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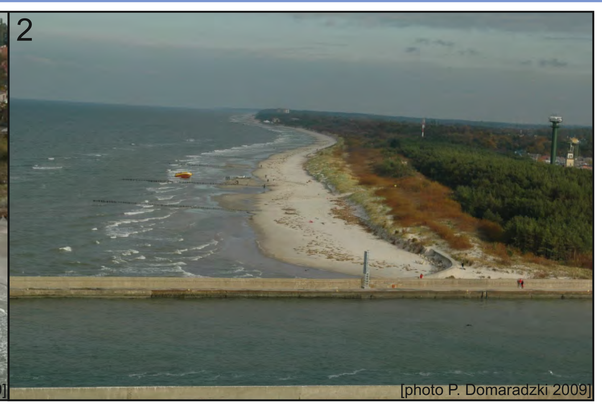
Dune erosion as a result of the significant storms at the western Polish coast (Dziwnow Spit example)



This poster presents analysis of significant storm parameters' influence on dune erosion size at fourteen 1-kilometer segments at the south Baltic dune coast (Dziwnow Spit).

AREA OF INVESTIGATION

The investigations were carried for 14-kilometer (399-385 km Maritime Office) segment of the south Baltic coast. The area of the analysis was mainly dune coasts of Dziwnow Spit, which constitutes only the fragment of the western Polish coast (Figure 1).

The area in the west of Martwa Dziwna mouth between 399 and 393 km is a natural coast, lacking of any hydrotechnical infrastructure. The segment localized in the east of Martwa Dziwna mouth is protected by the variable hydrotechnical constructions and activities, as groynes, seawalls and artificial beach nourishment.

