Scientific Report

concerning the implementation of the project

Assessment of the Climate Change effects on the WAve conditions in the Black Sea - ACCWA

in the period January - December 2019

In the last stage of the project implementation carried out in the period above mentioned, the specific objectives of the project were pursued:

1. Simulations with the wave climate system for the 'future' period (2071-2100), RCP8.5 scenario
2. Analysis of the results and the estimation of the changes in the Black Sea for both scenarios
3. Dissemination of the results

1. Simulations with the wave climate system for the 'future' period (2071-2100), RCP8.5 scenario

1.1 Wind speed analysis for the 'future' period (2071-2100)

For the period 'future' various analysis regarding the wind speed were performed over the entire basin and in several reference points. Thus, for each scenario the mean values for the entire period and also for seasons and months were computed. Differences between the projected mean values of the wind speed corresponding to each scenario and the historical values were calculated. As in the case of the 'near future', in the winter the higher differences are encountered (see Figure 1).

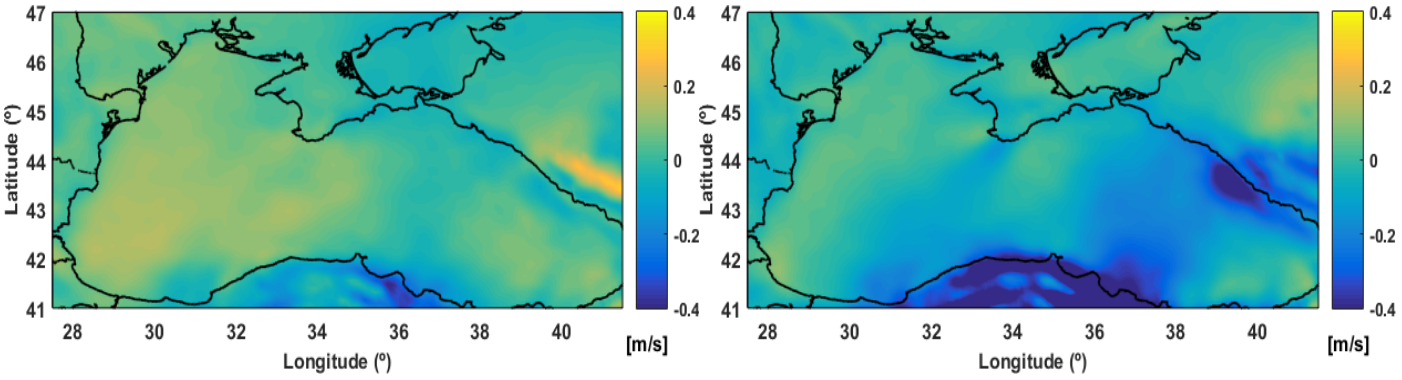


Figure 1. The modification of the wind speed in winter (DJF) represented as the difference between the mean computed for 'future' (2071-2010) and the 'control' period (1976-2005): RCP4.5 (left) și RCP8.5 (right).

Due to the economic development, both navigation and harbor operations in the Black Sea have been constantly increasing in the last decades. On the other hand, the climate changes have an important influence on the dynamics of the most relevant environmental parameters of the sea environment, represented by the wind speed and the significant wave height

In Figure 2 is presented the bathymetric map of the Black Sea basin corresponding to the SWAN simulations and the positions of the six points located near to the harbors Constanta (P1), Istanbul (P2), Samsun (P3), Batumi (P4), Novorossiysk (P5) and Odessa (P6).

The wind speeds at 10 m above the sea level (U10) are analysed in each reference point indicated in Figure 2 and for three periods considered: historical (1976-2005), near future (2021-2050) and distant future (2071-2100). The mean values of U10 are presented in Figures 3. A slightly increase of the near future mean values, followed by a small decrease in the distant future can be observed for U10. In the Black Sea basin a seasonal variability of the wind fields exists, as seen in Figure 4.

