Bulletin of the Maritime Institute

Gdańsk, 2001, 28, 2

MACIEJ KAŁAS, ANTONI STAŚKIEWICZ, KAZIMIERZ SZEFLER
Maritime Institute, Gdańsk, Poland

VERIFICATION OF NUMERICAL FORECAST OF ATMOSPHERIC PARAMETERS NEAR THE POLISH COAST USING THE DATA FROM MIG-1 BUOY

Abstract

The paper presents results of comparison of the numerical weather forecast data from two models (UMPL - ICM, Warsaw University and HIRLAM - SMHI Norrköping) with the measurements made in 2000 and 2001 at the open sea near the Hel Peninsula from the automatic buoy MIG-1. The agreement of both models with the experimental data is quite good.

1. Introduction

Increasing economic activities at sea cause that there is a strong need for a reliable information on present conditions at sea and for a marine forecast, which may effectively aid these activities. The demanded information concerns not only atmosphere over the sea (mainly wind, air temperature and visibility), but also hydrodynamic parameters from both the sea surface and water body (wind waves, water level, ice phenomena, currents, water temperature and salinity). This information is more and more needed for the navigation purposes, particularly along navigation routes near coasts, along fairways and at shallow water areas, in particular, for secure transportation of cargo, hazardous for the marine environment. Fast access to such data allows for more effective SAR actions at sea, combating oil and chemical spills. Such information is also helpful for planning hydro-technical activities, for example, laying down underwater cables and pipes. Fast development of marine forecast methods, applying numerical models for the atmosphere and for ocean or sea, meets these demands.

The HIROMB agreement, concluded first between Germany and Sweden, and now broadening for the all states surrounding the Baltic Sea, was aimed at the establishment of an operational system, enabling effective combating oil spills. The 3-dimensional model HIROMB (High Resolution Operational Model of the Baltic Sea, which covers the North Sea and the Baltic Sea region with a horizontal resolution 1 and 3 nm, is daily run in Sweden, giving a 48-hours forecast for water level, ice parameters, water currents, salinity and temperature in 24 layers. Atmospheric forcing of this model is provided by HIRLAM (High Resolution Limited Area Model), in its version, being run in SMHI Norrköping, Sweden.

Current validation of the numerical forecast is important for its further development, but in situ measurements are very expensive and remote sensing also does not solve the problem completely. Coastal stations are exposed to the sea-land interaction and they cannot replace measurements from the open sea. Some data are available from different ships. Data collected during experiments with many ships may be especially valuable, as they can give simultaneously data from an area. Such series of four periods, each of several weeks long, was conducted in the Gdańsk Basin in 1996-1999 [1 - 4, 6]. These experiments, called „POLRODEX", allowed for local validation of marine forecast models.

A permanent automatic station, performing measurements of meteorological parameters over the sea and hydrodynamic and hydro-physical parameters of the water column in the sea gives another opportunity for the model validation. In May 2000, at the distance of 8 nm to north-northeast from Władysławowo, the automatic station MIG-1 of the Maritime Institute, began its work. It was possible thanks to the funds from Phare project PL9708.02.10. The meteorological station was mounted at the anchored surface buoy. Now, after several months of the land maintenance and reconstruction, it continues measurements at sea. Till present, all the planned meteorological measurements are being made. Two, each lasting for several months, data series, unique for the Polish zone of the Baltic Sea, have been collected. These data allowed for quality assessment, in the point of the measurements, of meteorological forecast given by two models of atmosphere: UMPL and HIRLAM, which are in operational service at the Baltic Sea.

2. Numerical models of weather conditions for the Baltic Sea

Meteorological services of the Baltic Sea states use different regional prognostic models for atmosphere. These models can produce a very detailed forecast up to two days ahead. These are models of LAM (Limited Area Models) type, like, for example, Europa-Modell with the horizontal grid step of about 55 km, run by the German service (DWD) (in Poland, results of this model are used by IMGW), HIRLAM (High Resolution Limited Area Model), developed by several West-European services, which had established the European Centre for Medium-Range Weather Forecasts (ECMWF). Thanks to the HIROMB project we have access to the HIRLAM atmospheric pressure and wind forecast, versions with the resolution of 44 km and 22 km, from SMHI Norrköping, Sweden.

