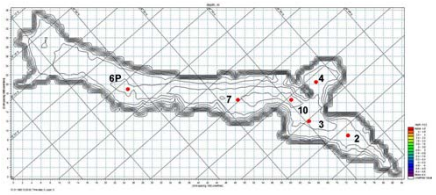
Modelling the response of thermo-hydrodynamic conditions of the Vistula Lagoon on the scenario of climate change in the Baltic Sea Region

Chubarenko B.V., Esiukova E.E., Leitsina L.V.
Atlantic Branch of P.P.Shirshov Institute of Oceanology of Russian Academy of Sciences, Prospect Mira, 1, Kaliningrad, 236000, Russia
chuboris@mail.ru, elena_esiukova@mail.ru, lvleitsina@mail.ru

DESCRIPTION OF MIKE21 MODEL SET-UP FOR THE VISTULA LAGOON



Area of investigation: Vistula lagoon.

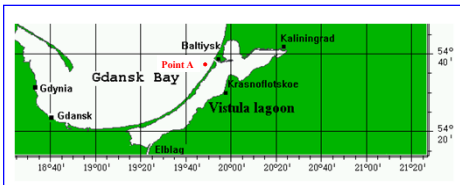
Map projection	UTM-34
Bathymetry	1 KB
Simulation period	01.01.1061-29.12.1937
Courant number	1.27812
Time step interval	180 sec
Grid	1000 m x 1000 m
Grid size	85 x 37 (0...84 - 0...36)
Origin of the grid λ	54.1016
Origin of the grid φ	19.5967
Orient.ofthe grid	310.96
Coordinates of open boundary	(57;22) - (58;22)
Bed Resistance	32 $m^{1/3}$/sec
Eddy Viscosity	20 m^2/sec
Dispersion coefficient	45 m^2/sec
Wind friction coefficient	Constant (0.0017)
Sources	12 rivers

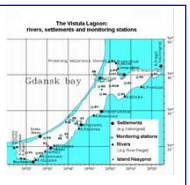
Calibration

For calibration of HD-module of MIKE21 on the grid 1000x1000m 26 tasks for period 5-14 October 1994 with various conditions were simulated : 3 different open boundaries + 3 kinds of wind + 3 wind friction coefficients + 4 Bed Resistance + 4 Eddy Viscosity (levels comparison) + 4 Eddy Viscosity (flows structure) + 4 Eddy Viscosity (currents on the stations) + 1 final simulation; total 59 pages of hard copies.

For calibration of AD-module of MIKE21 on the grid 1000x1000m about 35 tasks for period January, 1 - December, 31 1994 with various conditions were simulated : 10 different dispersion coefficients + about 12 tests with rivers + 6 variants of ice-cover modelling + 2 tests with salinity on the boundary + 5 variants of initial field of salinity in 1994.

Name of river or point source	Discharge m3/sec	%	Coordinates in 1KB grid x	Coordinates in 1KB grid y
Pregel	86.5	1	**81**	**3**
Pasleka	18.6	0.21503	**34**	**16**
Elblag	7.26	0.08393	**1**	**20**
Nogat	5.87	0.06786	**4**	**27**
Prockhladnaya	5.09	0.05884	**70**	**6**
Momonovka	3.49	0.04035	**44**	**14**
Bauda	2.74	0.03168	**27**	**15**
Szkarpawa	2.06	0.02382	**2**	**29**
Sewage collector	1.96	0.02266	**70**	**20**
Primorskaya	2.53	0.02925	**67**	**25**
Nelma	1.66	0.01919	**70**	**24**
Graevka	1.4	0.01618	**72**	**13**