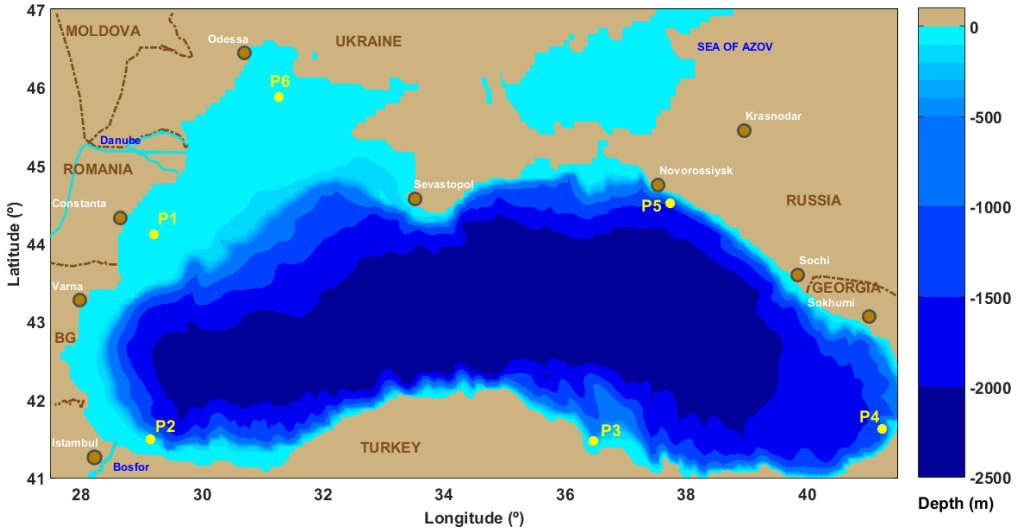


Figure 2. The bathymetric map of the Black Sea basin and the locations near to the harbors considered.

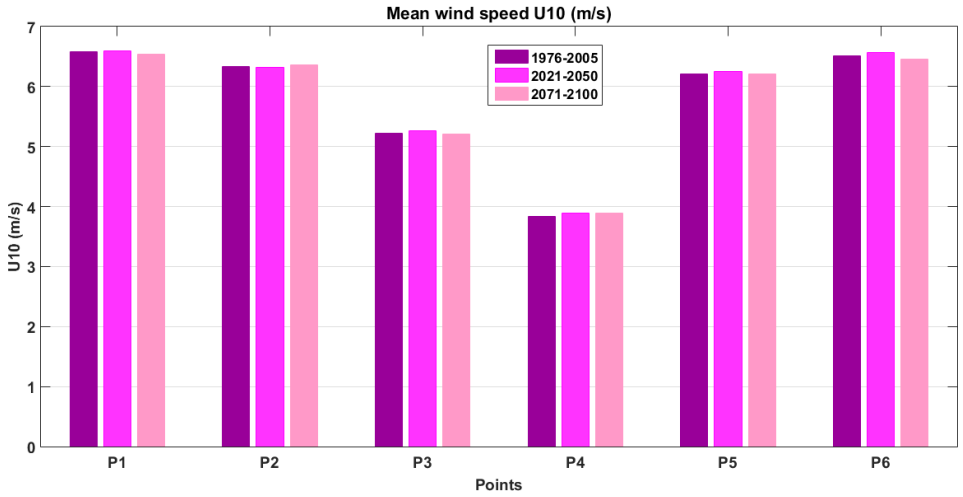


Figure 3. The U10 means in the points located near to the ports for all three periods considered.

The higher mean values are found in the winter time, while the lower in summer. The seasonal variability of U10 induced the same behaviour for the sea state conditions. Besides the mean values, the maximum values, the standard deviation, the 50th and 95th percentiles and the skewness were computed using their standard definitions. Table 1 presents some results.