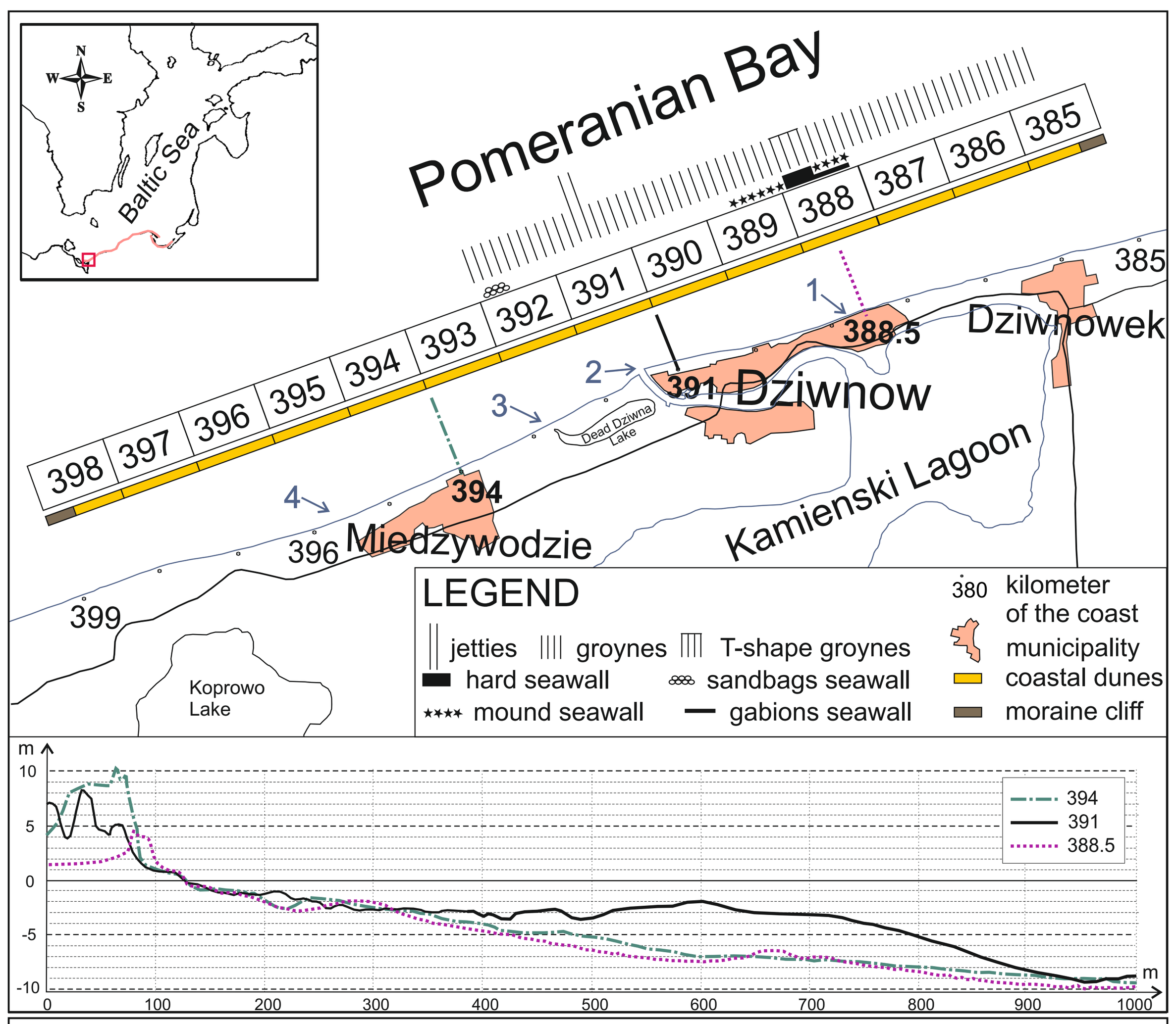


Figure 1. Area of investigation including kilometrage of the coast, methods of protection and representative profiles.

MATERIALS

For the described area size of dune erosion per every coast kilometer (m^3/km) were assembled, as well as storm parameters causing these consequences were defined. Table 1 shows combinations of the parameters used for the analysis. The following parameters were taken into consideration: dune volume eroded by every storm (D), the maximum height of the significant wave (H), the direction of the significant wave (A), the sea level (F), and the time of lasting (T) and storm energy (L).

Volume of dune eroded by every storm were estimated on a base of reports from the Maritime Office in Szczecin for the period 1978-2009.

Sea level data for Dziwnow was estimated using the average values of the sea levels recorded at Świnoujście and Kołobrzeg harbours.

Estimates of significant waves height and direction of max Hs were obtained from WAM model, using wind data from COAMPS model provided by the Interdisciplinary Centre for Mathematical and Computational Modeling of Warsaw University (ICM) in the framework of the project HIPOCAS EU. On a base of these parameters the storm duration Hs>1m and the storm energy $\Sigma(T*Hs^2)$ were calculated.

Table 1. Characteristics of the storms that caused dune erosion at every kilometer of the coast.

