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Implementation of a joint modeling system to provide support in the prediction of the extreme environmental events in the Black Sea

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Objective: To implement and validate in the Black Sea basin a joint modeling system based on numerical models for waves and currents. This system would be used to support harbor operations and to provide support in the case of environmental alerts.

Contents:

1. Environmental matrix in the Black Sea as reflected by in situ measurements and remotely sensed data
2. Development of a joint modeling system based on numerical models for the Black Sea basin
3. Environmental support for the harbor operations
4. Modeling the wave current interactions in the Black Sea
5. Application of the system in case of an environmental alert
6. Final considerations

1. Environmental matrix in the Black Sea as reflected by in situ measurements and remotely sensed data

In the last years satellite data became available on various internet sites. An altimeter node gives near real time multi-mission merged non interpolated values of the significant wave height, wind and current speed. In order to provide a more complete picture concerning the characteristics and dynamics of the environmental matrix in the Black Sea as they are reflected by recent remotely sensed data, some synthetic results will be presented bellow for the period 2005-2010.

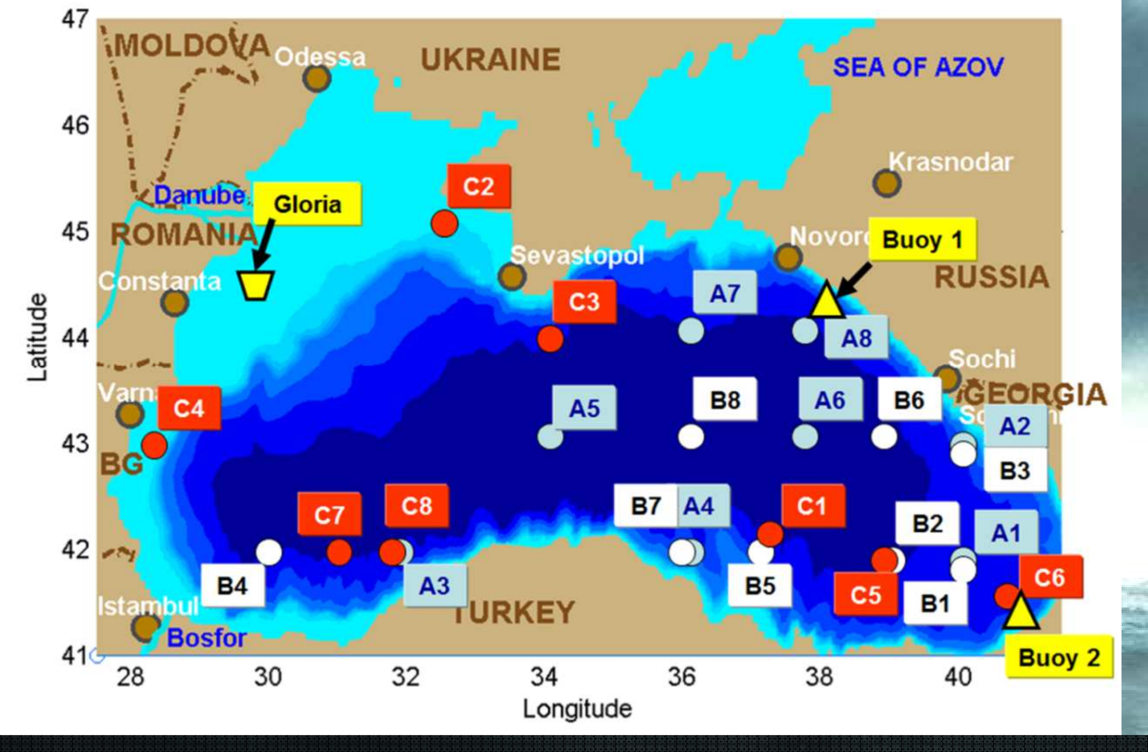


Figure 1. Location of the reference points considered for the analysis of the environmental parameters in the Black Sea. A - significant wave height; B – wind speed; C – current velocity.

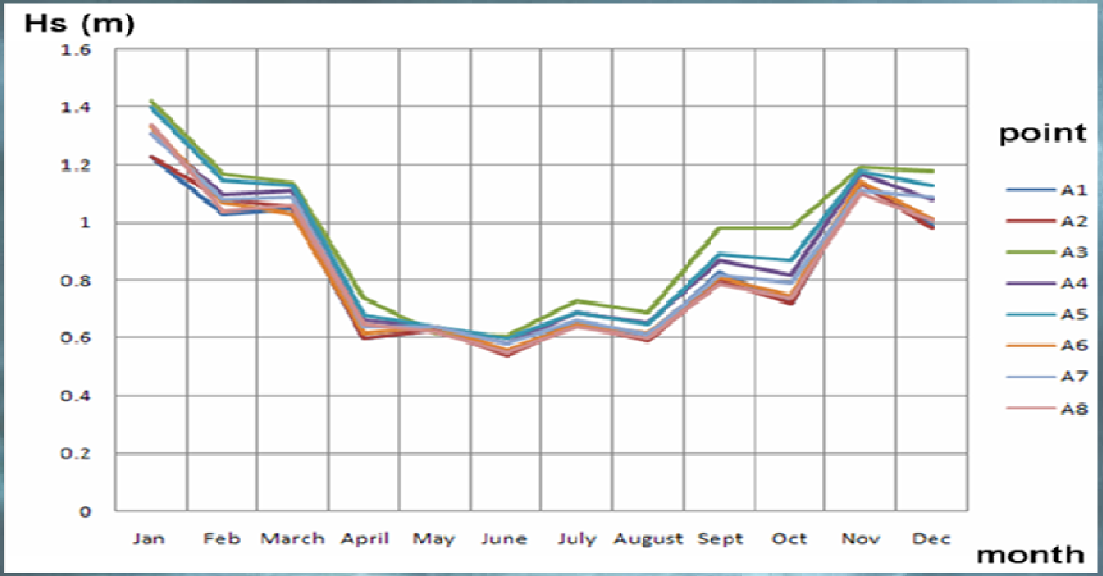


Figure 2

Table 1

Nr of data points =1500	A1	A2	A3	A4	A5	A6	A7	A8
Minimum	0	0	0.2	0.2	0.2	0	0.2	0.2
Maximum	5.4	5.2	5.1	5.1	5.1	5.1	5.1	5.1
Mean	0.85	0.85	0.97	0.91	0.94	0.87	0.89	0.86
Median	0.7	0.7	0.8	0.8	0.8	0.7	0.8	0.7
Mode	0.6	0.5	0.6	0.5	0.5	0.5	0.5	0.5
Std dev	0.54	0.53	0.55	0.50	0.50	0.50	0.48	0.48
Skewness	2.47	2.33	1.84	1.92	1.79	2.02	1.85	1.95
Kurtosis	11.75	10.41	5.58	7.25	6.12	8.17	6.90	7.82

Figure 2 and Table 1. Monthly averaged values for the significant wave heights (Hs) in 8 selected points and the overall statistics of those points, for the period 2005-2010

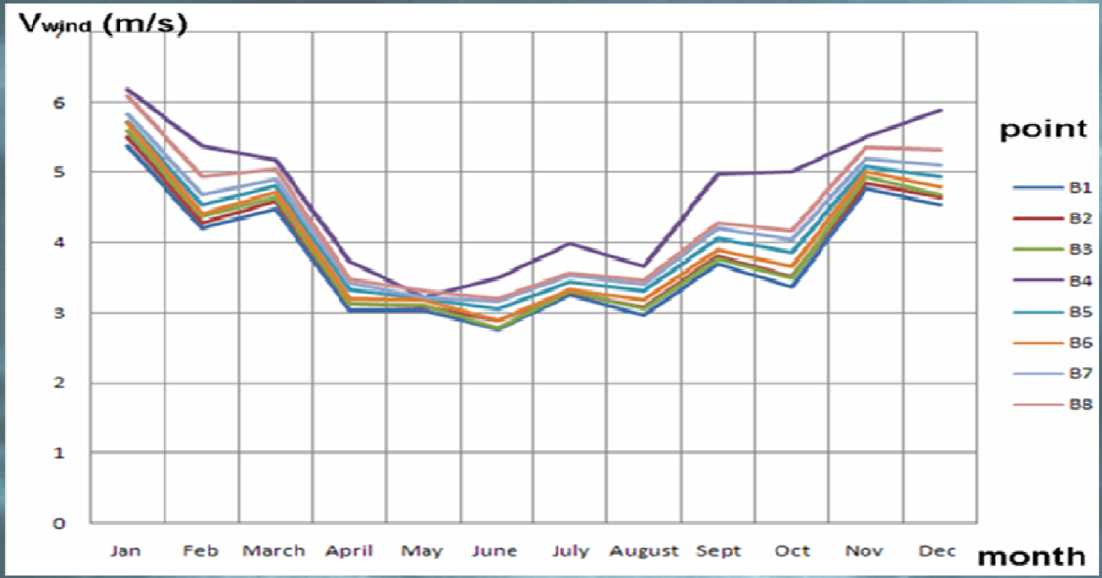


Figure 3

Table 2

Nr of data points =1500	B1	B2	B3	B4	B5	B6	B7	B8
Minimum	0.2	0.3	0.3	0.4	0.7	0.3	0.7	0.8
Maximum	16.4	16.4	16.4	16.3	16.3	16.3	16.2	16.2
Mean	3.86	3.96	3.97	4.76	4.18	4.07	4.28	4.42
Median	3.4	3.5	3.5	4.3	3.8	3.6	3.9	4
Mode	2.7	3.4	3.3	3.4	3.2	3.4	3.3	3.7
Std dev	2.27	2.22	2.25	2.37	2.12	2.20	2.09	2.11
Skewness	1.27	1.20	1.18	1.03	1.05	1.08	1.03	1.00
Kurtosis	2.55	2.20	2.10	1.22	1.50	1.66	1.42	1.28