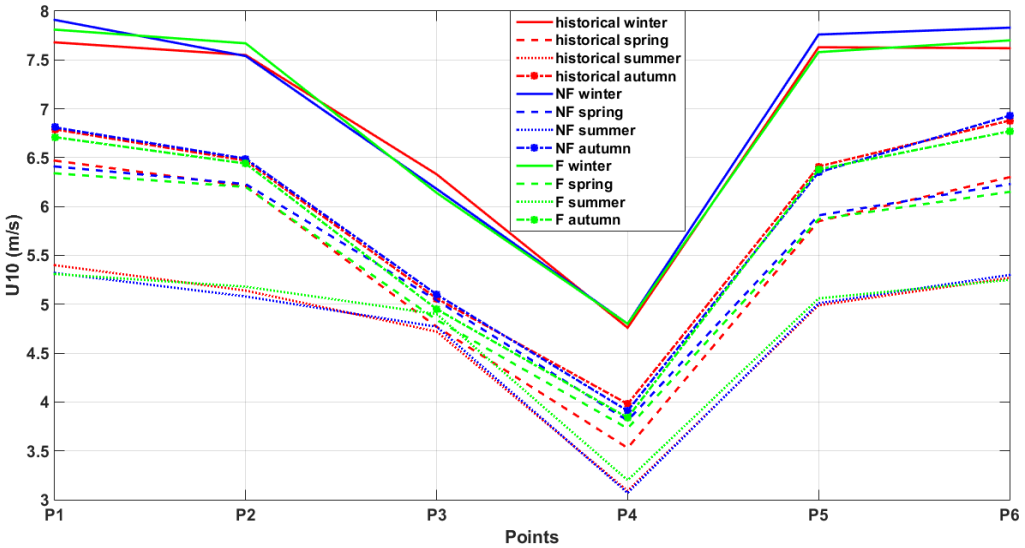
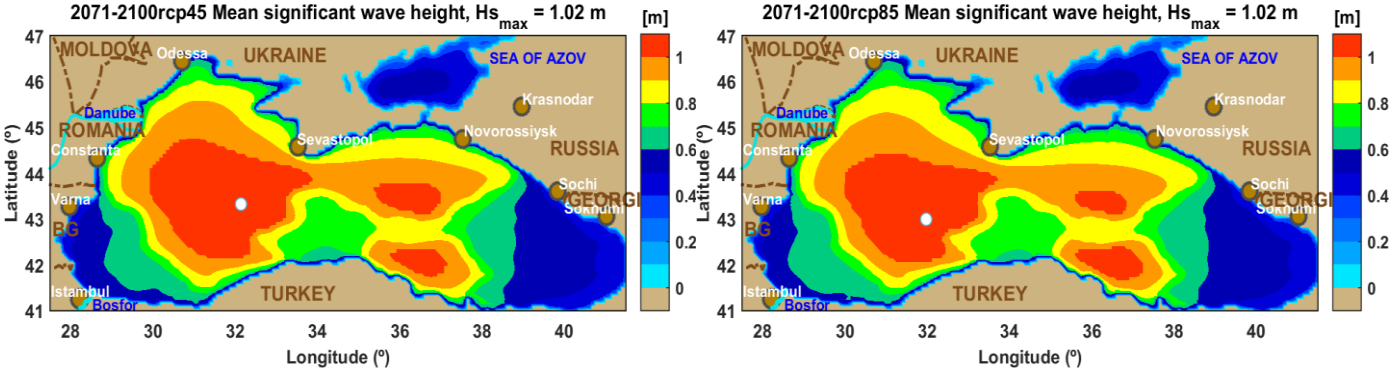


Figure 4. The U10 means in the points located near to the ports for the periods: historical, near future (NF) and distant future (F).

1.2 Simulations of the sea state conditions for the 'future' period (2071-2100), RCP8.5 scenario

In this stage of the project, the SWAN simulations for the period 'future' (2071-2100) were performed in the Black in order to obtain the projections of the sea state conditions in this basin. The wind fields to force the SWAN model are those simulated by RCA4 model under the RCP8.5 scenario. The same wave parameters as in the previous simulations were considered in SWAN simulations, and the results are obtained in all points of the calculation grid. The spatial resolution of the data is 0.08°, both in latitude and longitude, and at each grid point the data of the time series have a frequency of 3 hours.