Another regional atmospheric model for the Central Europe, including the Baltic Sea area - the UMPL (Unified Model for Poland), is a mesoscale version of the British Meteorological Office Unified Model. The model is operationally run from 1997 in the Interdisciplinary Centre of Mathematical and Computational Modelling (ICM), University of Warsaw, with the grid resolution of 17 km. Upon the agreement with the ICM we have also on line access to the forecast of air pressure, wind components, air temperature, relative humidity and cloudiness. More detailed description of these models can be found at the appropriate web sites, e.g., SMHI, DHI, ICM UW, British MetOffice and in publications [4, 5, 7].

It means that there is the possibility to compare forecast data from the HIRLAM and the UMPL with the data measured at MIG-1 buoy. Fig. 1 shows the positions of the buoy, grid points of the UMPL (∗) and HIRLAM (☼) in the Gdańsk Basin. The grid points, chosen for the comparison, are marked as I for the UMPL and H for HIRLAM

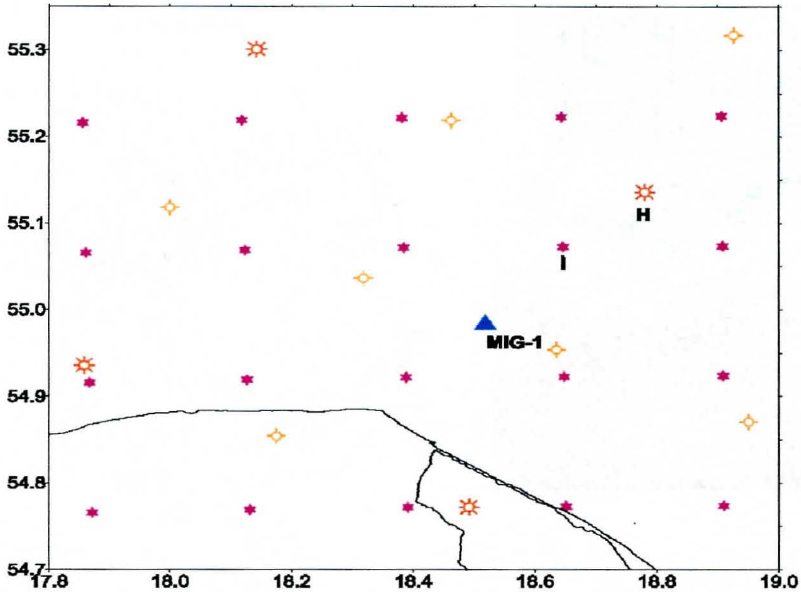


Fig. 1. Position of the MIG-1 buoy at sea (▲) together with the grid points of the numerical models: UMPL (*), HIRLAM-44 (☼) and HIRLAM-22 (◇)

2.1. UMPL model

The mesoscale model of the atmosphere UMPL, gives the meteorological forecast for the atmosphere over the Baltic Sea and surrounding areas for 48 hours ahead. The operational data are available for every hour. Generally, such forecast is calculated four times a day, with the initial data of 00, 06, 12 and 18 UTC.