Figure 3 and Table 2. Monthly averaged values for the wind speed V_{wind} (m/s) in 8 selected points and the overall statistics for those points, for the period 2005-2010

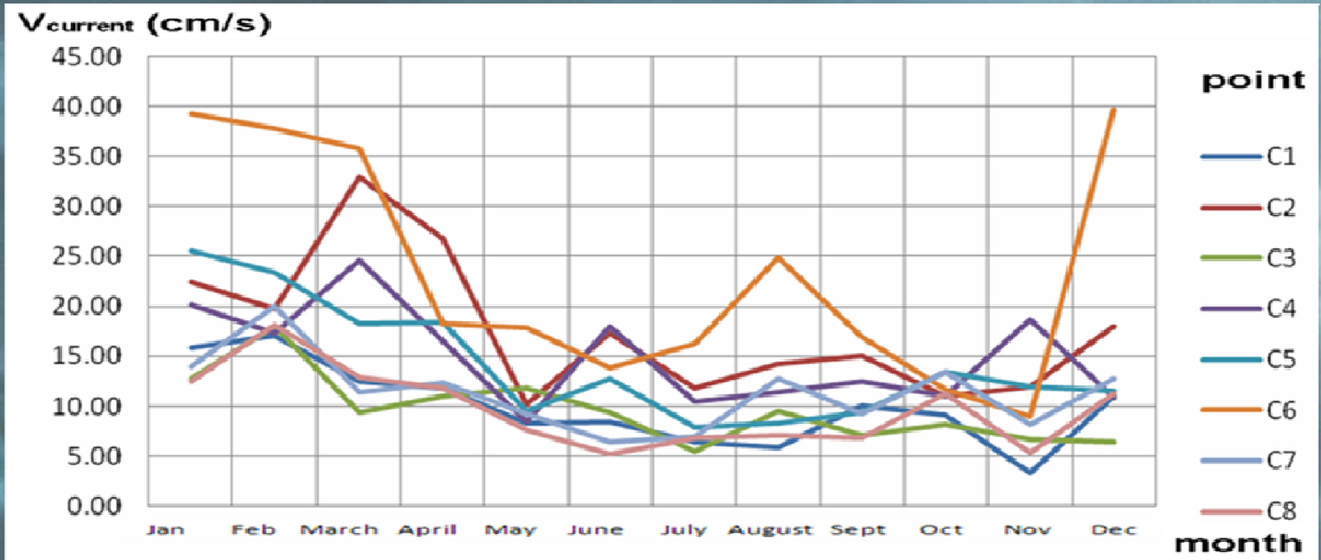


Figure 4

Table 3

Nr of data points =1500	C1	C2	C3	C4	C5	C6	C7	C8
Minimum	3.25	10.22	5.49	8.39	7.87	8.91	6.42	5.17
Maximum	17.04	33.00	17.97	24.58	25.55	39.74	19.96	18
Mean	9.95	17.66	9.65	14.96	14.19	23.42	11.36	9.68
Median	9.56	16.21	9.36	14.47	12.35	18.04	11.81	9.41
St Dev	4.01	6.94	3.44	4.92	5.91	11.60	3.72	3.87
Skewness	0.28	1.09	1.26	0.50	0.89	0.47	0.87	0.76
Kurtosis	-0.21	0.73	2.12	-0.62	-0.36	-1.59	1.43	0.28

Figure 4 and Table 3. Monthly averaged values for current velocity, $V_{current}$ (cm/s) in eight reference points for the period 2005-2010 and the overall statistics of the 8 reference points

2. Development of a joint modeling system based on numerical models for the Black Sea Basin

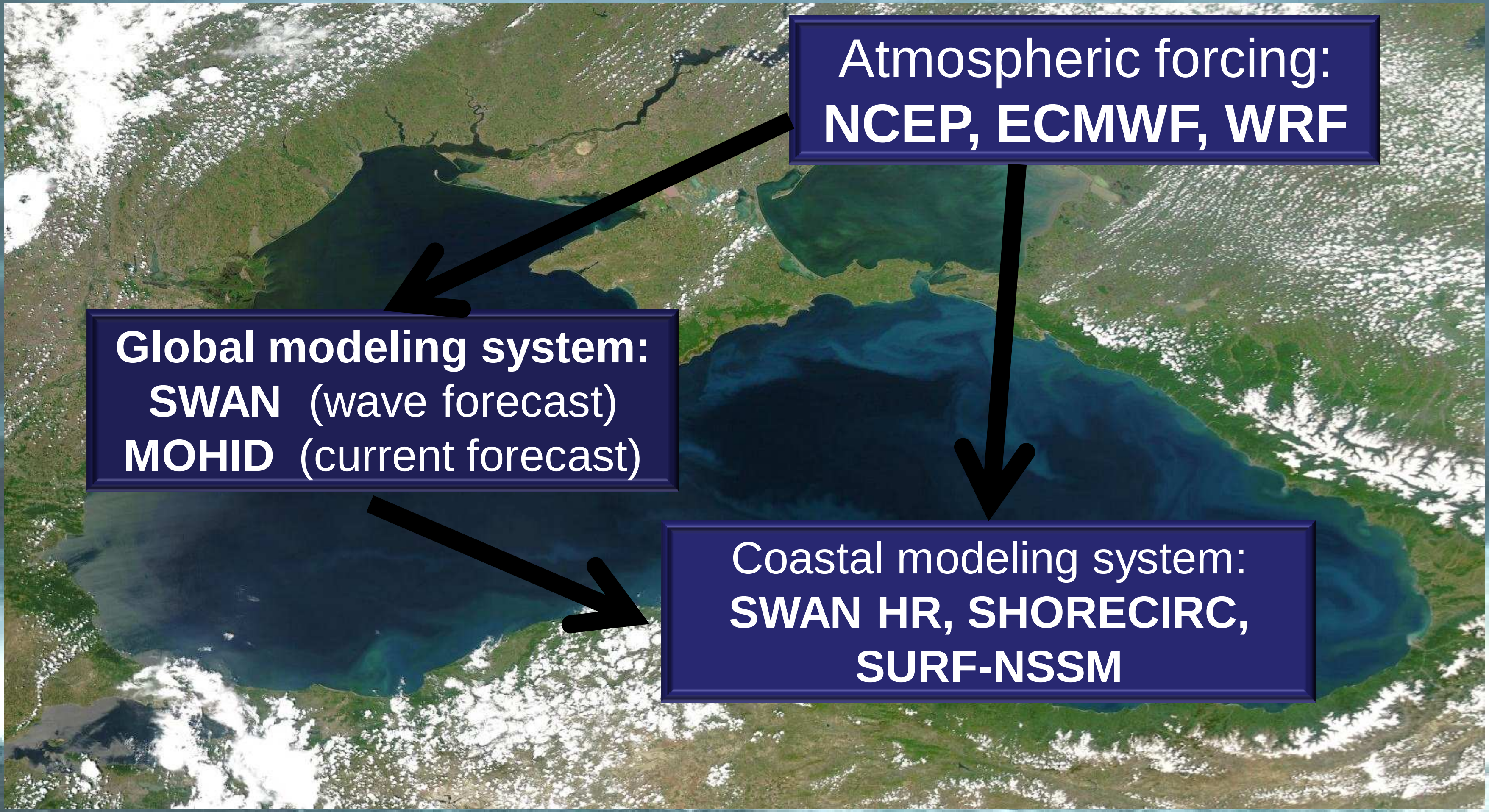


Figure 5. The structure of the proposed system. Wind fields are provided by NCEP, ECMWF or WRF. The offshore module consists of the models SWAN for wave generation and MOHID for currents that are runned in an interative manner. For the nearshore module high resolution SWAN computational domains are considered together with the SURF-NSSM system.