Scenarios for simulations

Atmospheric forcing / Open sea boundary	**RCAO-HadCM3 ref-a1b-25km** (01.09.1957 –30.11.2099 [ftp.smhi.se]): 1. Air temperature; 2. Relative humidity; 3. Clearness coefficient; 4. Precipitation; 5. Precipitation Concentrations.	**RCAO_ECHAM5 5_a1b_25km** (01.09.1957 –31.12.2100 [ftp.smhi.se]): 1. Air temperature; 2. Relative humidity; 3. Clearness coefficient; 4. Precipitation; 5. Precipitation Concentrations.
BAU (hadley_a1b) (30.12.1945-30.12.2038): 1. sea surface elevation; 2. Wind (Constant in Space); 3. Salinity on the open boundary; 4. Temperature on the open boundary.	Results (01.01.1961 –29.12.2037): Temperature, Salinity, Water level, Surface elevation, U-velocity, V-velocity, Discharge (salinity)	Results (01.01.1961 –29.12.2037): Temperature, Salinity, Water level, Surface elevation, U-velocity, V-velocity, Discharge (salinity)
BSAP hadley_a1b (30.12.1945-29.12.2037): 1. sea surface elevation; 2. Wind (Constant in Space); 3. Salinity on the open boundary; 4. Temperature on the open boundary.	Results (01.01.1961 –29.12.2037): Temperature, Salinity, Water level, Surface elevation, U-velocity, V-velocity, Discharge (salinity)	Results (01.01.1961 –29.12.2037): Temperature, Salinity, Water level, Surface elevation, U-velocity, V-velocity, Discharge (salinity)

Open sea boundary

IOW biogeochemical model ERGOM:

st4_hadley_a1b_BSAP.dat

st4_hadley_a1b_BAU.dat

Information about point A (coordinates):

lons=19.85 lats=54.58

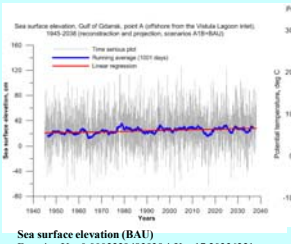
period of time for BSAP: 30.12.1945-29.12.2037

period of time for BAU: 30.12.1945-30.12.2038

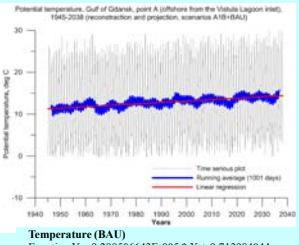
Atmospheric forcing

Numerical calculations of regional climate models for the entire Baltic Sea region - RCAO-HadCM3ref-a1b-25km and RCAO-ECHAM5_a1b_1_25km (Full coupled atmosphere-ocean circulation model with a horizontal resolution of ΔH = 25 km, with a script based on the emission A1B [IPCC, 2007]) give prognostic fields of temperature, mass fraction of moisture, the vector horizontal wind speed, surface pressure fields, etc. with sampling time Δt = 3 hours for the period 1957-2099 .[ftp.smhi.se].

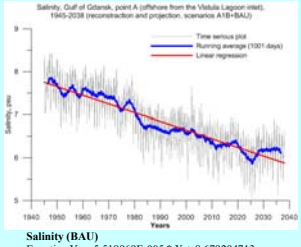
Open sea boundary conditions



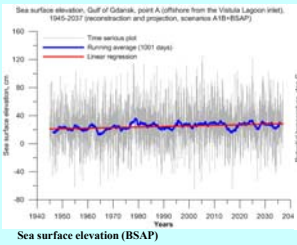
Sea surface elevation (BAU)
Equation Y = 0.0002229483939 * X + 17.20336221
30.12.1945-30.12.2038
Average Y = 24.7356
Coef of determination, R-squared = 0.0109



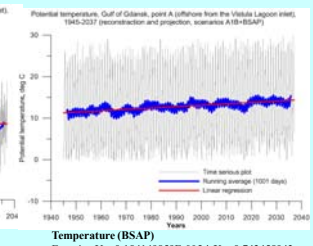
Temperature (BAU)
Equation Y = 9.288506643E-005 * X + 9.713984044
30.12.1945-30.12.2038
Average Y = 12.8521
Coef of determination, R-squared = 0.0116596



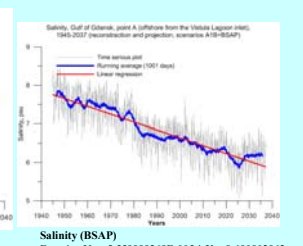
Salinity (BAU)
Equation Y = -5.518969E-005 * X + 8.679294713
30.12.1945-30.12.2038
Average Y = 6.81473
Coef of determination, R-squared = 0.721999



Sea surface elevation (BSAP)
Equation Y = 0.000220536097 * X + 17.27110507
30.12.1945-29.12.2037
Average Y = 24.6816
Coef of determination, R-squared = 0.0104399