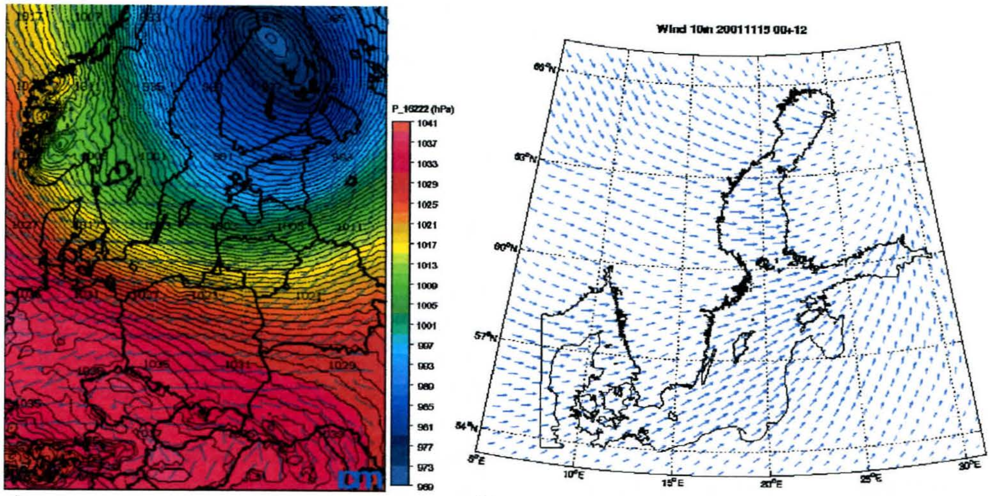
The time series of forecast data for the first 24 hours of the forecast been created and compared to the measurements data (UM1, UM2). Additionally, data of the analysis (based on the field observation data) with the time step of 3 hours are available, and they also have been used for the comparison with the data registered from the buoy.

Fig. 2a shows examples of atmospheric pressure and wind fields, given everyday at the ICM web site.

2.2. HIRLAM model

HIRLAM is a numerical weather forecasting system developed for short-range forecasts purposes. The model covers the area of Northern Atlantic, Europe, coastal areas of Africa and North America. The computations are realised at two numerical grids, of 44 km and 22 km space resolution. In the paper, the forecasts from both grid versions have been used. In the operational mode, HIRLAM-44 data are available for every hour till 48 hours ahead, and HIRLAM-22 data are available for every third hour till 36 hours ahead. Fig. 2b is an example of the wind field over the Baltic Sea, usually available at the SMHI web site.

Numerical prognostic information from the atmospheric model HIRLAM is the basic input for the sea model HIROMB. That is why assessment of atmospheric model is so important for oceanographers.



a) b)

Fig. 2. Examples of visual presentation of numerical forecast for the Baltic Sea area during the strong gale 2001.11.15 12 UTC: UMPL low pressure and wind fields (a) and HIRLAM - wind field (b) *(from ICM UW and SMHI home pages respectively)*

3. Measurements at the open sea by MIG-1 buoy

The buoy MIG-1 is at present the only automatic station in the Polish zone of the Baltic Sea, measuring meteorological and hydro-physical parameters. Placing and exploitation of the autonomous buoy in the Polish zone of the Baltic Sea is also a result of Polish participation in the HIROMB project. The aim of the buoy operation is operational delivery of information on meteorological, hydrodynamic and hydro-physical parameters of the marine environment for the needs of:

- aid to search and rescue actions,
- aid to combating of oil and chemical spills,
- navigation safety, especially for the navigation in coastal sea areas, and for protection of other different human activities at sea,
- marine forecast services and maritime administration,
- validation and further development of the marine forecast system, based on the meteorological and hydrodynamic numerical models,
- monitoring of the state of natural marine environment.

Moreover, information from the buoy gives the opportunity for better investigation of local hydrological and hydrodynamic parameters variability, pollutant spreading, marine ecosystem variability in this area of the Baltic Sea.

For the accomplishment of these tasks, from May to December 2000 and from October 2001 till present, the autonomous measuring buoy MIG-1 was anchored at the position of 54° 56.16 N', 18° 31.09' E (blue triangle at Fig. 1), where the sea bottom is at the depth of 42 m, that is, about 8 nm to north-northeast from Władysławowo. The choice of that position was dictated by the fact that it is an area with high intensity of hydrodynamic phenomena, horizontal and vertical, with often occurrence of upwelling there. Moreover, significant distance from the coast means that quantities, measured there, should be characteristic for an open sea area.