SWAN (Simulating WAves Nearshore)

The numerical wave model SWAN is a model of the Delft university of Technology. This SWAN model is a third-generation stand-alone (phase-averaged) wave model for the simulation of waves in waters of deep, intermediate and finite depth. It is also suitable for use as a wave hindcast model.

Atmospheric forcing:
NCEP, ECMWF, WRF

Global modeling system:
SWAN (wave forecast)
MOHID (current forecast)

Coastal modeling system:
SWAN HR, SHORECIRC, SURF-NSSM

MOHID (Hydrodynamic Model)

MOHID is a three-dimensional water modeling system developed by MARETEC at the Technical University of Lisbon. This system allows the adoption of an integrated modeling philosophy of different scales (allowing the use of nested models) and systems (estuaries and watersheds), due to the adoption of an object oriented programming philosophy.

NSSM (Navy Standard Surf Model)

NSSM is an easily operable computational system for simulation of waves and longshore currents. The system is composed of a MATLAB GUI in the foreground, which directs the integration of the SWAN shallow water wave model with a 1D surf model in the background.

3. Environmental support for harbor operations

A system based on the SWAN model was developed by nesting in the main generation domain of subsequent areas with higher resolution. An average to high energetic situation is illustrated in Figure 6 and presents the system focusing towards Constanta harbor for the time frame 2002/03/11/h13.

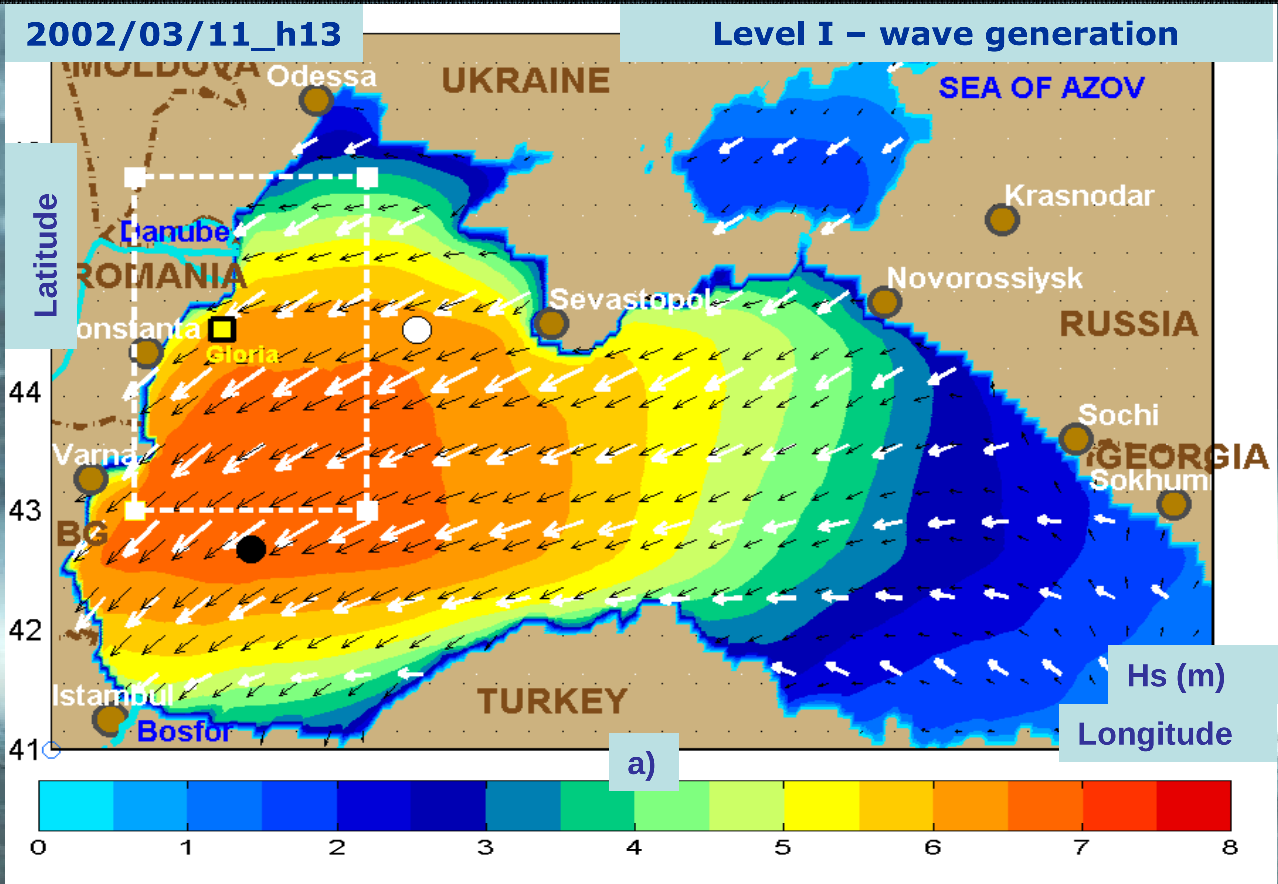
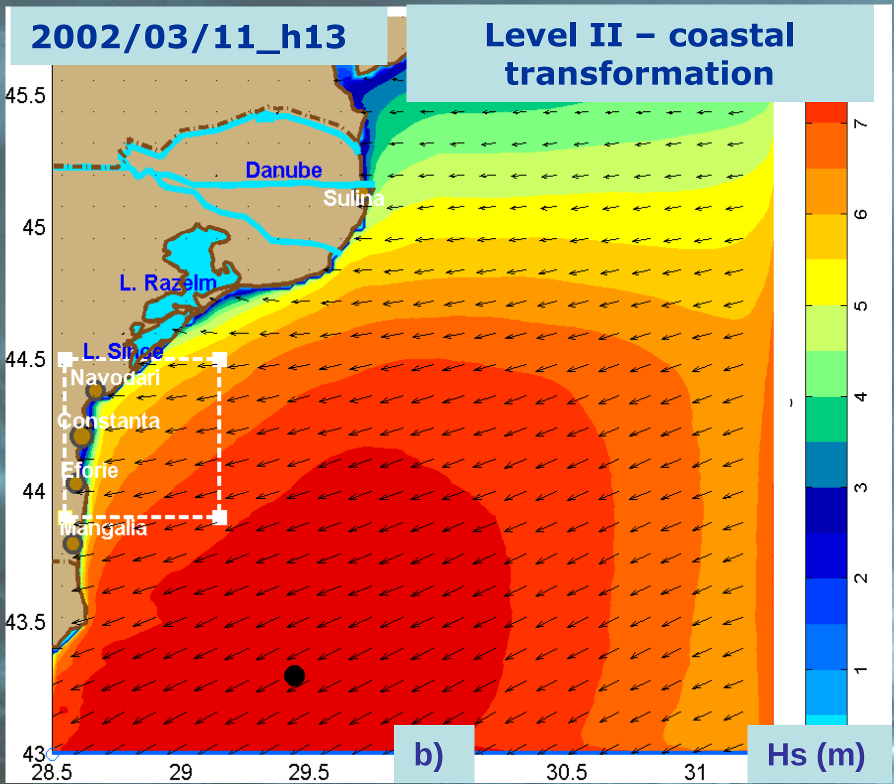
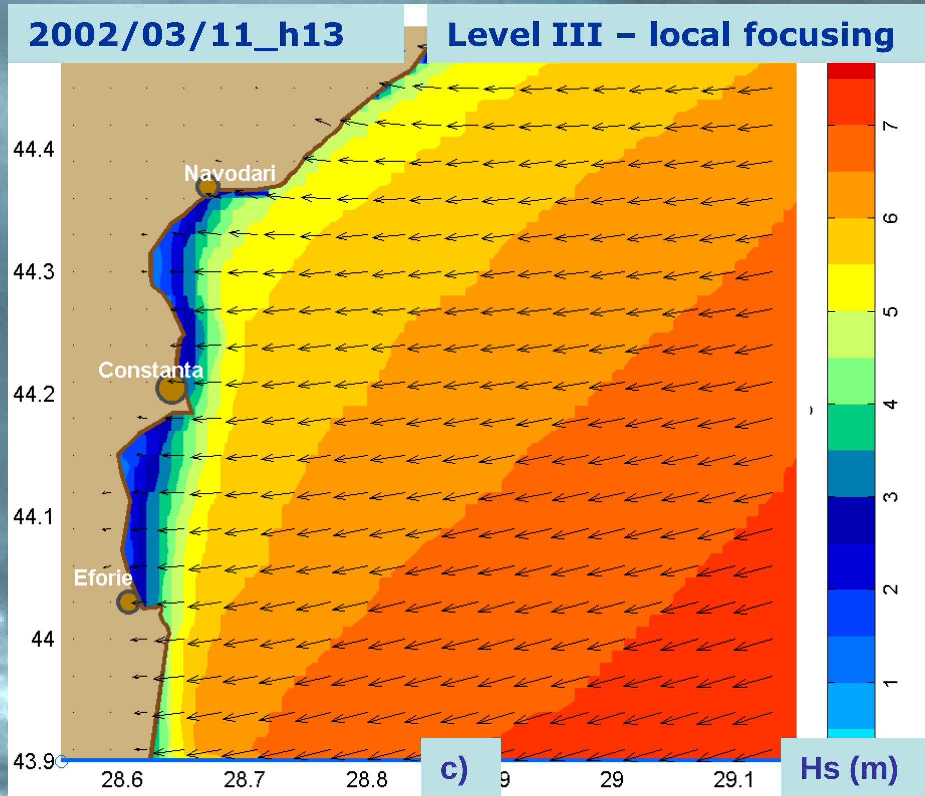


Figure 6a. The entire basin of the sea, in background is being presented the significant wave height scalar fields, and in foreground the wave vectors (black arrows) and the wind vectors (white arrows)





Figures 6b and 6c illustrate the coastal and local levels presenting in background the significant wave height scalar fields and in foreground the wave vectors (black arrows). Figure 6d presents level four of focalization, which is currently under implementation.