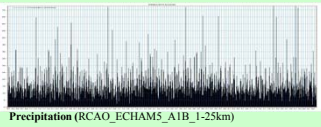


Temperature (BSAP)
Equation Y = 9.184149859E-005 * X + 9.743458943
30.12.1945-29.12.2037
Average Y = 12.8295
Coef of determination, R-squared = 0.0111698



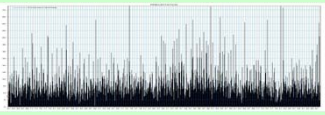
Salinity (BSAP)
Equation Y = -5.559988268E-005 * X + 8.690802962
30.12.1945-29.12.2037
Average Y = 6.82253
Coef of determination, R-squared = 0.721167

Atmospheric forcing



Precipitation (RCAO_ECHAM5_A1B_1-25km)

axis X: Years - 01.01.1961-31.12.2098; *axis Y*: **Pr** from 0 mm/day to 73mm/day

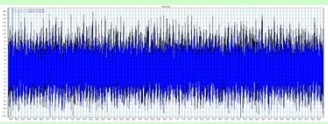


Precipitation (RCAO_HadCM3_A1B_25km)

axis X: Years - 01.01.1961-31.12.2098; *axis Y*: **Pr** from 0 mm/day to 73mm/day

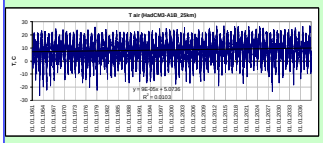
Relative humidity (RCAO HadCM3_A1B_25km)

axis X: Years - 01.01.1957-31.12.2047; *axis Y*: **Hum** from 0 to 1

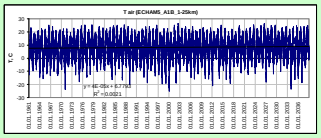


Wind: velocity U and V (RCAO HadCM3_A1B_25km)

axis X: Years - 01.01.1957-31.12.2057; *axis Y*: **U, V** from (-12.5m/s) to (17m/s)

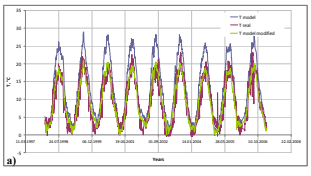


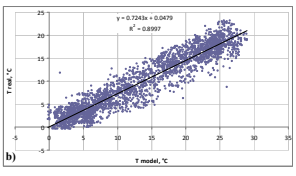
Air temperature (RCAO_HadCM3_A1B_25km)
axis X: Years - 01.01.1961-31.12.2037; *axis Y*: **T air** from (-30 °C) to (30°C)
Equation y = 9E-05x + 5.0736
R2 = 0.0103



Air temperature (RCAO_ECHAM5_A1B_1-25km)
axis X: Years - 01.01.1961-31.12.2037; *axis Y*: **T air** from (-30 °C) to (30°C)
Equation y = 4E-05x + 6.7793
R2 = 0.0021

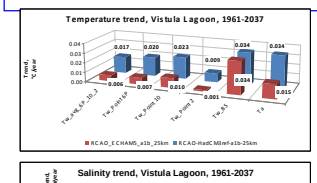
Sea water temperature: corrections of boundary conditions using observations in Baltiysk

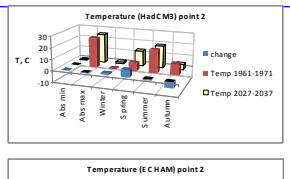


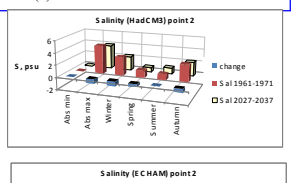


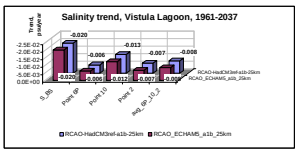
Modeled water temperature (BAU, BSAP (**Hadley_A1B**) at the point A, obtained by ERGOM model, and measured **water temperature** registered in the Baltiysk Strait were compared (a).

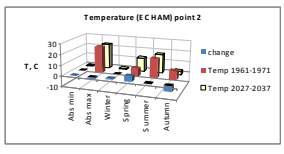
Linear regression equation for the period 01.01.1998-21.02.2007 was used (y = 0.724·x + 0.047) to tune the boundary conditions to real temperature conditions (b).