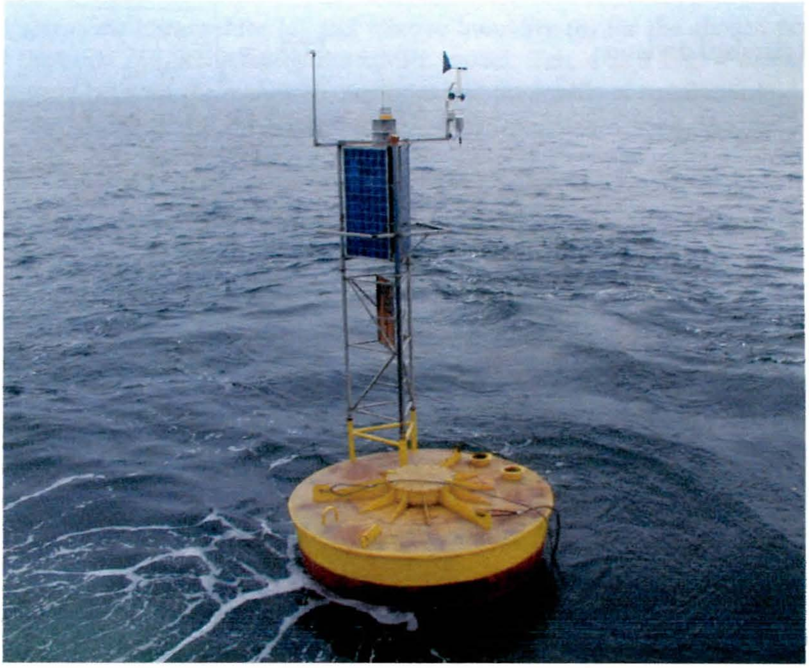


Fig. 3. General view of buoy MIG-1 with the meteorological station at sea

At Fig. 3 the buoy together with the meteorological station at sea can be seen. During each measurement, recorded every 30 minutes, following parameters of the atmosphere are measured: atmospheric pressure, air temperature and relative humidity, solar radiation, wind velocity and direction. These data are every 30 minutes transmitted to the Operational Centre in the Maritime Institute, where they are processed, archived, put into the Internet and compared with the information from the models of the atmosphere.

4. Comparison of computed and measured data

For two periods of the buoy operation, 18 May - 5 December 2000 and 27 October 2001 till present, two series of meteorological parameters at the open sea near Hel Peninsula were registered. They have been compared with numerical forecast data of UMPL and HIRLAM models at their grid points, closest to the position of the buoy MIG-1 (Fig. 1).

For the comparison of measured and computed series, we assumed the following statistical characteristics :

Simulated mean value $\bar{x} = \frac{1}{N} \sum_{i=1}^{N} x_i$

Observed mean value $\bar{y} = \frac{1}{N} \sum_{i=1}^{N} y_i$

Simulated standard deviation $STD_{xx} = \sqrt{\frac{\sum (x_i - \bar{x})^2}{N-1}}$, Observed standard deviation $$STD_{yy} = \sqrt{\frac{\Sigma(y_i - y)^2}{N-1}},$$

Correlation coefficient $$R = \frac{\Sigma(x_i - \bar{x})\cdot(y_i - \bar{y})}{(N-1)\sigma_{xx}\cdot\sigma_{yy}},$$

Mean absolute error $$MAE = \frac{\Sigma|x_i - y_i|}{N},$$

Root mean square error $$RMSE = \sqrt{\frac{\Sigma(x_i - y_i)^2}{N}},$$

Bias (mean error) $$BIAS = \bar{x} - \bar{y},$$

where simulated values are denoted by (x_i), and the observed ones by (y_i).

