Use of satellite data by the Copernicus program for assessment of modeled wind field from atmospheric weather prediction models for the Black Sea

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Key words: *Scatterometers , ALADIN, HRES, WW3, SWAN models*

Abstract: *The National Institute of Meteorology and Hydrology of Bulgaria (NIMH) is responsible for the marine meteorological forecast service in the western part of the Black Sea, according to the requirements of the World Meteorological Organization (WMO) and the International Maritime Organization (IMO). The issue of marine forecasts in NIMH is carried out by the numerical wind- wave forecast system for the Black Sea, which was developed and improved through the years.The existing operational marine forecasting system is based on state of art numerical spectral wave models SWAN and WAVEWATCH III (WW3), providing 72-hours wind wave forecast for the Black Sea area. The input data for the system are the wind fields at 10 m over the sea surface provided by the atmospheric model ALADIN, specially set up for the Black Sea. The accuracy of the wind - wave forecast depends largely on the quality of the wind fields and the type of atmospheric models - global or regional. This paper present the results of the evaluation of the wind speed at 10 m from the regional atmospheric model ALADIN and HRES – a global atmospheric model with high spatial resolution of the European Center for Medium-Range Weather Forecast (ECMWF). The statistical assessment was made by comparing of modeled wind speed fields with satellites wind data (in near real time) at 10 m from ASCAT scatterometers of satelltes MetOP B and MetOP C over the Black Sea, which are disseminated by the Copernicus Marine Environment Monitoring Service (CMEMS), part of the Copernicus Program. The statistical results show a good agreement between the models and satellite measurements.*

Приложение на спътникови данни от програма „Коперник" за оценка на вятъра от атмосферните прогностични модели за Черно море

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Ключови думи*: скатерометри, ALADIN, HRES, WW3, SWAN модели*

Резюме*: Националният Институт по Метеорология и Хидрология (НИМХ) в качеството си на национална хидрометеорологична служба на България осъществява дейността по морското метеорологично обслужване в западната част на Черно море, съгласно международните изисквания на Световната Метеорологична Организация (СМО) и Международната Морска Организация (ИМО). Издаването на морски метеорологични прогнози в НИМХ се осъществява с помощта на разработената и усъвършенствана през годините оперативна система за числена прогноза на ветровото вълнение в Черно море. Действащата оперативна системата е напълно автоматизирана, изградена на базата на съвременни числени спектрални вълнови модели SWAN и WAVEWATCH III (WW3), осигуряваща 72 часова прогноза на вятъра и вълнението в басейна на Черно море. Системата се захранва с прогностични данни за вятъра на височина 10м от версия на модела ALADIN, специално подготвена за атмосферен форсинг на вълновите модели за акватория на Черно море. Точността на числените прогнози на вълнението зависи от качеството на информацията за вятъра на 10 м. от атмосферните модели и от вида на атмосферните модели - глобални или регионални. Представят се резултатите от проверката на точността на прогнозата на скоростта на вятъра на 10 м. от регионалния атмосферен*

модел ALADIN и глобалния атмосферен модел с висока резолюция HRES на Европейският център за средносрочна прогноза на времето (ECMWF). Направена е статистическа оценка на точността чрез сравнение на моделните и на спътниковите данни (в почти реално време) за скоростта на вятъра на 10 м от скатерометъри ASCAT на спътниците MetOP B и MetOP C за Черно море, разпространявани от Службата за наблюдение на морската среда (CMEMS) - част от услугата Морски мониторинг по програмата на Европейската Комисия "Коперник". Статистическите резултати показват добро съвпадение между моделните и спътниковите данни.