ID	Date	Total dune eroded (thou m^3)	Dune volume (thou m^3) eroded by every storm (- no data)														Storm energy $\Sigma(t*Hs^2)$	Sea level (cm)	Storm duration (h)	Max Hs (m)	Direction of max Hs (°)
		D	398	397	396	395	394	393	392	391	390	389	388	387	386	385	L	F	T	H	A
1	30.11.1978	72.8	–	–	–	–	–	–	–	6.8	25.6	17.7	12.4	9.4	0.9		205	580	56	2.42	204
2	8.11.1981	0.2									0.2						376	597	111	2.85	145
3	26.10.1986	0.6	0.1	0.05	0.05		0.3			0.1							125	595	24	3.6	137
4	20.12.1986	14.3				1.0		2.9		8.4	2.0						57	613	35	1.45	170
5	6.01.1987	0.7									0.7						92	610	29	2.18	218
6	2.11.1988	0.2				0.2											96	586	43	1.9	147
7	29.11.1988	76.9	1.2	1.4	3.5	4.8	12.4	11.0	3.5	0.6	6.2	2.5	0.5	8.6	13.4	7.3	195	632	45	3.21	155
8	27.11.1989	7.5	0.3	0.4	0.1		1.0	0.3	0.3		1.6	0.5	1.0	2.0			126	607	50	2.71	181
9	9.12.1989	0.7					0.5		0.2								186	614	54	2.89	170
10	2.03.1990	1.0									0.4	0.6					76	586	30	2.08	145
11	24.12.1991	1.1		0.05		0.05					0.4	0.6					202	587	58	2.48	166
12	17.01.1992	11.1	0.6	0.8	0.4	1.2	1.2				0.7	2.5	0.3	1.3	0.8	1.3	207	628	86	2.49	171
13	22.01.1993	10.1	0.3		0.05	0.1	0.05			4.8	0.5	0.4		1.3	0.2	2.4	190	582	62	2.34	124
14	21.02.1993	73.3	5.1	3.0	3.4	7.8	3.7	2.0	0.3	11.2	3.0	10.1	5.8	6.4	6.9	4.6	571	632	139	3.55	194
15	3.01.1995	6.1	0.5	0.3		2.0	0.4	0.6		0.7	0.2	0.4	0.2	0.5	0.3		141	618	86	1.77	206
16	28.03.1995	1.4								1.4							275	585	136	2.98	165
17	7.04.1995	22.2	1.1	0.8		0.1	1.0	0.5	1.0	7.7		3.2	3.9	0.7		2.2	153	614	79	2.05	167
18	31.08.1995	19.2	5.5	1.2	3.4	3.7	4.7	0.7		–	–	–	–	–	–	–	466	593	88	4.72	207
19	3.11.1995	497.6	14.0	26.0	22.0	38.0	48.0	26.0	14.5	20.0	18.3	5.6	108.2	50.0	57.0	50.0	313	650	72	3.97	208
20	11.04.1997	0.1						0.1									267	606	61	3.72	157
21	31.01.1998	2.3							0.8			0.5	1.0				150	585	54	2.27	208
22	21.01.2000	3.7							0.5			1.2	1.4	0.2		0.4	497	600	129	2.76	176
23	22.11.2001	8.9							1.8			5.2	1.1	0.6		0.2	198	598	61	2.67	176
24	2.01.2002	16.2	–	–	–	–	–	–	–			3.0	4.6	3.7	1.1	3.8	189	613	38	3.49	129
25	21.02.2002	21.8		2.0	0.6	0.2	0.2	0.6			2.2	4.3	4.2	4.0	0.7	2.8	60	622	11	3.34	207
26	8.10.2002	2.1							1.8				0.3				154	582	72	2.24	185
27	6.04.2003	1.1							0.6	0.5							173	590	64	2.09	206
28	6.12.2003	7.7		0.6	0.1	0.1	0.6	1.1	1.2		2.2	1.0	0.8				128	607	38	2.46	163
29	23.11.2004	50.1	0.1	1.6	4.1	1.3	4.7	8.6	5.4	1.3	4.6	4.6	4.6	4.6	4.6		153	602	43	2.44	183
30	1.11.2006	60.2		5.3	9.2	6.1	8.0	7.7	4.8		3.6	4.0	4.5	3.0	4.0		111	633	47	2.57	184
31	31.12.2006	6.4	–	–	–	–	–	–	–		0.9	1.5	1.5	1.0	1.5		54	553	13	3.03	116
32	14.10.2009	39.3	0.3	3.9	2.6	4.4	4.5	4.3	0.7	1.6	6.9	3.4	4.1	1.7	0.9		380	596	92	3.2	199