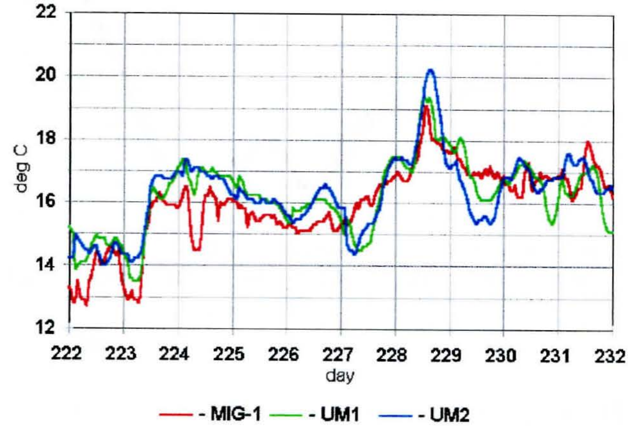
4.1. Measurements in the year 2000

The analysed period consists of observations from 10.05 to 01.12.2000. For the comparison, registrations from full hours were chosen (Obs.). As predicted data computations from numerical model UMPL for the first (UM1) and for the second (UM2) day of forecast were chosen. Statistical characteristics in Tab. 1 are presented in turn: amount of analysed data (N), mean values, standard deviations, correlation coefficients, mean absolute errors, root mean square errors and mean errors.

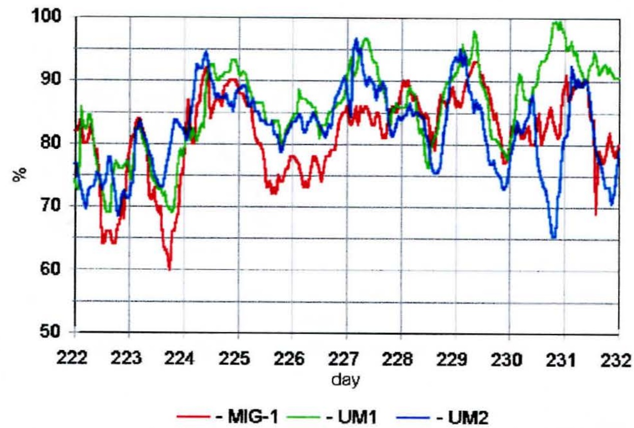
Tab. 1 Statistical characteristics for the comparison of the buoy registrations with the data from the UMPL model (first and second day forecasts) during 19.05 – 01.12. 2000

	Model	N	Mean	STD	Max	Min	R	MAE	RMS	BIAS
Atmo-spheric pressure	Obs.	4553	1011.	7.3	1032.	990.5				
	UM1	4701	1014.	7.3	1035.	993.9	0.983	2.673	1.200	2.7
	UM2	4701	1014.	7.6	1037.	994.4	0.961	2.914	1.786	2.8
Air tempera-ture	Obs.	4617	11.9	3.4	19.4	2.8				
	UM1	4701	12.6	3.0	20.5	3.4	0.9.6	1.209	0.997	0.5
	UM2	4701	12.6	3.0	20.2	3.5	0.891	1.283	1.057	0.5
Humidity	Obs.	4617	80.3	9.4	98.0	44.0				
	UM1	4701	83.5	8.5	99.8	48.2	0.707	5.708	4.996	3.2
	UM2	4701	82.5	8.5	99.5	49.1	0.668	5.777	4.937	2.2
Wind speed	Obs.	4617	6	2.9	17.1	0.0				
	UM1	4701	6.3	2.9	15.7	0.1	0.770	1.533	1.252	0.3
	UM2	4701	6.3	3.1	18.5	0.0	0.627	1.968	1.658	0.3
WE wind comp.	Obs.	4617	0.2	2.2	15.1	-13.6				
	UM1	4701	1.0	5.2	14.3	-11.4	0.765	2.571	2.570	0.8
	UM2	4701	0.9	5.3	17.5	-12..9	0.711	2.946	2.736	0.7
NS wind comp.	Obs.	4617	2.3	3.5	13.7	-10.2				
	UM1	4701	1.8	4.2	14.4	-13.7	0.617	2.608	2.227	-0.5
	UM2	4701	1.6	4.2	12.8	-12.4	0.560	2.882	2.367	-0.7

Fig. 4 shows air temperature (a) and relative humidity (b) for the chosen period, recorded at the buoy and predicted by the UMPL model. Tab. 1 and Fig. 4 demonstrate a good agreement between the measured quantities and the results of simulations.



a)



b)

Fig. 4 Air temperature (a) and relative humidity (b) registered at buoy MIG-1 (—) and from the UMPL model for the first (—) and the second (—) day of forecast, 9 – 19. Aug. 2000

4.2. Measurements in the year 2001

The analysed here period of the year 2001 included measurements made from 27 October to 28 November, made at full hours. They have been used for the comparison with the numerical results from the UMPL model (from the analysis - UM0 and from the first day of the forecast - UM1), and from the HIRLAM model, from the first day of the forecast at the grids with the 44 km - resolution (H44) and with 22 km - resolution (H22).