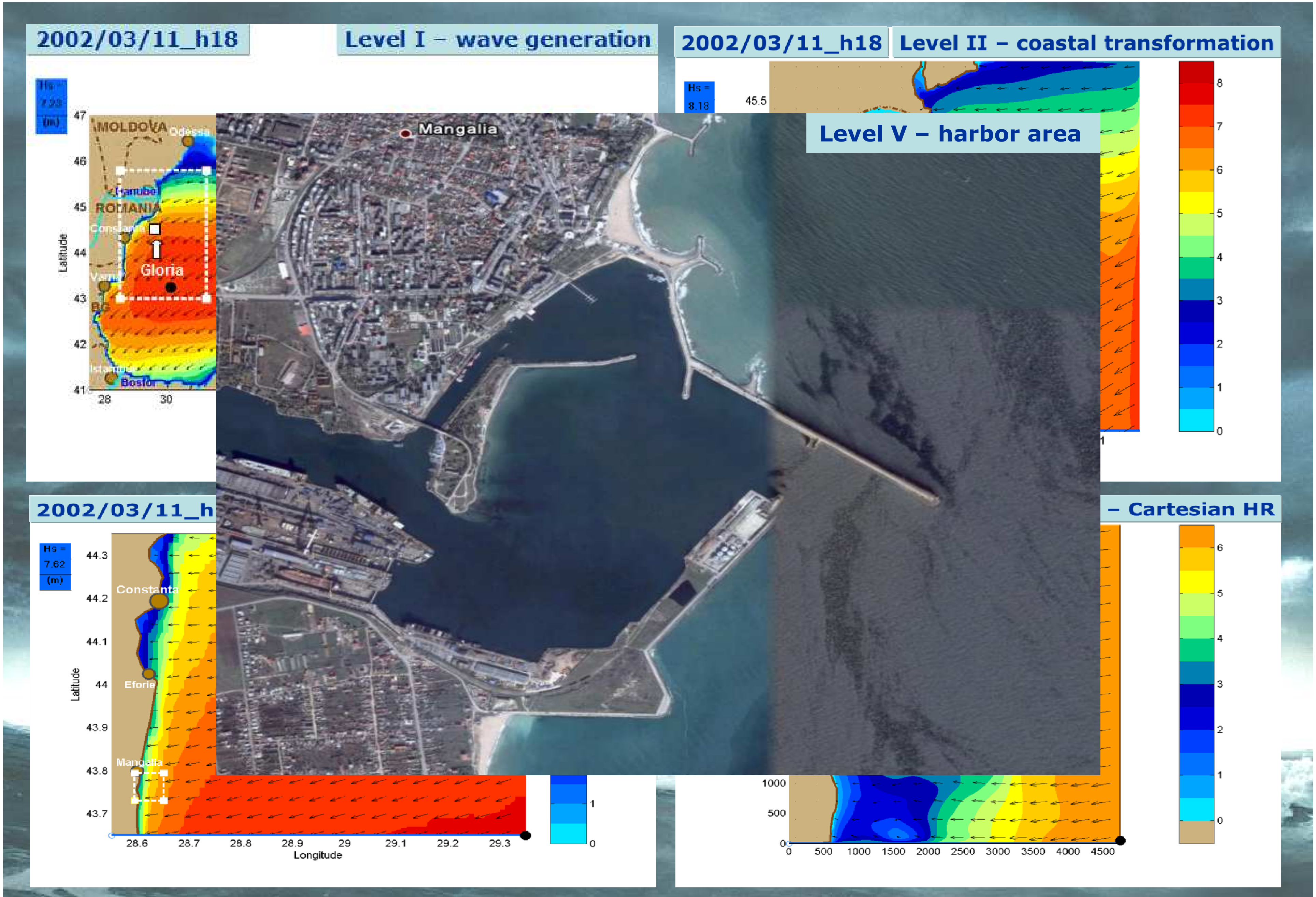


Figure 7. System focusing towards Mangalia harbor for the time frame 2002/03/11/h13.

4. Modeling the wave current interactions in the Black Sea

MOHID modeling system was implemented in the Black Sea basin and the process of validation using remotely sensed data is still ongoing. Presently a coupled modeling system based on SWAN for assessing the wave conditions and MOHID for the sea circulation is under development. Such a system can be used in an iterative manner and in this way the interactions between waves and currents can be also evaluated. Fig. 8 illustrates some results concerning the current fields resulted from the simulations with MOHID modeling system in the Black Sea.

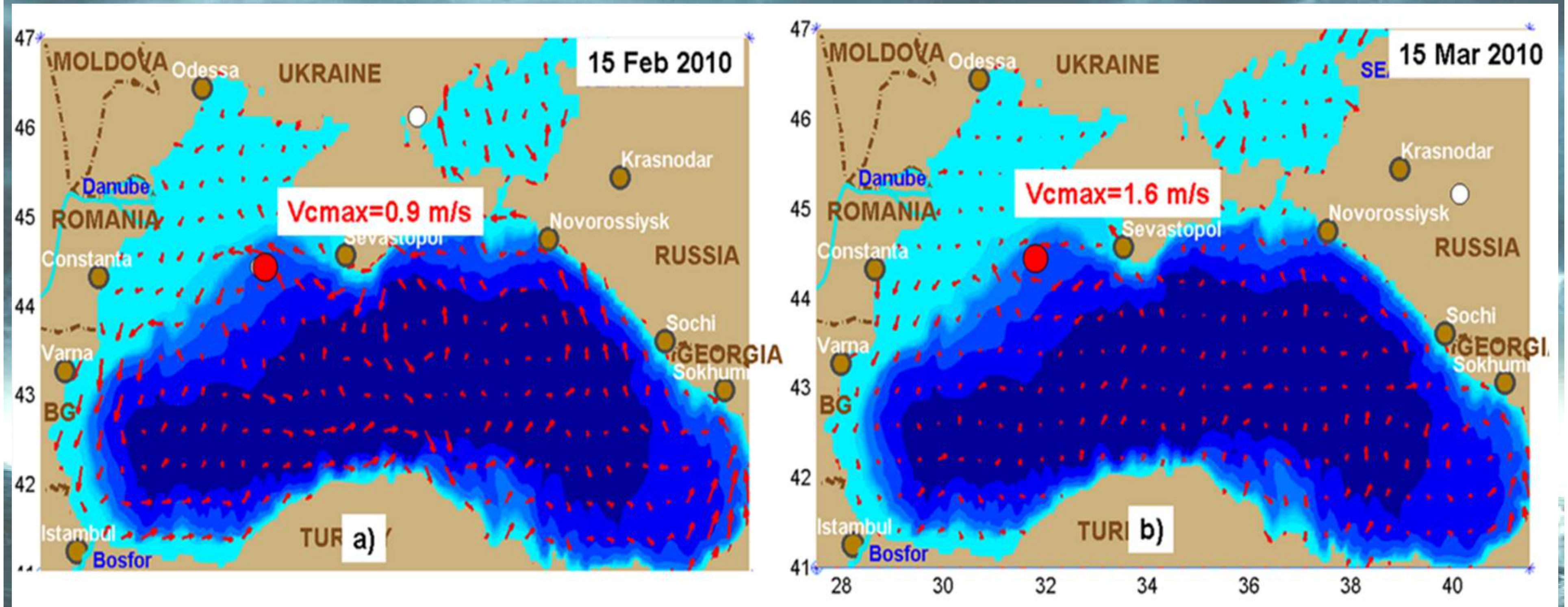


Figure 8. Simulation with MOHID modeling system in the Black Sea. With red arrows, average current fields computed for a ten-day period before the time frame defined. a) Time frame 15 February 2010; b) Time frame 15 March 2010.

A hybrid framework integrating SWAN with SURF-NSSM was also developed. The NSSM input is generated by interpolation directly from the SWAN output frame.