Introduction

The western part of the Black Sea area is highly vulnerable to natural hazards. The major hazards which pose a real danger to shipping and many other human activities in the coastal zone are strong winds, wind waves and especially the extreme ones, occurring during severe storms as well as storm surge events. Therefore accurate and reliable prediction of such events and timely early warning of severe weather, are absolutely necessary in order to minimize the risk offshore and along the coasts. The National Institute of Meteorology and Hydrology of Bulgaria is responsible for the marine forecasts services and issue of early warnings on operational basis. The issue of sea state forecasts in NIMH is carried out by using the numerical wind- wave forecast system for the Black Sea, which was developed and improved through the years. The system was created in 1996 as a result of the common efforts of the scientists of NIMH-BAS and Meteo-France (Kortcheva et al, 2010, Kortcheva et al, 2014). The existing operational marine forecasting system is based on state of art numerical models. It is a coupled system and consists of third-generation spectral wave models WAVEWATCH III (WW3; Tolman, 2009) and SWAN (Booij et al. 1999, SWAN, 2019), and the limited area Numerical Weather Prediction (NWP) model ALADIN (ALADIN, 2019). The system is used to deliver early warning information for the extreme weather events along the Bulgarian Black Sea coast to end-users and incorporated into the publically available European early warning alert system Meteoalarm on the website of NIMH freely accessible by the public (Dimitrova et al., 2019). Figure 1 shows an overview of the current operational marine forecasting system in NIMH.The recent advances in satellite technology have created the possibility to evaluate the quality of the 72 hours wind wave forecast. Use of the remotely sensed wind and wave data is important for the improvement of the accuracy of the operational numerical wind and wave forecasts and hindcast applications (Galabov et al, 2015). It has to be noted that the validation of the models outputs (wind speed and direction, significant wave height and direction, wave period) for the Black Sea is a difficult task because the number of marine surface observations along the Bulgarian Black Sea coast are sparse and not sufficient. Therefore we chose the satellite-derived wind and wave data, which are the only continuous source of information to compare the atmospheric and wave models results with observations. Satellite altimeter wind and wave data from Jason-2, Jason-3, and SARAL AltiKa and scatterometer wind data from MetOP ASCAT-B and MetOP ASCAT-C are used for the statistical evaluation and calibration of the operational models for the Black sea area.

The atmospheric models provide winds field at 10m over sea surface as driving forces for the numerical wave models which provide detailed sea-state information for any given location in the Black sea area. The output from wave models depends largely on the quality of the wind fields as well as of the type of atmospheric models - global or regional. (Holthuijsen et al., 1996, Ardhuin et al., 2007, Galabov et al., 2013, Umesh, 2017)

This work has been designed to demonstrate how the Near Real Time (NRT) scatterometer wind data from MetOP ASCAT-B and MetOP ASCAT-C disseminated by the Copernicus Marine Environment Monitoring Service (CMEMS), part of the Copernicus Program are used operationally to evaluate the quality of the modeled wind products for the Black Sea.