Based on these data, a climate analysis was performed for the entire Black Sea basin by evaluating the average values for all data, and also for each season and month of the year. Figure 5 shows the spatial distributions of the mean values for Hs resulting from the SWAN simulations forced with the RCA4 wind fields corresponding to both scenarios considered. As in the case of the 'near future' period, both fields of Hs show a similar pattern, except that in this period the area with Hs values greater than 1 m is smaller in the case of scenario RCP8.5, compared to RCP4.5 .



(a) (b)

Figure 5. *Hs* fields, mean values resulted from the SWAN simulations forced with the RCA4 wind fields corresponding to RCP4.5 scenario (a) and RCP8.5 (b), 30-year period in 'future' (2071-2100).

2. Analysis of the results and the estimation of the changes in the Black Sea for both scenarios

For the same reference points considered in Figure 2, an analysis of the Hs values was performed for each 30-year period considered: historical or 'control' (1976-2005), near future (2021-2050) and future (2071-2100). The average values of Hs are shown in Figure 6. In general, an increase of the average values is observed in the near future, followed by a slight decrease in the distant future. However, there are cases where there is a clear decrease in the average value in the near future compared to historical data (point P6 near the port of Odessa), followed in the future by a slight increase.

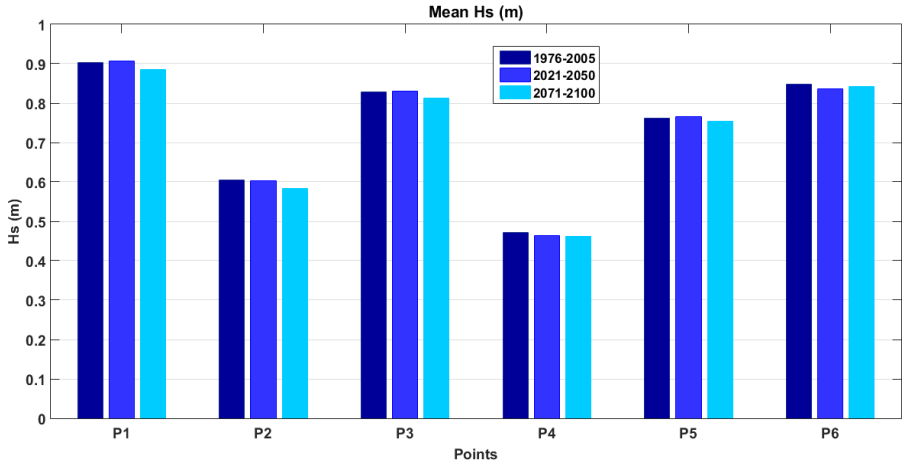


Figure 6. The Hs means in the six points considered for the periods: historical, near future and distant future.

As in the case of the wind speed (U10), various analyses were performed regarding the average values of Hs for each

season and month of the year. Besides the average and the maximum values, the standard deviation, the 50th and 95th percentiles, and the skewness using the standard definitions were calculated. Table 1 shows some of these results.

It can be also mentioned that, for the climatological analysis of the data (spatial analysis or at certain reference points) and for the visualization of the results the team members developed original scripts in the Matlab. This was absolutely necessary given the large amount of data that had to be analysed. The programs allow extracting information about the wind speed characteristics and wave parameters simulated by the SWAN model at any point in the Black Sea basin and to analyse the data. These scripts can be used for any geographical area on the globe.

Table 1. U10 and Hs statistics in the 6 reference points for RCP4.5 (h-historical, nf - df near and distant future).