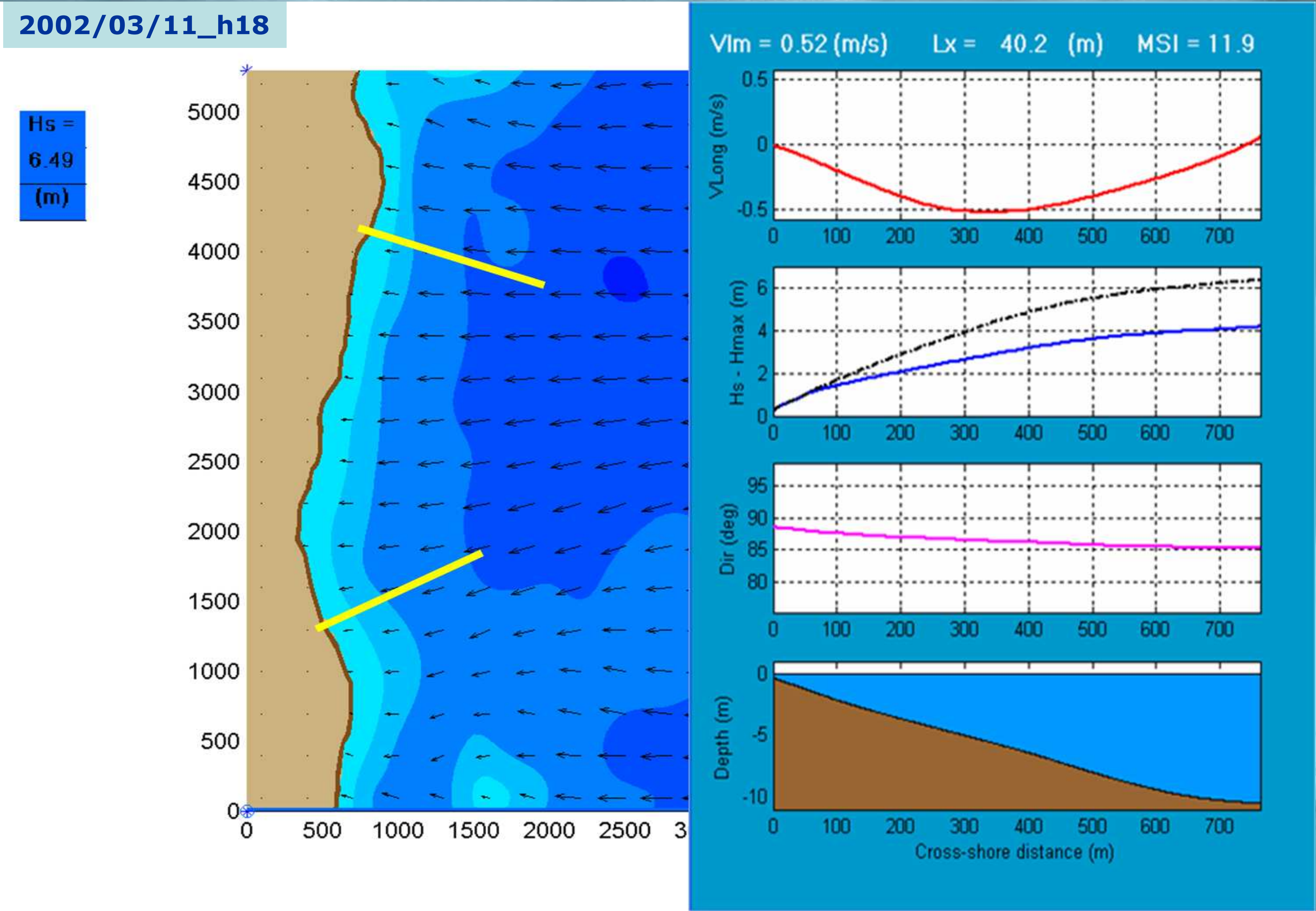
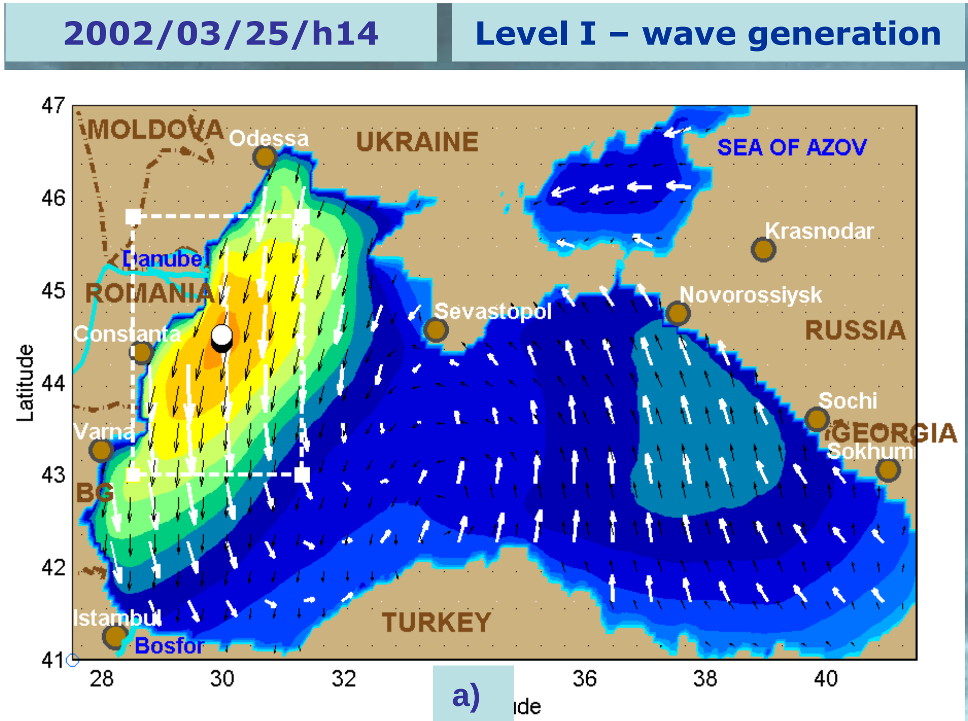
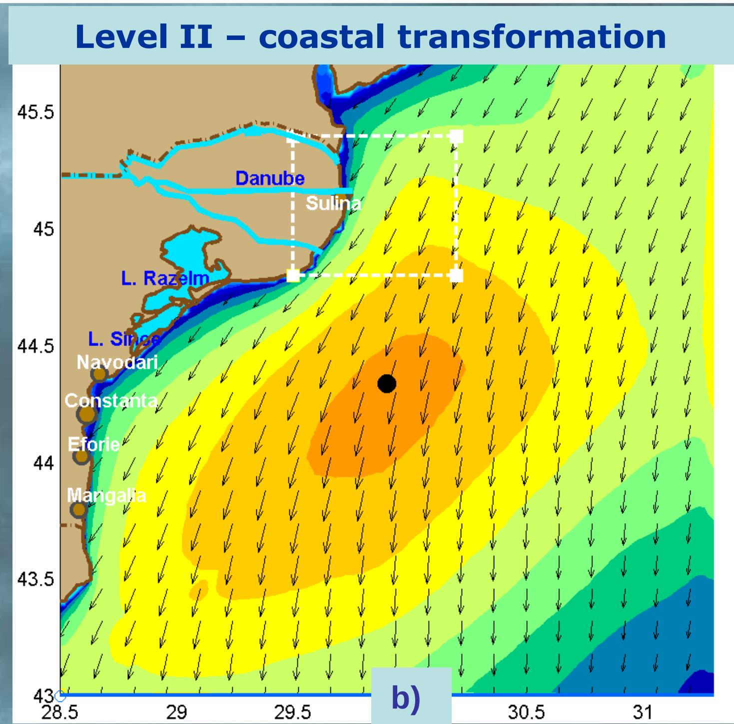


Figure 9. 1D simulation for nearshore circulation using NSSM model





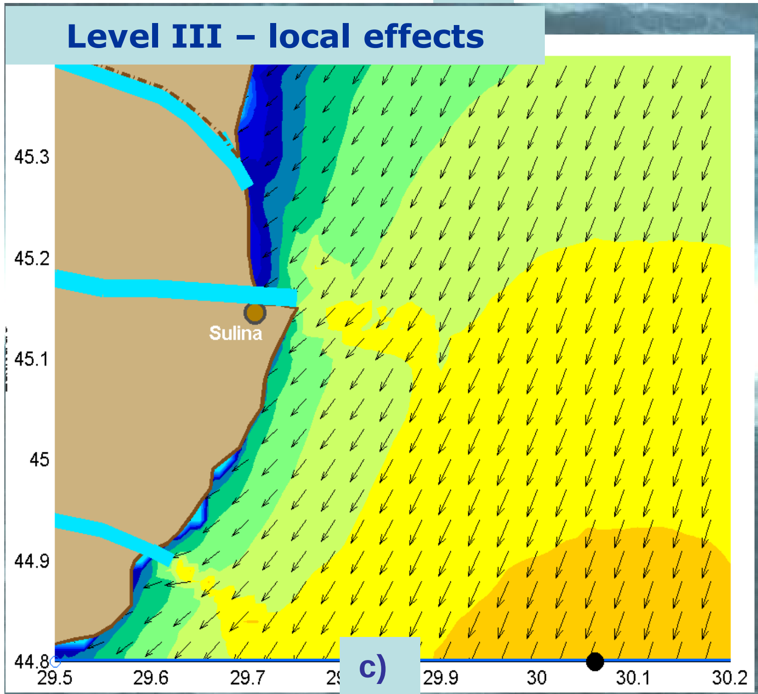


Figure 10. SWAN simulation focusing towards the Danube mouths. a) - the entire basin of the sea, in background being presented the significant wave height scalar fields, and in foreground the wave vectors (black arrows) and the wind vectors (white arrows). Figures 10b and 10c, illustrate the coastal and local levels presenting in background the significant wave height scalar fields and in foreground the wave vectors (black arrows), at the entrance in the Danube Delta.