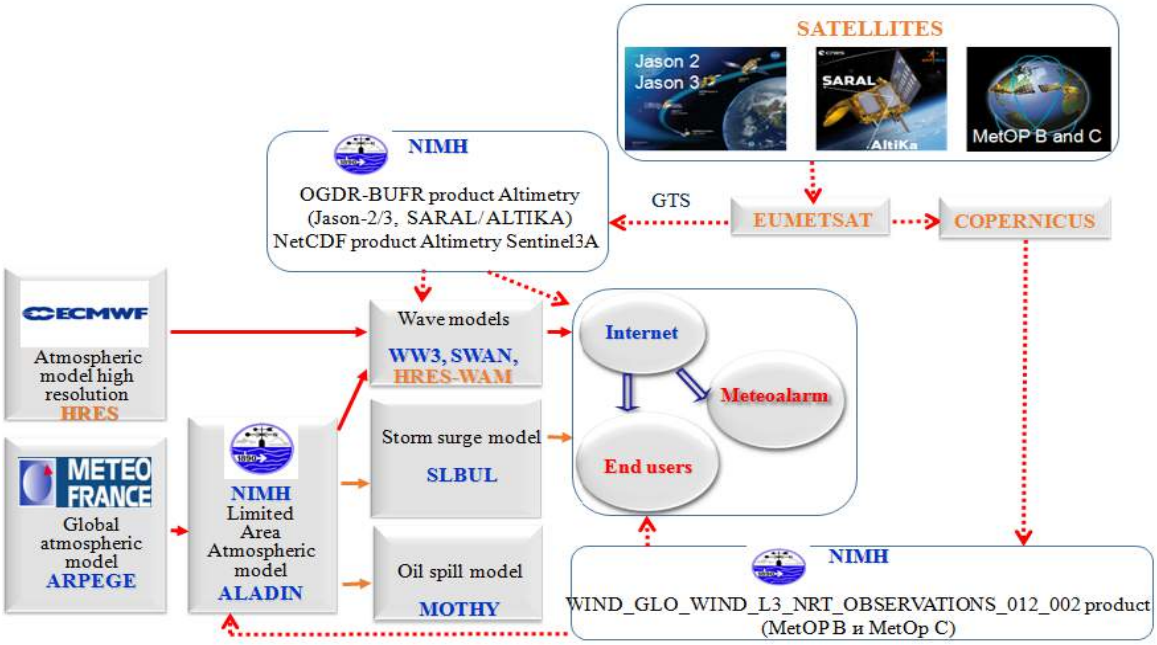

Fig. 1. The operational marine forecasting system of NIMH

Data and Methods

In 2019, a fully automated scheme was set up at NIMH for operational use of near real time satellite altimeter wind and wave data from Jason-2, Jason-3, and SARAL AltiKa and scatterometers wind data from MetOP ASCAT-B and MetOP ASCAT-C (Fig.1). The scheme work as additional module to the current operational marine forecasts system and it is integrated into the web-based system of NIMH. It consists by two parts with algorithms for combining satellites data with numerical models outputs. The first one is algorithm with a few technological steps for a comparison of atmospheric models and scatterometers data (Fig. 2).

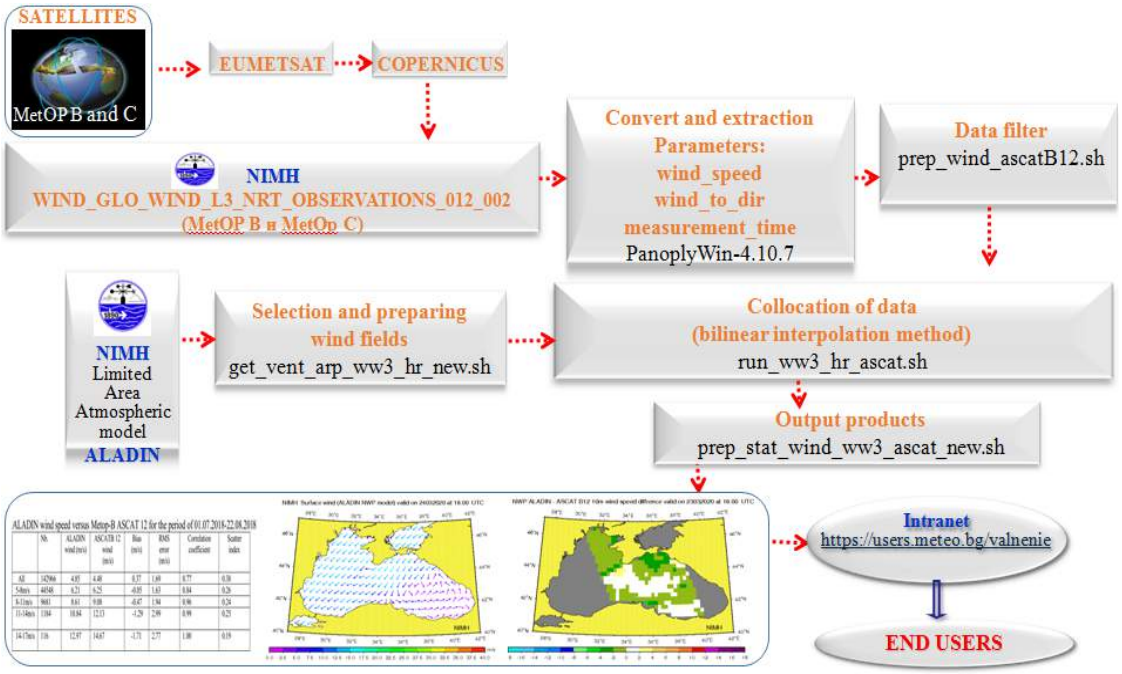

Fig. 2. Chart of the technological steps for comparison of the atmospheric models and scatterometers data

Advanced Scatterometers ASCAT on board of polar orbiting Meteorological Operational satellites MetOP-B and MetOP-C launched by the EUMETSAT, are designed to provide unique global ocean wind field products operationally (ASCAT, 2015). We used the Royal Netherlands Meteorological

Institute (KNMI), Global Wind Level-3 ASCAT 12 km (WIND_GLO_WIND_L3_NRT_OBSERVATIONS_012_002) coastal wind product downloaded from the CMEMS website (CMEMS, 2019). The scatterometer measurements from MetOP ASCAT-B and MetOP ASCAT-C over the Black sea are taken two times daily due to descending swaths (between 06:00 and 09:00) and ascending swaths (between 17.00 and 20.00) (Fig. 3 and Fig. 4). The near real time daily and reprocessing L3 wind products contains gridded L2 scatterometer wind vector observations and allows for direct use without preliminary manipulation. The scatterometer and models data are at different time scale. It means that ASCAT wind measurements had to be coordinated with the time of ALADIN wind forecast. The ASCAT B and ASCAT C scatterometers wind data are chosen to be with a minimal time difference compared to the NWP models winds (less than one hour). More details about technical steps can be found in Dimitrova, 2019.