Fig. 5 shows the course of the atmospheric pressure (a) and wind parameters: speed (b) and direction (c) registered on buoy and predicted from the numerical models, 3 - 13 November 2001.

The results of the statistical analysis for the scalar meteorological quantities are presented in Tab. 2. The atmosphere pressure, air temperature and humidity and wind parameters for observations made at MIG-1 buoy (Obs.) and numerical calculations are compared there.

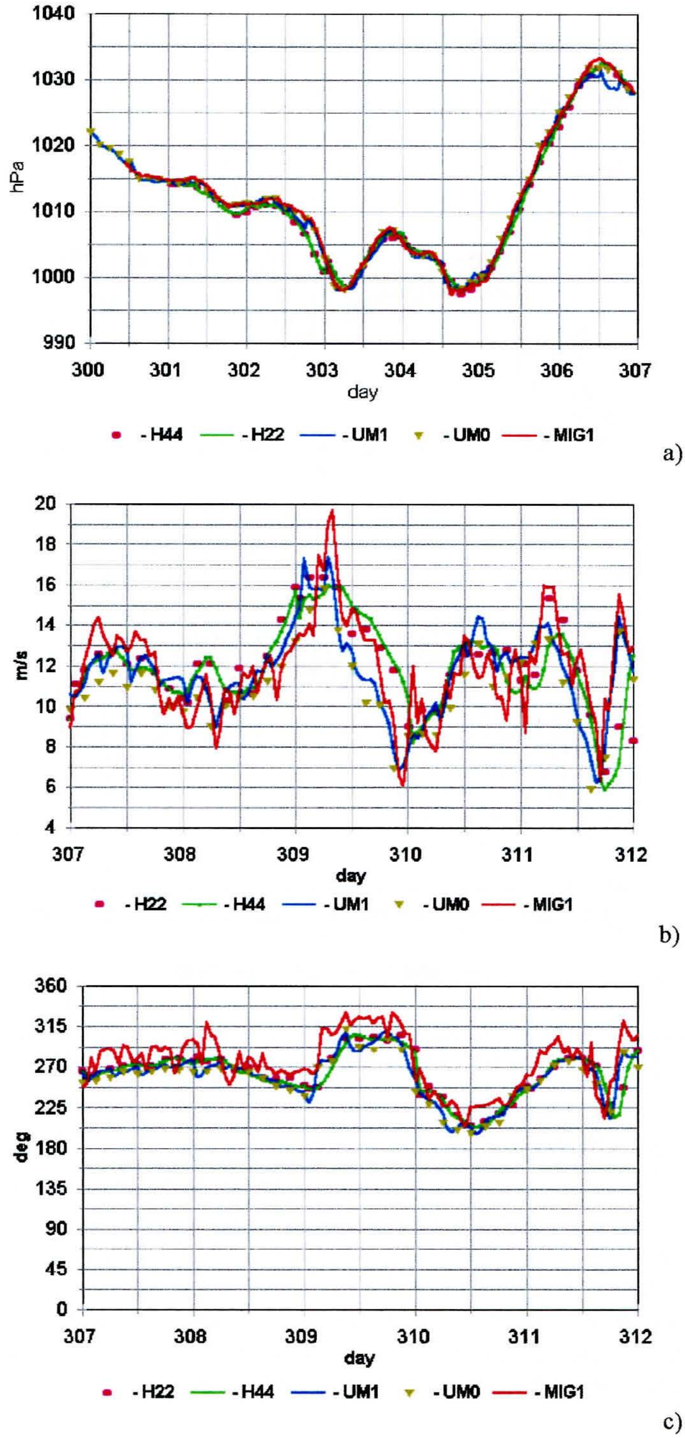


Fig. 5. The atmosphere pressure (hPa) (a), wind parameters: speed (m/s) (b) and direction (deg) (c) registered at buoy and computed, 03.11 - 13.11.2001