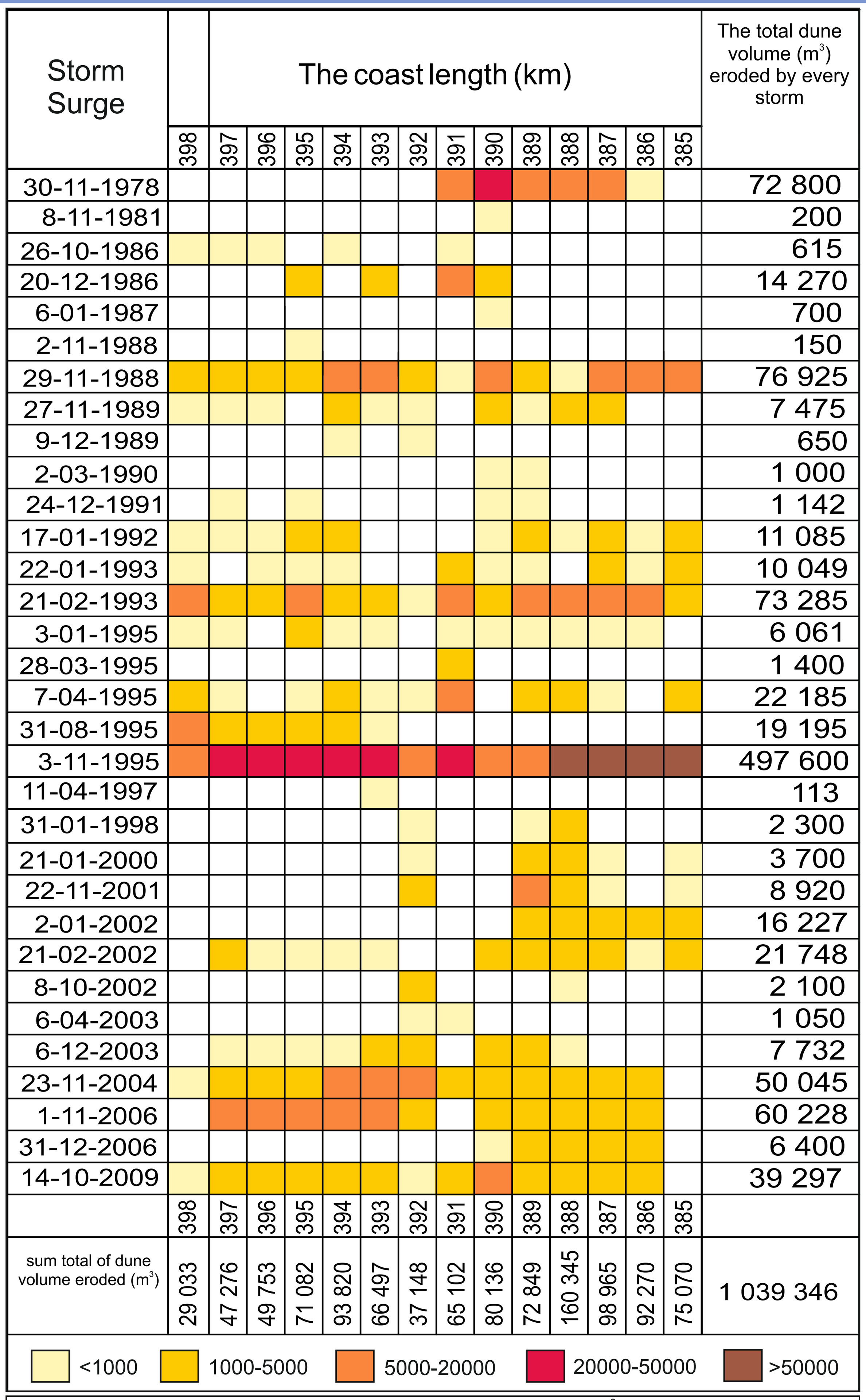


Figure 2. Spatial distribution of the dune volume eroded (m^3) per 1 kilometer of the coast.

METHODS

For the purpose of this study, it was assumed that a significant storm deemed significant causes noticeable sand dune erosion.

All collected data concerning the erosion size as well as wave parameters and storm surge shown in Table 1 have been analysed statistically. **Correlation analysis** between volume of dune erosion and storm parameters was carried out. **Hierarchical cluster analysis** using Ward's method, was applied to identify groups of storms affecting particularly kilometer of the coast (Figure 3A). **A classification tree** was used to identify storm thresholds for dune erosion for each kilometer of the coast (Figure 3B). All computations were performed using the **R package**.

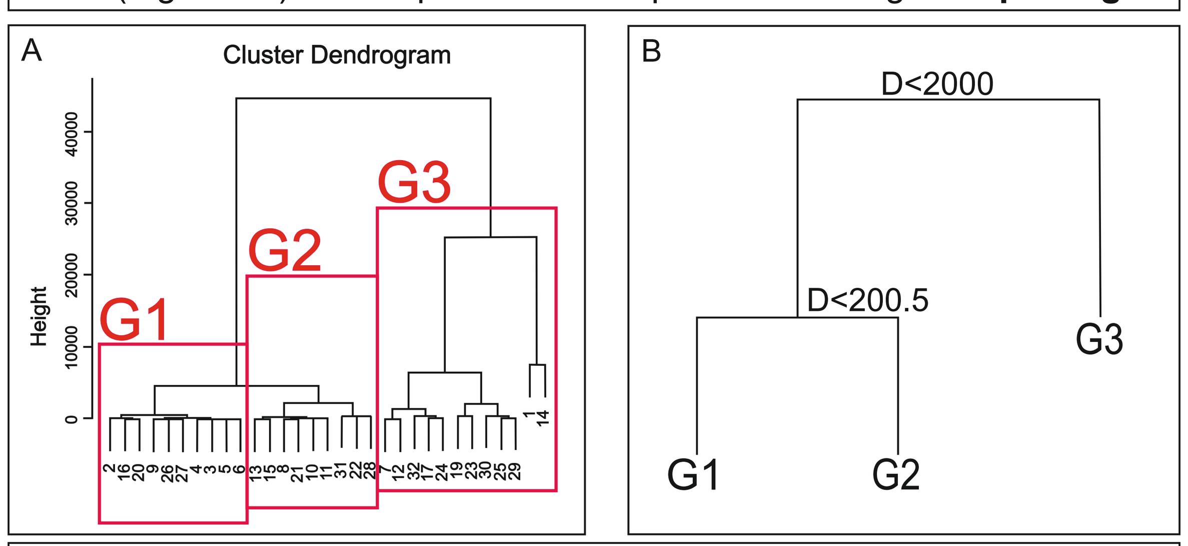


Figure 3. Example of the claster dendrogram (A) and a classification tree (B) for 389 km (results for the remaining 1 km segments are presented on Fig.4 & Fig.5).