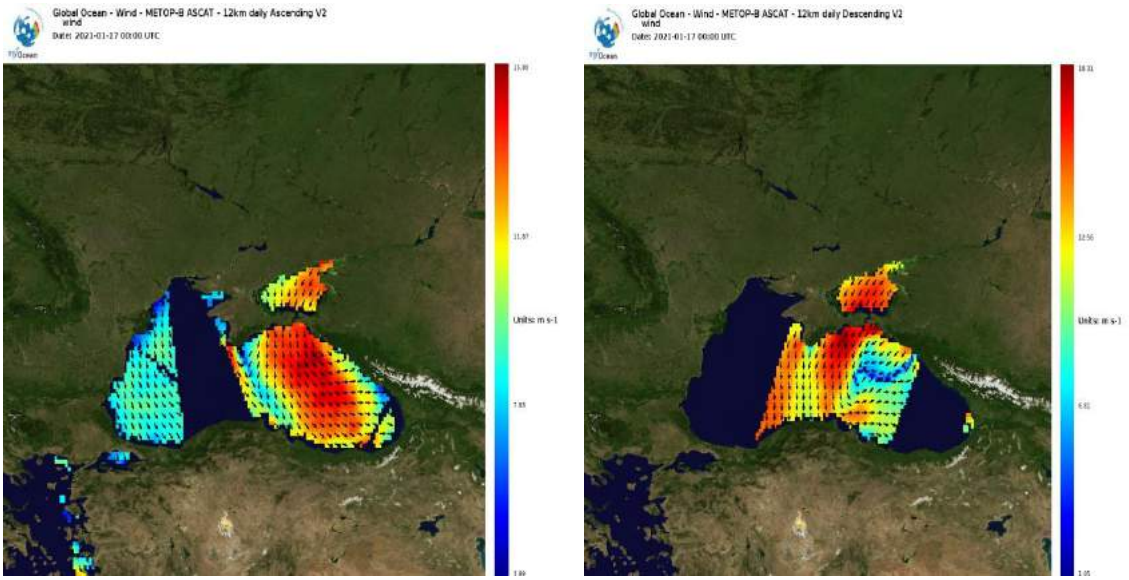

Fig. 3. Data for wind speed and direction obtained from MetOP-B ASCAT 12 km, on 17.01.2021, ascending (left) at 17:58 UTC and descending pass (right) at 06:33 UTC