5. Application of the system in the case of an environmental alert

In this section the propagation of the oil spill towards the coast due a hypothetic accident at the Gloria drilling platform will be evaluated using the above presented prediction system. The environmental conditions considered for this scenario were the real conditions corresponding to the time frame 2002/03/11/h18, which was a typical storm that affected the western side of the Black Sea basin and represents the zero moment of the accident, just six hours after the case illustrated in Figure 6. A model for a quick estimation of the oil propagation on the offshore sea surface was implemented and connected to the SWAN model.

Figure 11 and 12 presents wave, wind and Stokes drift driving the oil spill towards the Romanian coast. a) Time frame 2002/03/11/h18, (peak of the storm considered the zero moment of the hypothetic accident); b) Time frame 2002/03/12/h06; c) Time frame 2002/03/13/h00 (predicted coastal impact of the oil spill).

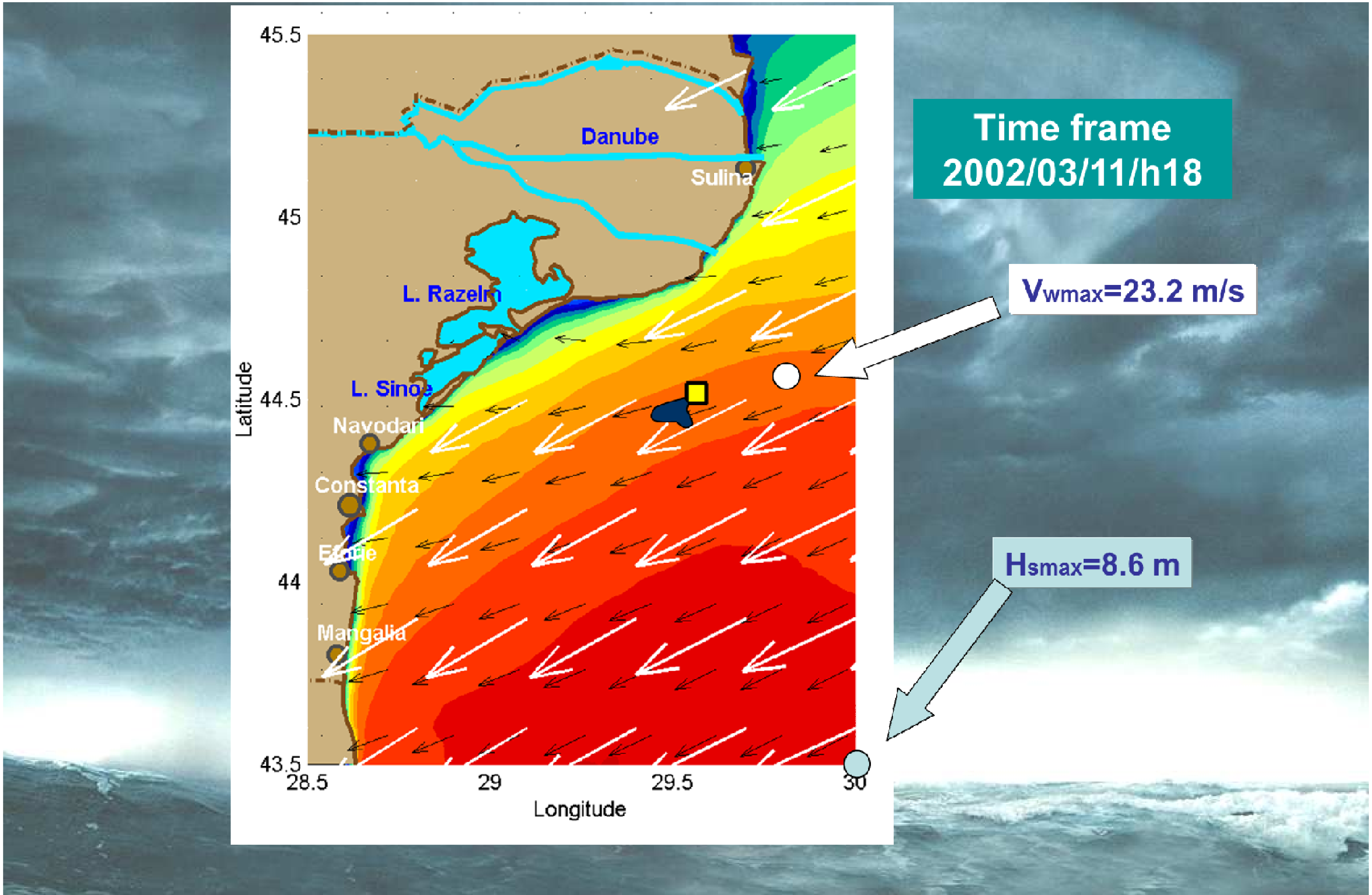


Figure 11. Wave and wind driving the oil spill towards the Romanian coast. a) Time frame 2002/03/11/h18, (peak of the storm considered the zero moment of the hypothetic accident)