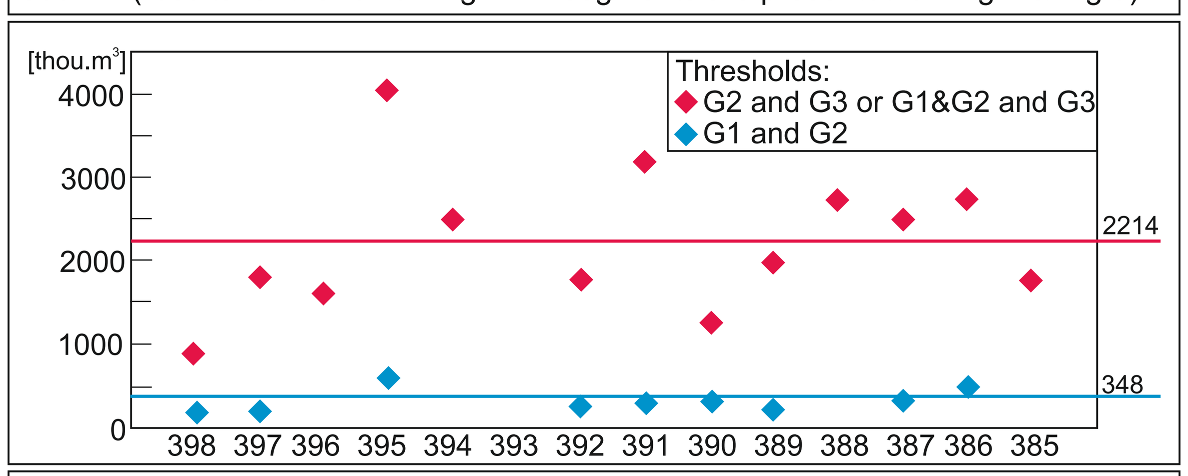


Figure 4. Thresholds values between groups of storm for particularly kilometer of the coast (with mean values between G1& G2 and G2&G3 for all kilometers).

ACKNOLEDGEMENT

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RESULTS

For the particular kilometers of the coast 3 classes of storms were distinguished: **small (G1), medium (G2) and high (G3).** The results are shown in Figure 5 (bottom panel). It is clear that the major number of storms causing the greatest erosive consequences are at kilometers 390, 389 and 387. Kilometer 387 is on the eastern side of hard seawall and there the side effects of seawall action converge. Kilometers 389 and 390 are between hard seawall (in the west of it) and groynes (in the east of them), which is an extreme disadvantage causing intensive coast erosion. Insignificant storm influence is recorded at 388 km (hard seawall), at 385 km (relatively stable coast), 394 and 396 km (lack of protection).

Analysis of the **correlation coefficient** value shows (Figure 5 top panel) that at almost every kilometer the greatest correlation exists between the sea level and the size of dune erosion, especially in the eastern part of examined coast (391-398 km). A relatively great correlation coefficient value was found for the protected part (385-388 km), whereas on the area between hard seawall and groynes the influence of the sea level on the size of dune erosion is relatively insignificant. Similarly, the height of the significant wave has great impact in the western and eastern part of the examined area, and only insignificantly smaller one at 389-391 km, that is between seawall and groynes. The significant wave azimuth shows the greatest correlation with the erosion size at kilometers 389 and 390. In case of the remaining storm parameters, their correlation with the dune erosion size is low. The storm duration time has no significance in most cases; only in case of groynes (391 km) and the western coast area (398 km) the correlation is more significant.

Using the classification scheme, dune erosion **threshold values** were evolved for the particular storm groups for every kilometer of the coast. The results are shown in Figure 4. For the following kilometers: 396, 394, 388 and 385, only threshold discrimination between groups G1 & G2 and G3 was possible, whereas in case of 393 km we were unable to distinguish any threshold.