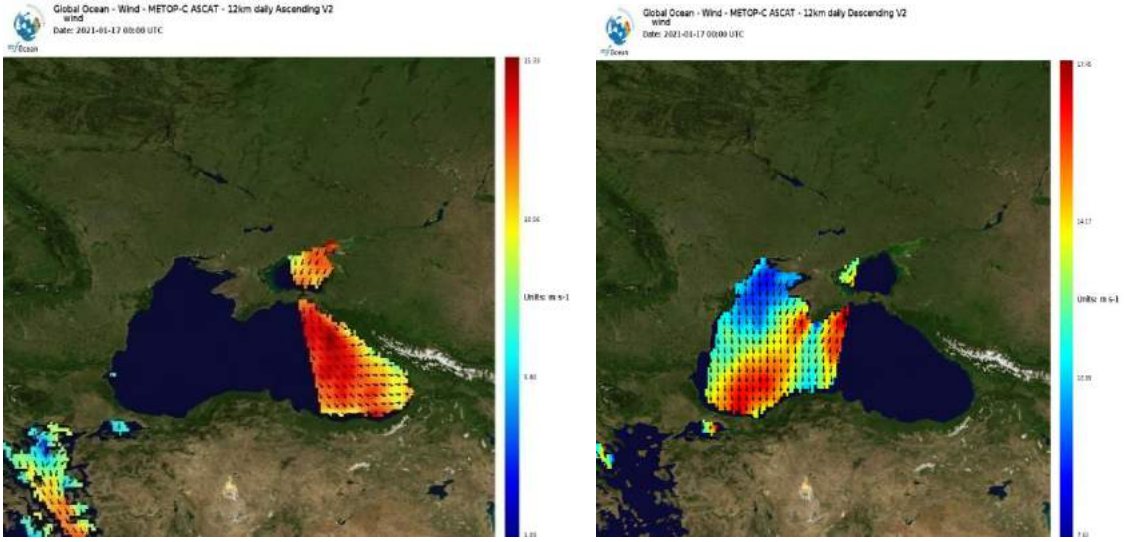

Fig. 4. Data for wind speed and direction obtained from MetOP-C ASCAT 12 km, on 17.01.2021, ascending (left) at 07:29 UTC and descending pass (right) at 18:49UTC

The second part of the module consist of algorithm for a relevant comparison of wave models and satellite altimeter data with several important steps, in order to make the time and space scales of the different systems compatible. The altimeter wind and wave NRT data from Jason-2, Jason-3 and SARAL AltiKa satellites is received at NIMH through the World Meteorological Organization (WMO) network Global Telecommunication System (GTS). The European Organization for the Exploitation of

Meteorological Satellites (EUMETSAT) distributes the wind speed at 10m above the mean sea level and the significant wave height as the operational geophysical data records (OGDR)-in BUFR format. The wind and wave data provided by the three altimeter missions mentioned above is passed through decoding tools to convert the OGDR-BUFR data to ASCII format and then a quality control process according to the products handbooks (i.e., Jason-3, 2016) and the best quality data is selected for the study after applying the editing criteria for Jason-2. Jason-3 and SARAL AltiKa altimetry (Dimitrova et al.,2019). Further details about technical steps can be found in (Dimitrova et al.,2013). Fig. 5 shows the daily coverage of satellite altimeter ground tracks over the Black Sea on 17.01.2021.