Tab. 2. Statistical characteristics for comparison of buoy registrations with data from numerical models UMPL and HIRLAM (first day forecast) during 27.10 – 28.11 2001

	Mode	N	Mean	STD	Max	Min	R	MAE	RMS	BIAS
Atmos-pheric pressure	Obs.	766	1011.	11.0	1033.	984.2				
	UM0	255	1011.	10.9	1033.	983.6	0.999	0.441	0.301	0
	UM1	766	1011.	10.8	1032.	983.2	0.998	0.922	0.669	0.3
	H22	269	1011.	11.2	1033.	979.4	0.995	0.768	0.604	0.1
	H44	766	1011.	11.2	1033.	981.0	0.995	0.818	0.789	0.4
Air tempera-ture	Obs.	766	5.4	2.6	13.1	0.1				
	UM0	255	6.8	2.6	13.0	0.6	0.949	1.515	0.900	-1.4
	UM1	766	6.7	2.6	13.6	0.6	0.954	1.436	0.838	-1.3
Humidity	Obs.	766	74.9	10.8	93.0	45. 0				
	UM0	255	73.5	13.2	92.6	38.6	0.877	4.901	3.431	0.6
	UM1	766	74.8	12.8	94.9	38.9	0.882	4.523	3.913	0.1
Wind speed	Obs.	766	10.6	3.6	21.7	1.7				
	UM0	255	9.5	3.6	20.6	1.4	0.891	1.588	1.040	1.1
	UM1	766	10.2	3.7	21.8	1.0	0.884	1.391	1.143	0.4
	H22	269	10.8	3.9	21.8	1.1	0.858	2.031	1.901	-0.2
	H44	766	10.6	3.8	21.4	1.2	0.864	1.455	1.254	0
WE wind component	Obs.	766	5.3	5.2	17.6	-8.0				
	UM0	255	6.2	5.4	20.3	-4.6	0.914	1.955	1.272	0.9
	UM1	766	6.7	5.9	21.07	-5.1	0.922	2.165	1.569	1.4
	H22	269	7.1	6.3	21.7	-5.7	0.917	3.041	2..00	1.8
	H44	766	6.9	6.1	21.3	-5.4	0.913	2.871	2.119	1.6
NS wind component	Obs.	766	-3.3	5.5	11.2	-14.3				
	UM0	255	-1.0	5.9	12.0	-14.1	0.848	2.738	1.849	2..3
	UM1	766	-1.4	6.2	13.0	-14.8	0.859	2.364	1.835	1.9
	H22	269	1.7	6.1	11.4	-15.2	0.814	3.092	2.169	1.6
	H44	766	-1.8	6.3	12.1	-15.2	0.839	2.814	2.295	1.5

Tab. 2 and Fig. 5 demonstrate a good agreement between the measured quantities and the results of simulations. However, in the case of air temperature, mean values calculated by UMPL are higher at about 1.5 °C than the observed ones.

5. Conclusions

The measurements from the buoy MIG-1 in 2000 and 2001 allowed to collect long and valuable series of meteorological data from the open sea. Until the buoy has been anchored, there was no such series of measurements in Polish waters and only scarce measurements from ships or measurements from the coast could be used for the characteristics of marine conditions. The data are of good quality, with almost no gaps in two main periods of measurements. These data have been used for the local assessment of two different models of the atmosphere, applied everyday by the marine operational services. Practically for the all measured parameters a good agreement has been obtained, and the existing discrepancies can serve as a valuable indicator, showing the way for the improvement of the validated models.

The data from the buoy MIG-1 are useful also for solving other research problems, they are used for current planning of activities in the sea in different maritime enterprises, rescue services, e.g., for combating oil or chemical spills. Long series of measurements can help for planning of hydro-technical constructions and in coastal protection.

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