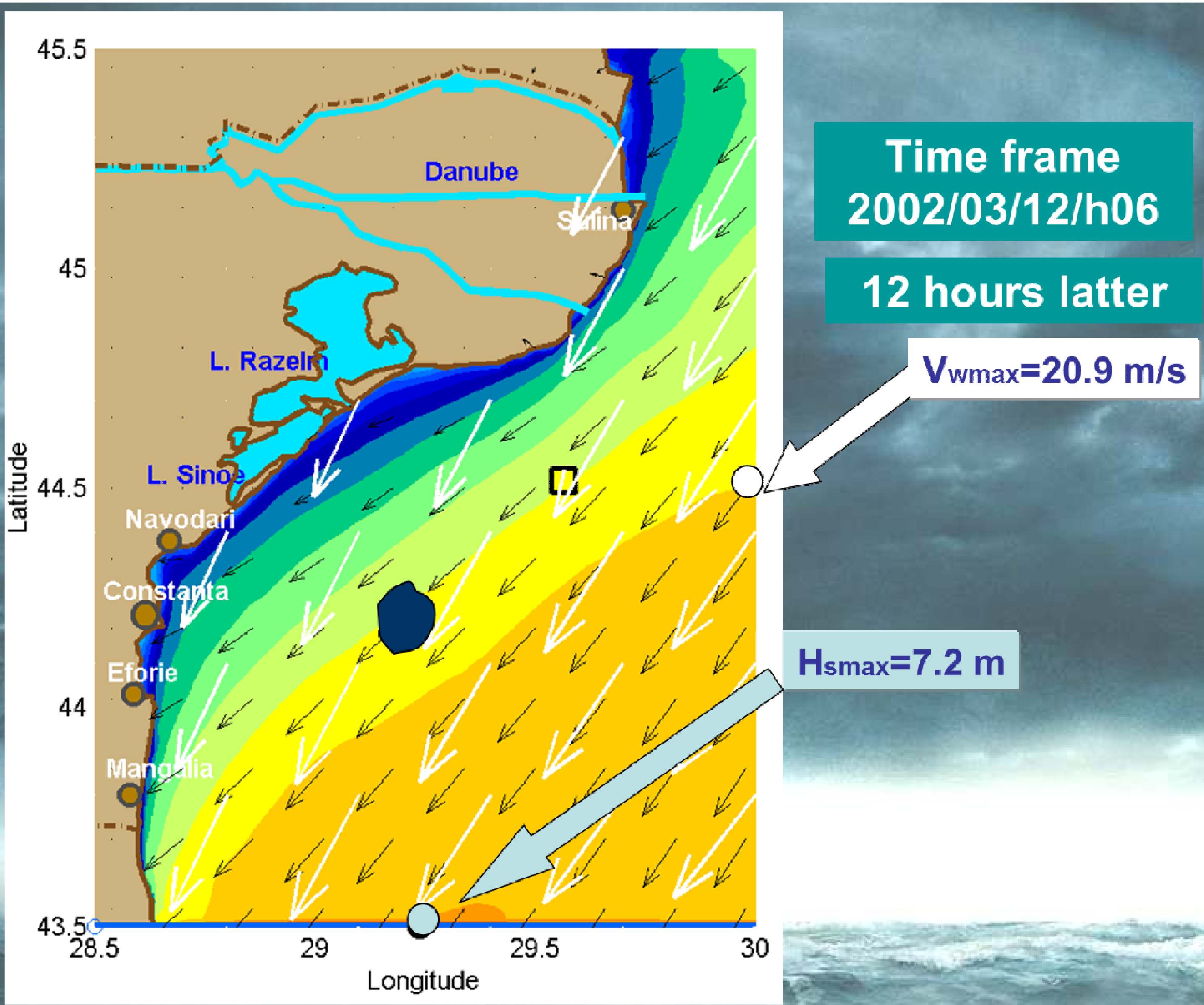
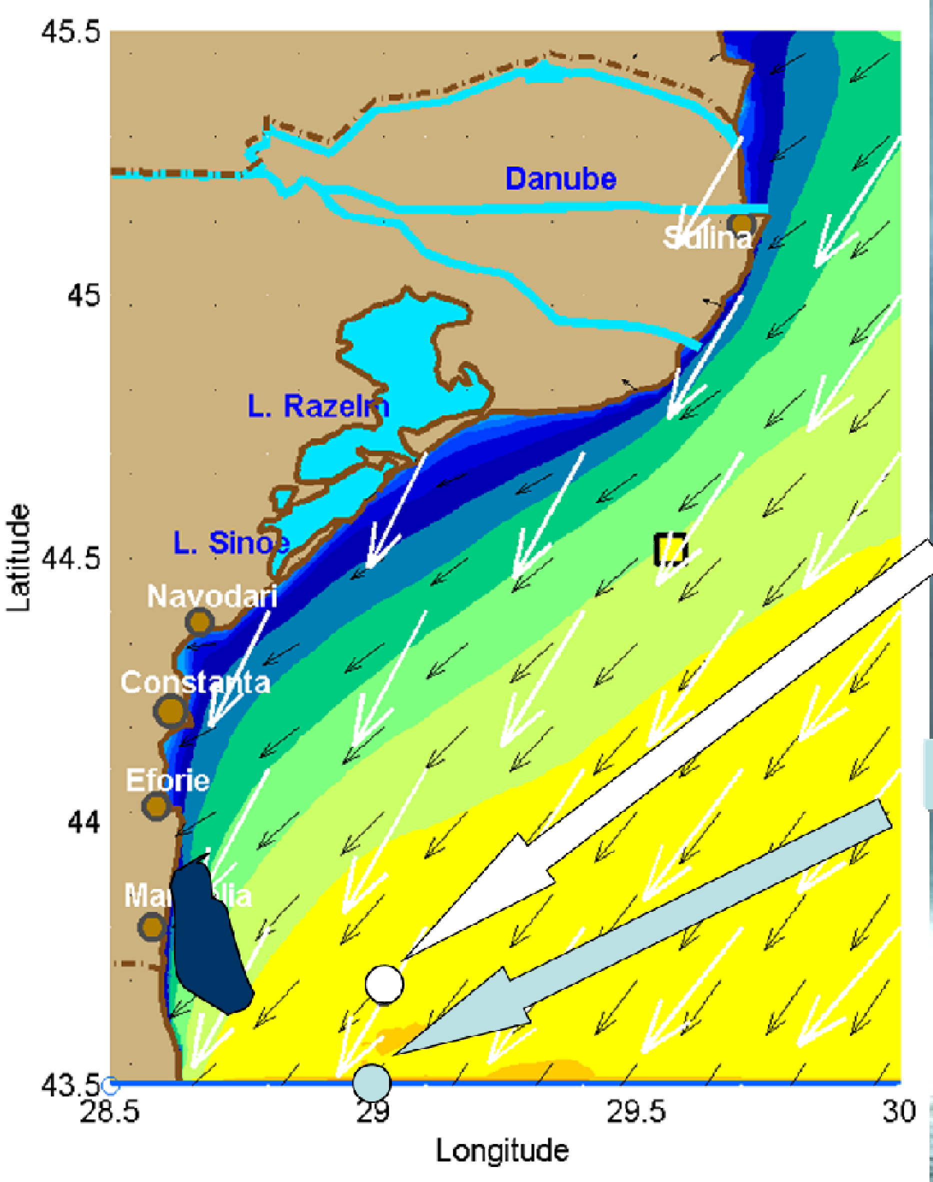


Figure 11. Wave and wind driving the oil spill towards the Romanian coast. b) Time frame 2002/03/12/h06



Time frame 2002/03/13/h00

V_{wmax}=19.5 m/s

H_{smax}=6.8 m

The coastal impact of the oil spill occurs after about 30 hours

Figure 11. Wave and wind driving the oil spill towards the Romanian coast. c) Time frame 2002/03/13/h00 (predicted coastal impact of the oil spill).

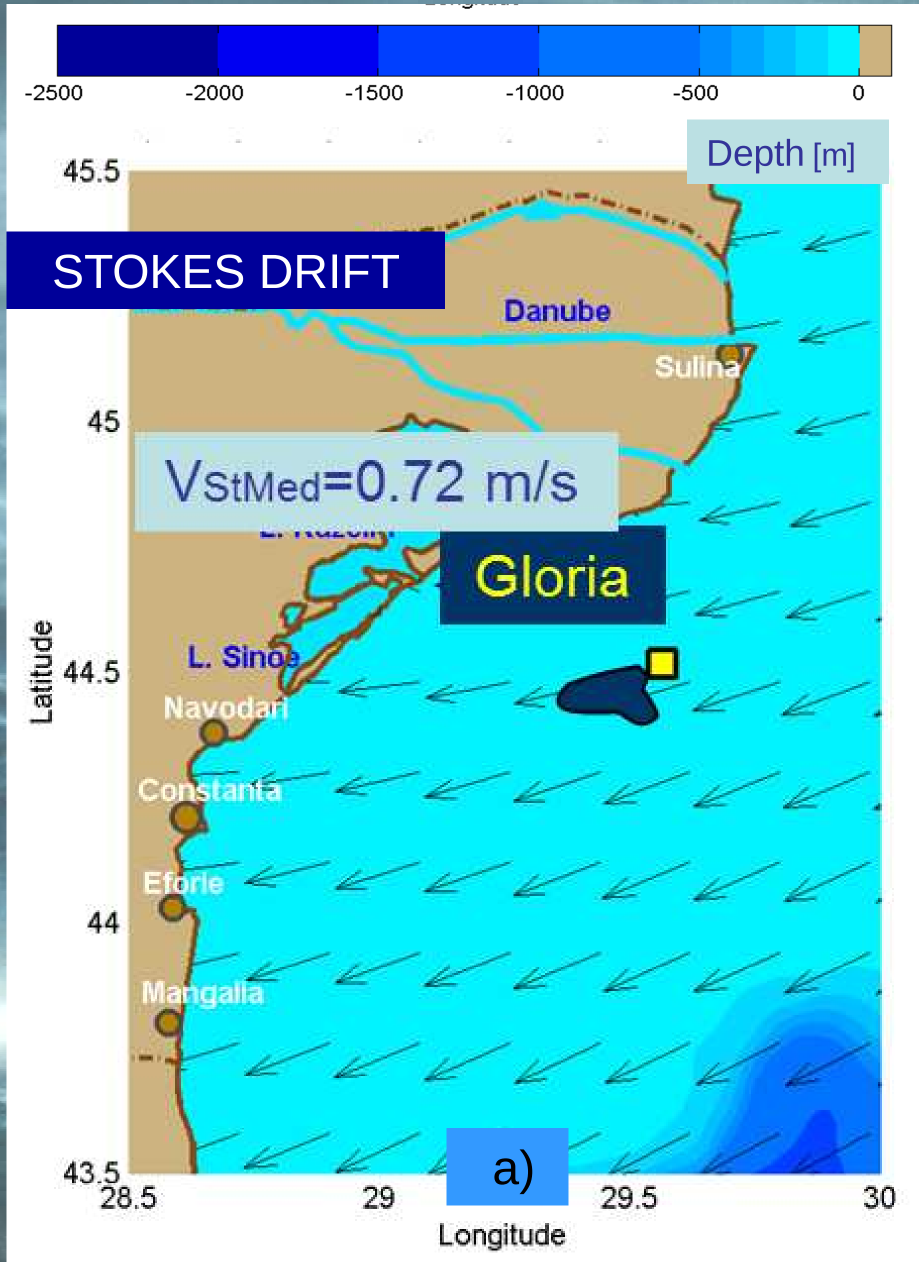


Figure 12. Stokes drift driving the oil spill towards the Romanian coast. a) Time frame 2002/03/11/h18, (peak of the storm considered the zero moment of the hypothetic accident