Points	Wind									Wave								
	Std (m/s)			95th (m/s)			Skew			Std (m)			95th (m)			Skew		
	hist	nf	df	hist	nf	df	hist	nf	df	hist	nf	df	hist	nf	df	hist	nf	df
P1	3.10	3.16	3.10	12.11	12.24	11.91	0.44	0.46	0.45	0.65	0.66	0.63	2.19	2.20	2.09	1.78	1.81	1.88
P2	3.11	3.11	3.13	12.03	12.01	12.12	0.58	0.63	0.61	0.46	0.47	0.44	1.51	1.53	1.41	2.26	2.18	2.28
P3	2.87	2.88	2.84	10.50	10.49	10.45	0.66	0.63	0.64	0.67	0.66	0.63	2.13	2.12	2.05	2.12	2.12	2.08
P4	2.76	2.78	2.73	9.54	9.57	9.50	1.35	1.37	1.30	0.35	0.33	0.34	1.16	1.12	1.13	2.23	1.99	1.88
P5	3.25	3.26	3.22	12.22	12.26	12.23	0.66	0.65	0.67	0.69	0.70	0.70	2.17	2.19	2.20	2.16	2.26	2.25
P6	3.14	3.14	3.09	12.02	12.03	11.87	0.39	0.43	0.41	0.65	0.65	0.66	2.15	2.13	2.16	1.52	1.57	1.61

3. Dissemination of the results

3.1 Preparation of the scientific articles and oral presentations to disseminate the results

The team members disseminated the results obtained during this stage by publishing articles in journals, by participating in international and national conferences where oral presentations or posters were made.

- Publications in international journals WoS indexed (4)

1. Rusu, L., 2019. Evaluation of the near future wave energy resources in the Black Sea under two climate scenarios, *Renewable Energy* 142, 137-146. https://doi.org/10.1016/j.renene.2019.04.092 (**WoS Q1, IF=5.439**)
2. Rusu, E., 2019. A 30-year projection of the future wind energy resources in the coastal environment of the Black Sea, Renewable Energy 139, 228-234 https://doi.org/10.1016/j.renene.2019.02.082 (**WoS Q1, IF=5.439**)
3. Ganea, D., Mereuta, E., Rusu, E., 2019. An Evaluation of the Wind and Wave Dynamics along the European Coasts, *Journal of Marine Science and Engineering*, 7(2), 43 https://doi.org/10.3390/jmse7020043 (**WoS Q3, IF=1.732**)
4. Anton, I.A., Rusu, L., Anton, C., 2019. Nearshore Wave Dynamics at Mangalia Beach Simulated by Spectral Models, *Journal of Marine Science and Engineering*, 7(7), 206 https://doi.org/10.3390/jmse7070206 (**WoS Q3, IF=1.732**)

- Publications in the proceedings of international conferences (12)

1. Rata, V, Hobjila, A., Rusu, L., 2019. LNG to Power in the Romanian port of Constanta, Paper presented at 4th International Conference on Advances on Clean Energy Research (ICACER 2019), Coimbra, Portugal, April 5-7, 5 pag. **SCOPUS** https://doi.org/10.1051/e3sconf/201910301007

2. Rata, V. Rusu, L., 2019. Impact on air quality of the offshore-ships which are operating in the Black Sea maritime borders of Romania, *5th International Scientific Conference* SEA-CONF 2019, 17-18 May, Constanta, Romania https://www.anmb.ro/ro/conferinte/sea-conf/

3. Rata, V., Rusu, L, 2019. Air pollutant products resulting from port activity of ships in Constanta harbour, *XIX International Multidisciplinary Scientific GeoConference* SGEM 2019, Section Air Pollution and Climate Change, 28 June – 7 July, Albena, Bulgaria, pp. 821-828, **SCOPUS** https://www.sgem.org/index.php/elibrary?view=publication&task=show&id=5909

4. Hobjila, A., Rata, V., Rusu, L., 2019. "*Benefit of Combined Renewable Energy Farms in Western Black Sea*", XIX International Multidisciplinary Scientific GeoConference SGEM 2019, Section Renewable Energy Sources and Clean Technologies, 28 June – 7 July, Albena, Bulgaria, pp. 51-58, **SCOPUS** https://www.sgem.org/index.php/elibrary?view=publication&task=show&id=5812

