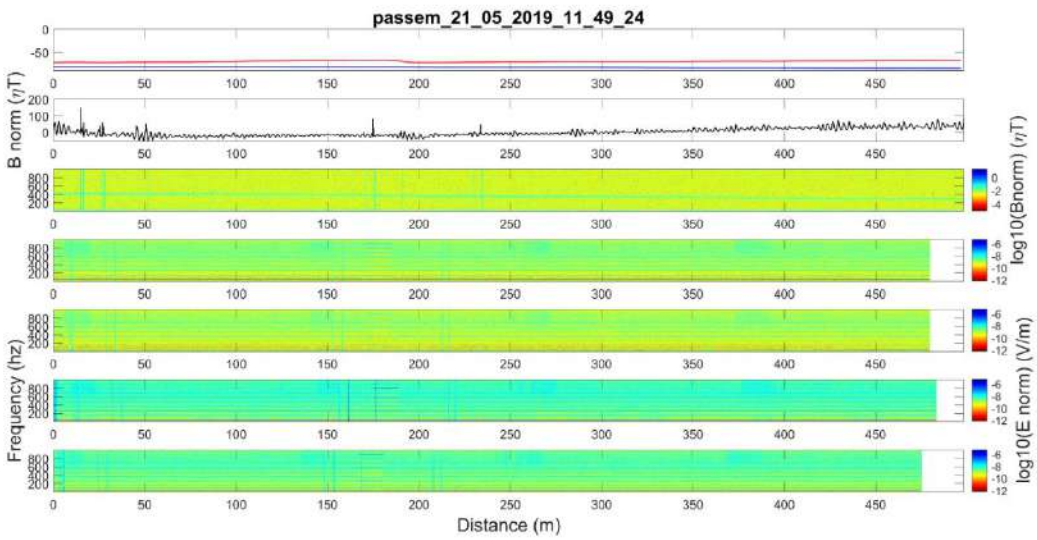

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