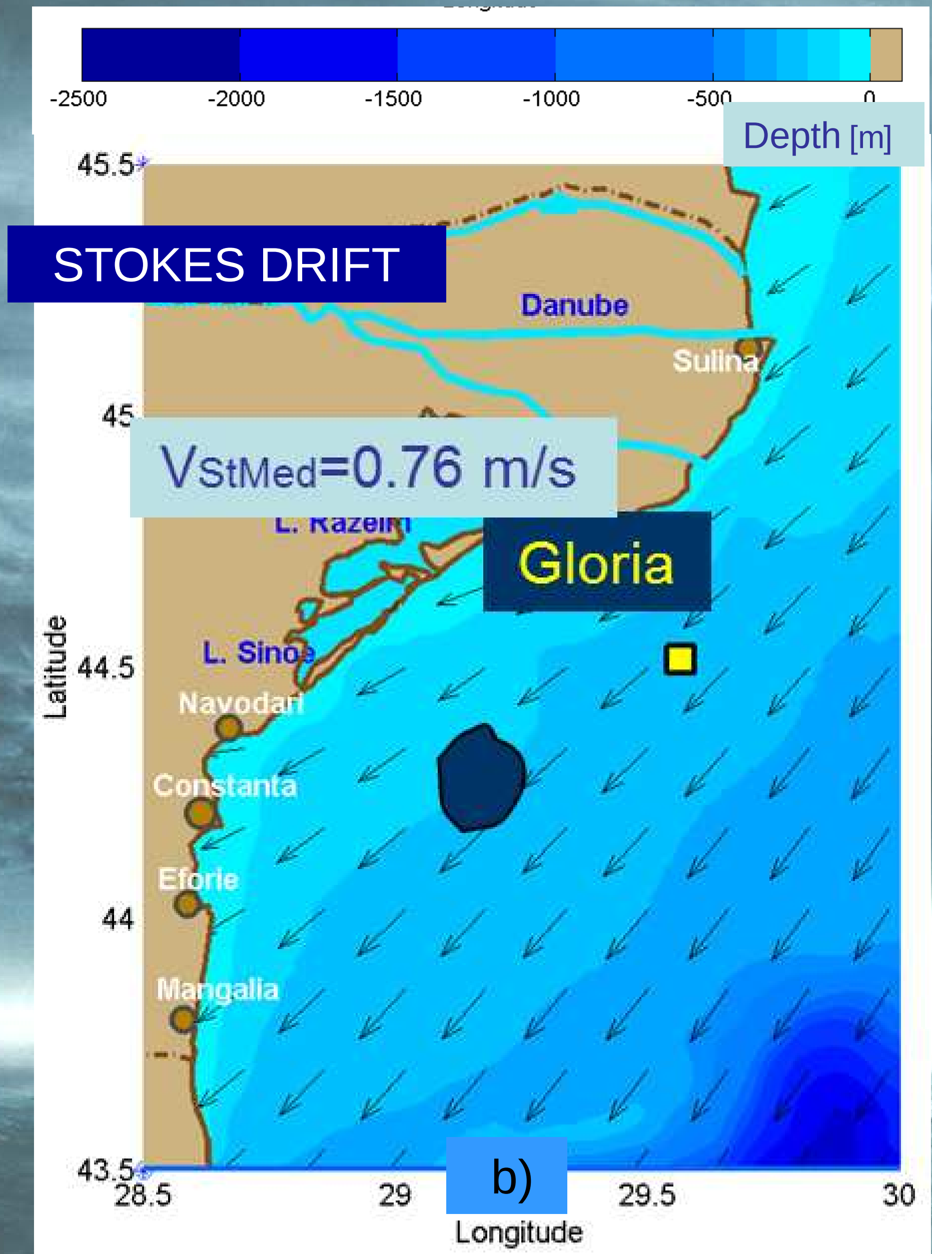


Figure 12. Stokes drift driving the oil spill towards the Romanian coast. b) Time frame 2002/03/12/h06

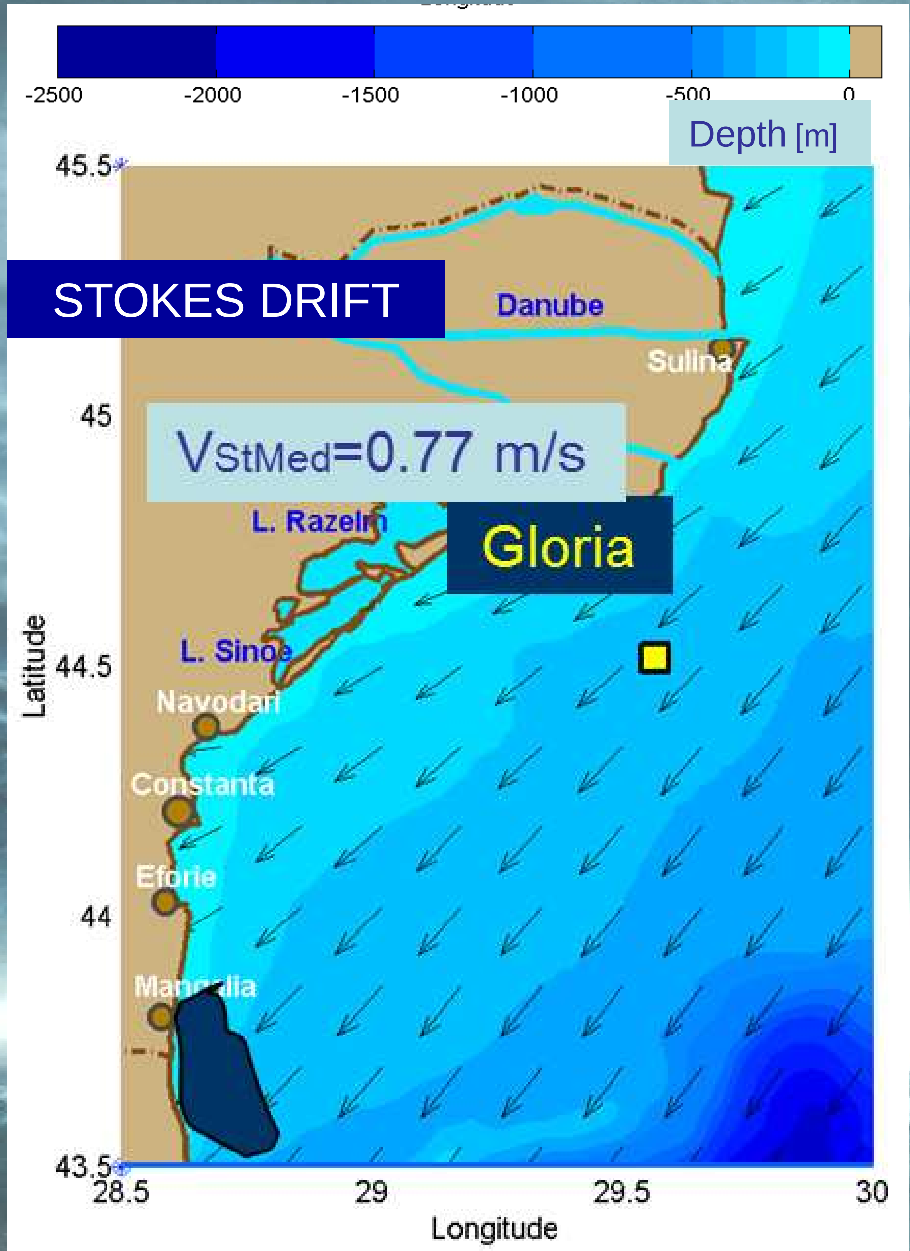


Figure 12. Stokes drift driving the oil spill towards the Romanian coast. c) Time frame 2002/03/13/h00 (predicted coastal impact of the oil spill).

6. Final considerations

A first conclusion coming from the present work would be that the near real time multi-mission merged non interpolated values of the significant wave height, wind and current speed provided by the satellite systems are a framework that allows analyzing properly the evolution of the environmental matrix over the sea. Nevertheless, since it deals in general with time and space average values, such methodology does not allow an estimation of the extreme environmental conditions. SWAN seems to be an adequate model for closed seas of medium size as Black Sea (or Caspian). Regarding the current modeling model (MOHID) a good concordance between the model results and the satellite data was encountered. In terms of current intensity the maximum relative errors are less that 12% and in terms of current direction the maximum relative errors are less than 9%.

Both wave (SWAN) and current (MOHID) models were implemented and validated in the Black Sea. The results concerning the wave and current predictions are in general reasonable. A joint modeling system based on the two models like the one presented above can give a better perspective on the interactions between waves and currents.

Thank you!