5. Ganea, D., Rusu, L, Mereuta, E., 2019. Turbines Evaluation in the Nearshore and Offshore of the Black Sea, *XIX International Multidisciplinary Scientific GeoConference* SGEM 2019, Section Renewable Energy Sources and Clean Technologies, 28 June – 7 July, Albena, Bulgaria, pp. 291-297, **SCOPUS** https://www.sgem.org/index.php/elibrary?view=publication&task=show&id=5880

6. Ganea, D., Rusu, L, Mereuta, E., 2019. Joint Evaluation of the Future Wave and Wind Energy Close to Bulgaria and Romania Coastlines, *XIX International Multidisciplinary Scientific GeoConference* SGEM 2019, Section Renewable Energy Sources and Clean Technologies, 28 June – 7 July, Albena, Bulgaria, pp. 585-592, **SCOPUS** https://www.sgem.org/index.php/elibrary?view=publication&task=show&id=5843

7. Banescu, A., Georgescu, L, Rusu, E., Murariu, G., 2019. Analysis of the floods risk in the peripheral localities from the north of the Danube delta using GIS technologies, *XIX International Multidisciplinary Scientific GeoConference* SGEM 2019, Section Cartography and GIS, 28 June – 7 July, Albena, Bulgaria, pp. 723-731, **SCOPUS** https://www.sgem.org/index.php/elibrary?view=publication&task=show&id=5553

8. Banescu, A., Georgescu, L, Iticescu, C., Rusu, E., 2019. Analysis of the flood risk agriculturals enclosures from the Danube delta using 2D modeling. Case study Pardina enclosure, *XIX International Multidisciplinary Scientific GeoConference* SGEM 2019, Section Hydrology and Water Resources, pp. 33-40, **SCOPUS** https://www.sgem.org/index.php/elibrary?view=publication&task=show&id=5602

9. Rusu, L., 2019. An Analysis of the Expected Climate Change Effects in the Vicinity of the Main Harbors from the Black Sea, *16th International Conference on Environmental Science and Technology* (CEST2019), 4-7 September, Rodos, Grecia. https://cest2019.gnest.org/

10. Rusu, E., 2019. A Comparison between the Past and Future Expected Wind Conditions in the European Coastal Environment of the Mediterranean Sea, *16th International Conference on Environmental Science and Technology* (CEST2019), 4-7 September, Rodos, Grecia. https://cest2019.gnest.org/

11. Rusu, L., 2019. Data assimilation methods to improve the wave predictions in the Black Sea, *2nd International Workshop on Waves, Storm Surges and Coastal Hazards*, incorporating the *16th International Waves Workshop*, 10-15 November, Melbourne, Australia. https://conference.eng.unimelb.edu.au/waves/

12. Rusu, E., 2019. An analysis of the expected storm dynamics in the basin of the Black Sea, *2nd International Workshop on Waves, Storm Surges and Coastal Hazards*, incorporating the *16th International Waves Workshop*, 10-15 November, Melbourne, Australia. https://conference.eng.unimelb.edu.au/waves/

- Publications in the proceedings of national conferences (1)

1. Rata, V., Rusu, L., 2019. Offshore operations effects on the Romanian coast air quality, PP1.9., Conference: CSSD2019 -*Scientific Conference of the Doctoral Schools* - Perspectives and Challanges in Doctoral Research, June 2019, Galati, Romania, http://www.cssd-udjg.ugal.ro/index.php/abstracts-2019

Observation: at this moment a manuscript is under review at *Journal of Operational Oceanography*