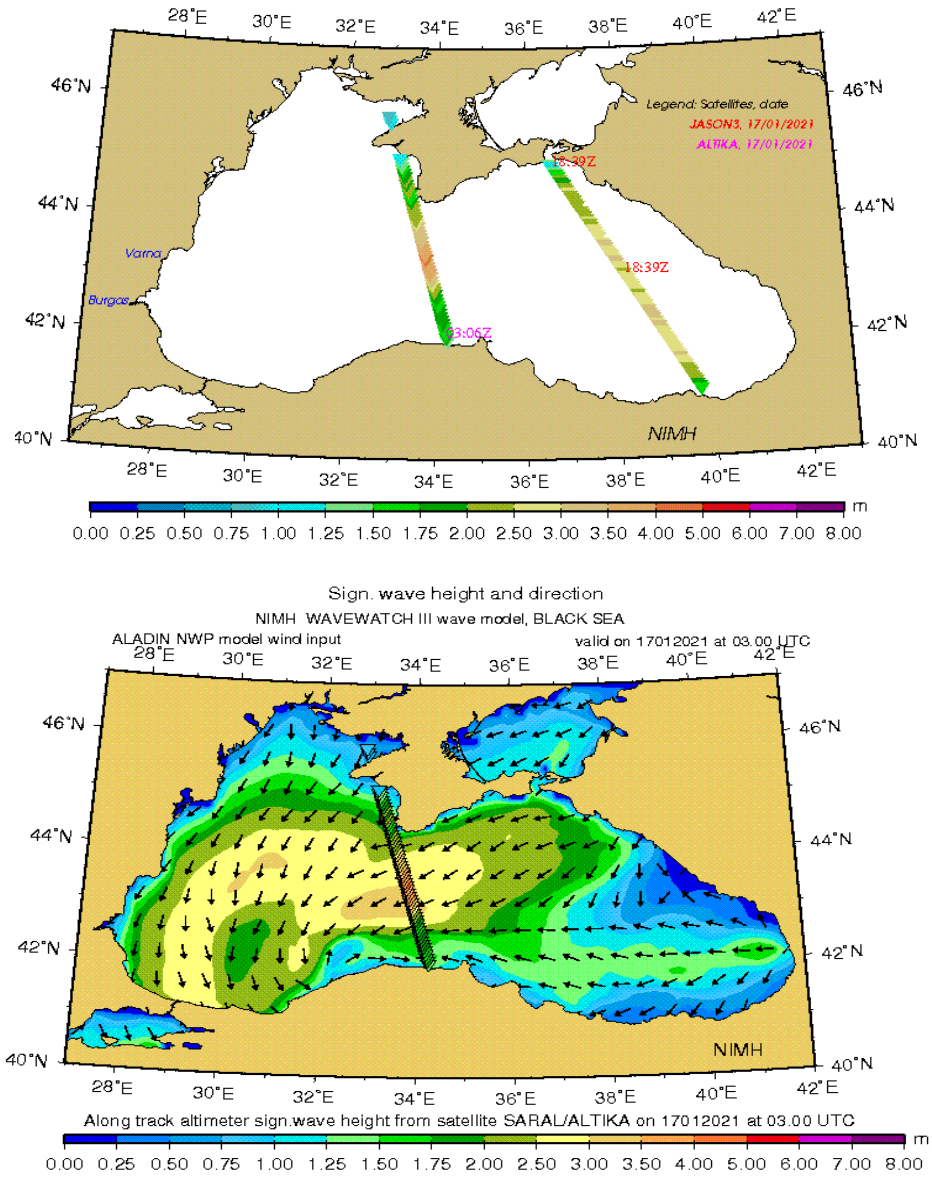

Fig. 5. Collection of altimeter satellite tracks over the Black sea for 17.01.2021 and wave field from WW3 in the Black Sea (the arrows indicate the mean wave directions), the black line denotes the ground track of Altika above the Black Sea on 17.01.2021 at 03h06min (down)

The products from the first part of the module are visualize by using GMT (GMT, 2019) software (Fig. 6) and tables with statistical characteristics (Table 1,Table 2,Table 3 and Table 4) are uploaded on the internal webpage https://users.meteo.bg/valnenie of NIMH on a daily basis for operational use. The statistics generated from verification scheme are important to represent effectiveness of the numerical models and reliability of wind wave forecasts. The statistical results show that the wind speeds from the limited area model ALADIN show better coincidence with the observed winds. The HRES model also in a good agreement with scatterometers ASCAT B and ASCAT C measurements, but there is tendency of some underestimation of the wind fields. This is not general conclusion, because the period of estimation is not long enought. Overall, the atmospheric models provide accurate forecast of wind field over the Black sea.

The outputs of the scheme can be used not only to improve the quality of the marine forecast and to prepare expert assessments for the benefit of state institutions and private sector.

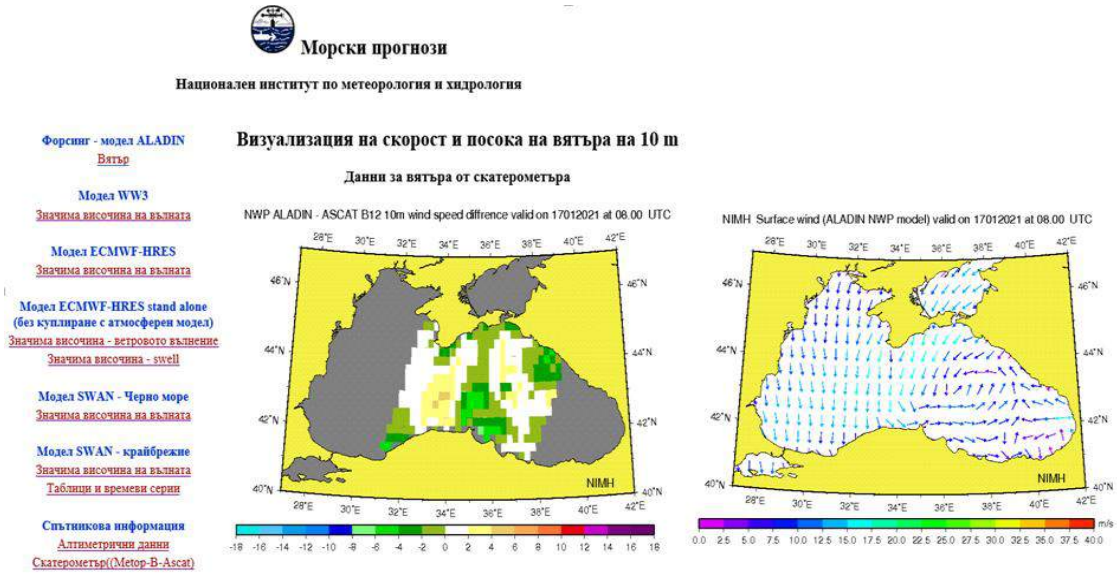

Fig. 6. Print screen of internal webpage with wind speed differences ALADIN-ASCAT B (left) and wind speed and direction from ALADIN model (right) with grid mesh 12km on 17.01.2021 at 08 UTC