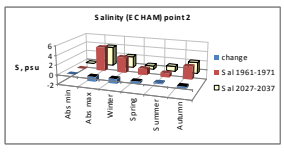












RESULTS

	Salinity (from Hadley_A1B): ΔS/Δt [psu/day]	Water salinity in Vistula lagoon (results of simulations) ΔS/Δt [psu/day]			
		Point 6P	Point 10	Point 2	avg_6P_10_2
RCAO-HadCM3ref-A1B-25km	-5.52E-05	-1.55E-05	-3.44E-05	-1.89E-05	-2.29E-05
RCAO_ECHAM5_A1B_1-25km	-5.52E-05	-1.69E-05	-3.42E-05	-1.83E-05	-2.31E-05

	Salinity (from Hadley_A1B): ΔS/Δt [psu/ year]	Water salinity in Vistula lagoon (results of simulations) ΔS/Δt [psu/ year]			
		Point 6P	Point 10	Point 2	avg_6P_10_2
RCAO-HadCM3ref-A1B-25km	-2.01E-02	-5.66E-03	-1.26E-02	-6.90E-03	-8.37E-03
RCAO_ECHAM5_A1B_1-25km	-2.01E-02	-6.17E-03	-1.25E-02	-6.68E-03	-8.44E-03

	Air temperature (from RCAO): ΔT/Δt [°C/day]	Temperature (from Hadley_A1B): ΔT/Δt [°C/day]	Water temperature in Vistula lagoon (results of simulations) ΔT/Δt [°C/day]			
			Point 6P	Point 10	Point 2	avg_6P_10_2
RCAO-HadCM3ref-A1B-25km	9.33E-05	9.29E-05	5.49E-05	6.25E-05	2.48E-05	4.74E-05
RCAO_ECHAM5_A1B_1-25km	4.06E-05	9.29E-05	1.97E-05	2.80E-05	3.49E-06	1.71E-05

	Air temperature (from RCAO): ΔT/Δt [°C/year]	Temperature (from Hadley_A1B): ΔT/Δt [°C/ year]	Water temperature in Vistula lagoon (results of simulations) ΔT/Δt [°C/ year]			
			Point 6P	Point 10	Point 2	avg_6P_10_2
RCAO-HadCM3ref-A1B-25km	3.41E-02	3.39E-02	2.00E-02	2.28E-02	9.05E-03	1.73E-02
RCAO_ECHAM5_A1B_1-25km	1.48E-02	3.39E-02	7.19E-03	1.02E-02	1.27E-03	6.23E-03

Conclusions

1. The calculations of the temperature and salinty of the Vistula Lagoon were made under the boundary conditions of scenarios RCAO-HadCM3 ref-a1b-25km and RCAO_ECHAM5 5_a1b_25km for the period of 1961 -2037.
2. Evironmental conditions of Vistula Lagoon vary according to changes in atmospheric forcing and conditions in the adjacent coastal waters of the Baltic Sea. The temperature of water increases, the trend in average is of 1.73E-02 (RCAO_HadCM3ref-A1B-25km) and 6.23E-03 (RCAO_ECHAM5_A1B_1-25km). Salinity decreases, the trend in average is of 8.37E-03 (RCAO_HadCM3ref-A1B-25km) and-8.44E-03 (RCAO_ECHAM5_A1B_1-25km).
3. The magnitude of temperature trend for the Vistula Lagoon is less than the temperature trend in both the adjacent sea areas (in 2-5.5 times) and in air conditions (in 2-2.4 times), the salinity trend for the Vistula Lagoon is less than the salinity trend in the adjacent sea areas in 2.4 times.
4. These unexpected features of the lower response of temperature and salinity of the Vistula Lagoon to the changing ambient conditions is likely due to increasing role of evaporation from the lagoon surface.

Acknowledgements

Authors thank colleagues from Swedish Hydrological and Meteorological Institute (especially Anders.Hoglund) for atmospheric forcing conditions, colleagues from Institute for Baltic sea Research, Warnemuende (especially Ivan Kuznetsov) for open sea conditions. MIKE21 model were provided by DHI during the Vistula Lagoon Project (1994-1996).

The investigation is supported by Bonus ECOSSUPORT Project and **RFBR grant № 08-05-92421**

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