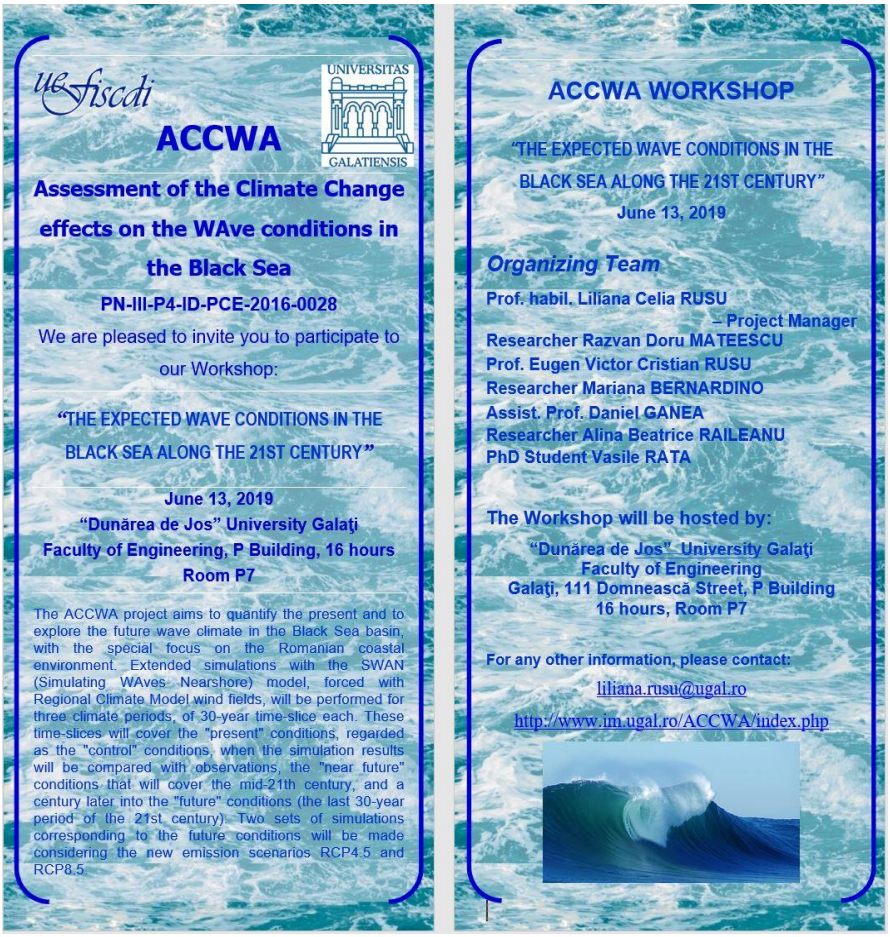
3.2 Updating of the project ACCWA site

The web page for the dissemination of the ACCWA project results http://193.231.148.42/accwa/index_en.php. was updated with the activities and the publications corresponding to this second stage of the project and it will be periodically updated also from now on.

3.3 Providing support for the young researchers

In the project team are included young researches (PhD students and Post-doc). Also, in the framework of the ACCWA project have been made and published an important number of scientific works in which young researchers are included.

The team members of the ACCWA project organized also a workshop with the topic „The expected wave conditions in the Black Sea along the 21st century”. The flyer is presented below.



The above mentioned workshop was held in 13 June 2019, it had 20 participants and it was associated with a major scientific event in Galati University, which was the 7th Scientific Conference of the Doctoral Schools, http://www.cssd-udjg.ugal.ro/index.php/news having more than 300 participants.

4. Conclusions

We can conclude that we succeeded to achieve all the objectives proposed for the second stage of the ACCWA project. All the activities included in the plan of achievement were accomplished.

The synthesis of the dissemination through scientific publications for each stage and publication category is presented bellow in Table 2. It has to be highlighted that in this table are indicated only the works which have been already published.

Table 2 Synthesis of the publication results

Stage / Publications	Stage I	Stage II	Stage III	Total
WoS journals	2	3	4	**9**
BDI Journals	3	2	-	**5**
International conferences	2	11	12	**25**
National conferences	-	1	1	**2**
Total	**7**	**17**	**17**	**41**

Budget 2019: 318 455 Lei

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