Table 1. ALADIN wind speed versus Metop-B ASCAT 12 for the period of 01.01.2018-31.12.2019

	Nb.	ALADIN wind (m/s)	ASCATB 12 wind (m/s)	Bias (m/s)	RMS error (m/s)	Correlation coefficient	Scatter index
All	783074	7.63	7.86	-0.23	1.76	0.88	0.23
5-10m/s	653831	6.93	7.06	-0.13	1.74	0.85	0.25
10-15m/s	127459	10.90	11.56	-0.66	1.75	0.91	0.16
15-20m/s	7582	14.59	16.21	-1.62	1.69	0.99	0.14
>20m/s	184	17.66	20.70	-3.04	1.42	0.99	0.16

Table 2. HRES wind speed versus Metop-B ASCAT 12 for the period of 01.01.2018-31.12.2019

	Nb.	ECMWF wind (m/s)	ASCATB 12 wind (m/s)	Bias (m/s)	RMS error (m/s)	Correlation coefficient	Scatter index
All	783074	7.30	7.86	-0.56	1.77	0.89	0.24
5-10m/s	653831	6.67	7.06	-0.39	1.62	0.87	0.24
10-15m/s	127459	10.27	11.56	-1.28	2.00	0.93	0.21
15-20m/s	7582	12.75	16.21	-3.47	3.35	0.99	0.30
>20m/s	189	13.70	20.70	-7.00	5.36	0.98	0.43

Table 3. ALADIN wind speed versus Metop-C ASCAT 12 for the period of 01.01.2020-31.12.2020

	Nb.	ALADIN wind (m/s)	ASCAT C 12 wind (m/s)	Bias (m/s)	RMS error (m/s)	Correlation coefficient	Scatter index
All	489616	7.65	7.93	-0.28	1.86	0.87	0.24
5-10m/s	404468	6.90	7.06	-0.17	1.84	0.83	0.26
10-15m/s	82965	10.93	11.66	-0.73	1.86	0.90	0.17
15-20m/s	5834	14.62	16.13	-1.52	1.66	0.99	0.14
>20m/s	184	17.70	20.72	-3.02	1.41	0.99	0.16

Table 4. HRES wind speed versus Metop-C ASCAT 12 for the period of 01.01.2020-31.12.2020

	Nb.	HRES wind (m/s)	ASCAT C 12 wind (m/s)	Bias (m/s)	RMS error (m/s)	Correlation coefficient	Scatter index
All	489616	7.36	7.93	-0.57	1.82	0.88	0.24
5-10m/s	404468	6.68	7.06	-0.39	1.68	0.85	0.24
10-15m/s	82965	10.40	11.66	-1.26	2.02	0.95	0.20
15-20m/s	5834	13.02	16.13	-3.11	2.99	0.99	0.27
>20m/s	184	13.93	20.72	-6.79	5.24	0.98	0.41

Conclusion

Satellite Earth Observation techniques matured over the last two decades to such a stage, that quality products of ocean wind and waves, can be produced routinely. The meteorological and oceanographic satellites information is freely disseminated within the framework of the Copernicus program of European Commission and has various applications in the field of marine meteorology.

Many studies have confirmed that scatterometers data is important and reliable data source for marine and NWP communities. The importance for operational real-time marine applications and oceanographic research is to characterize the differences between the scatterometer and NWP products (Stoffelen et al., 2006). The greatest benefit of ASCAT measurements is the possibility to analyze the wind fields over the sea and to understand how reliable the sea state forecast is. The accurate prediction of wind field by atmospheric models is absolutely necessary for accurate numerical simulation of the wave conditions over the sea.

The overall conclusion is that the operational marine forecast system produces a reliable wind wave forecasts for the Black Sea. The results from the evaluation of the wind speeds of the model systems by comparing very short-range forecasts of ALADIN and HRES with scatterometers ASCAT B and ASCAT C wind product show a good coincidence. There is a good agreement in terms of statistical characteristics between atmospheric models output and scatterometer wind data.

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