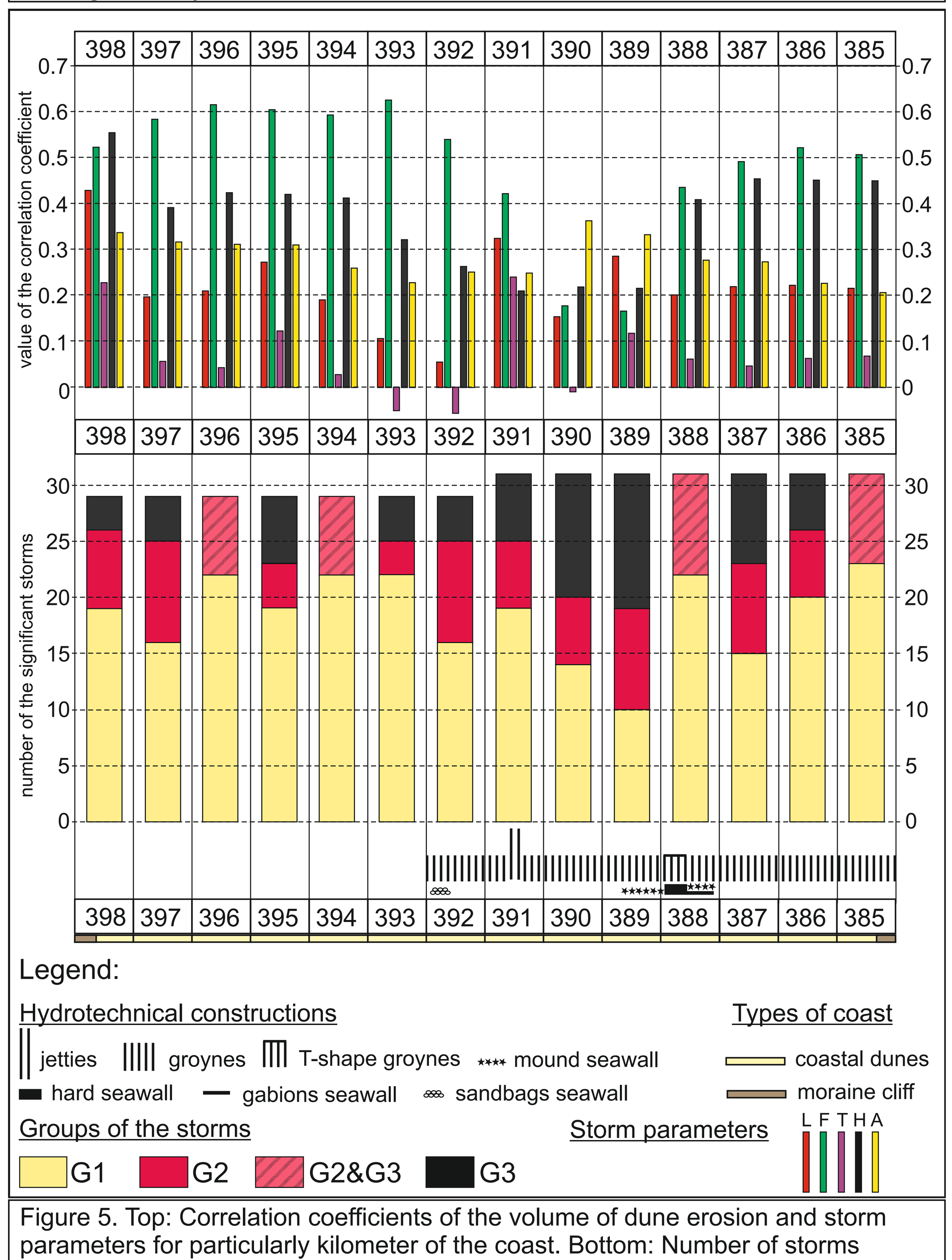

Figure 5. Top: Correlation coefficients of the volume of dune erosion and storm parameters for particularly kilometer of the coast. Bottom: Number of storms belong to groups of storms G1, G2 and G3 for particularly kilometer of the coast.

CONCLUSIONS

In case of significant storms sea level (F) has the highest impact to the size of dune erosion (D). Next significant is the wave hight (H) and subsequently significant is the wave direction (A). At the natural coast influence of the sea level (F) is slightly higher than at the protected coast. Significant wave height (H) is slightly more important for the protected coast. Significant wave direction (A) is slightly more important for the natural coast than for the protected coast.

Specific situation occurs at kilometers 389 and 390, located between the Dziwna mouth protected by jetties and hard seawall (388 km), where the highest impact to the size of dune erosion (D) is allocated to the direction of significant wave (A), next to the significant wave height (H) and subsequently to the level of the sea (F).