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

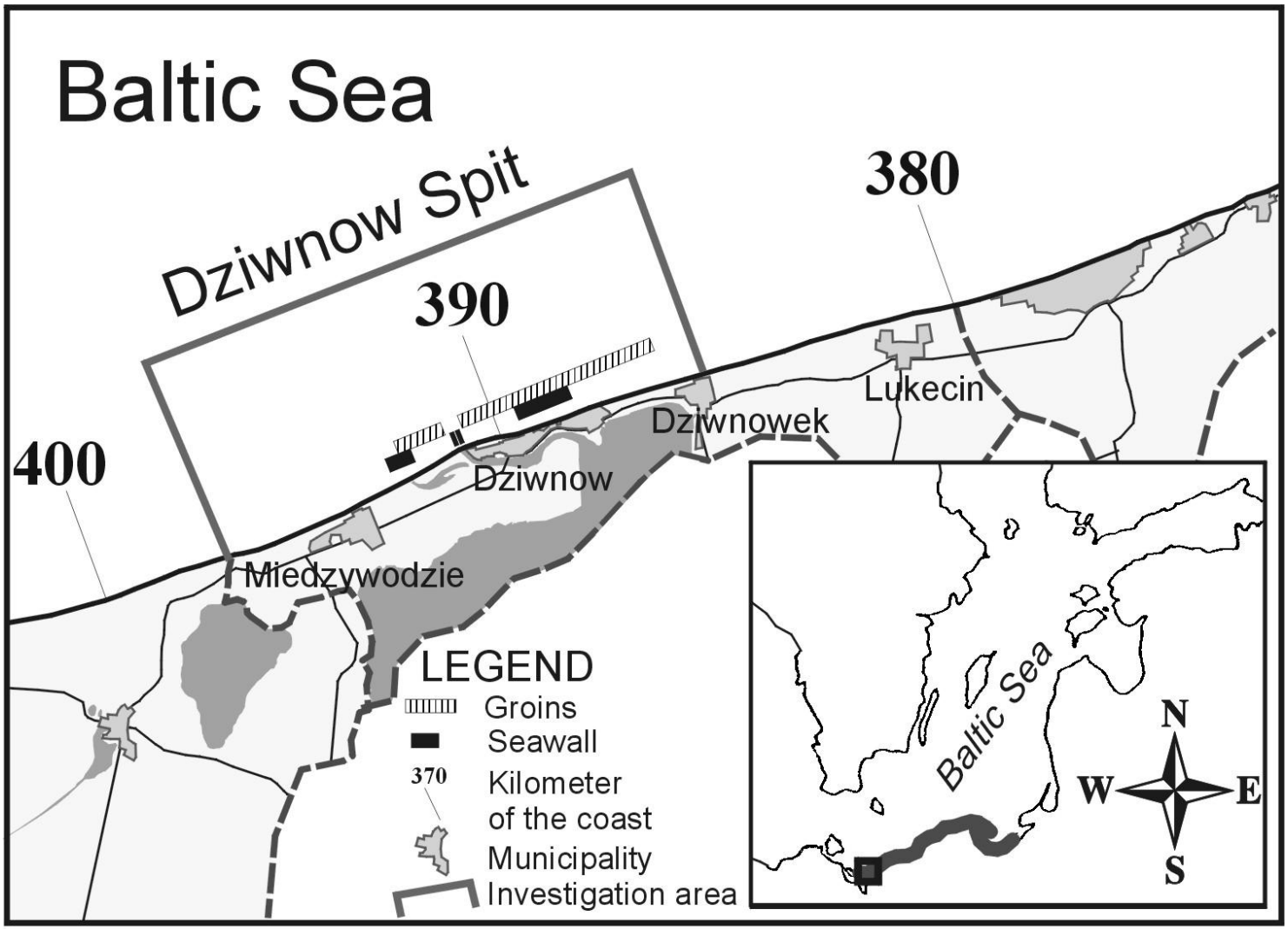
Joanna Dudzińska-Nowak[1], Kazimierz Furmańczyk[1], Konrad Furmańczyk[2], Barbara Paplińska-Swerpel[3], Natalia Brzezowska[1]

[1] University of Szczecin
[2] Warsaw University of Life Sciences
[3] Institute of Hydro-Engineering of the Polish Academy of Sciences

The research presented was supported by the European Community's Seventh Framework Programme under grant agreement No. 202798 (MICORE Project)

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

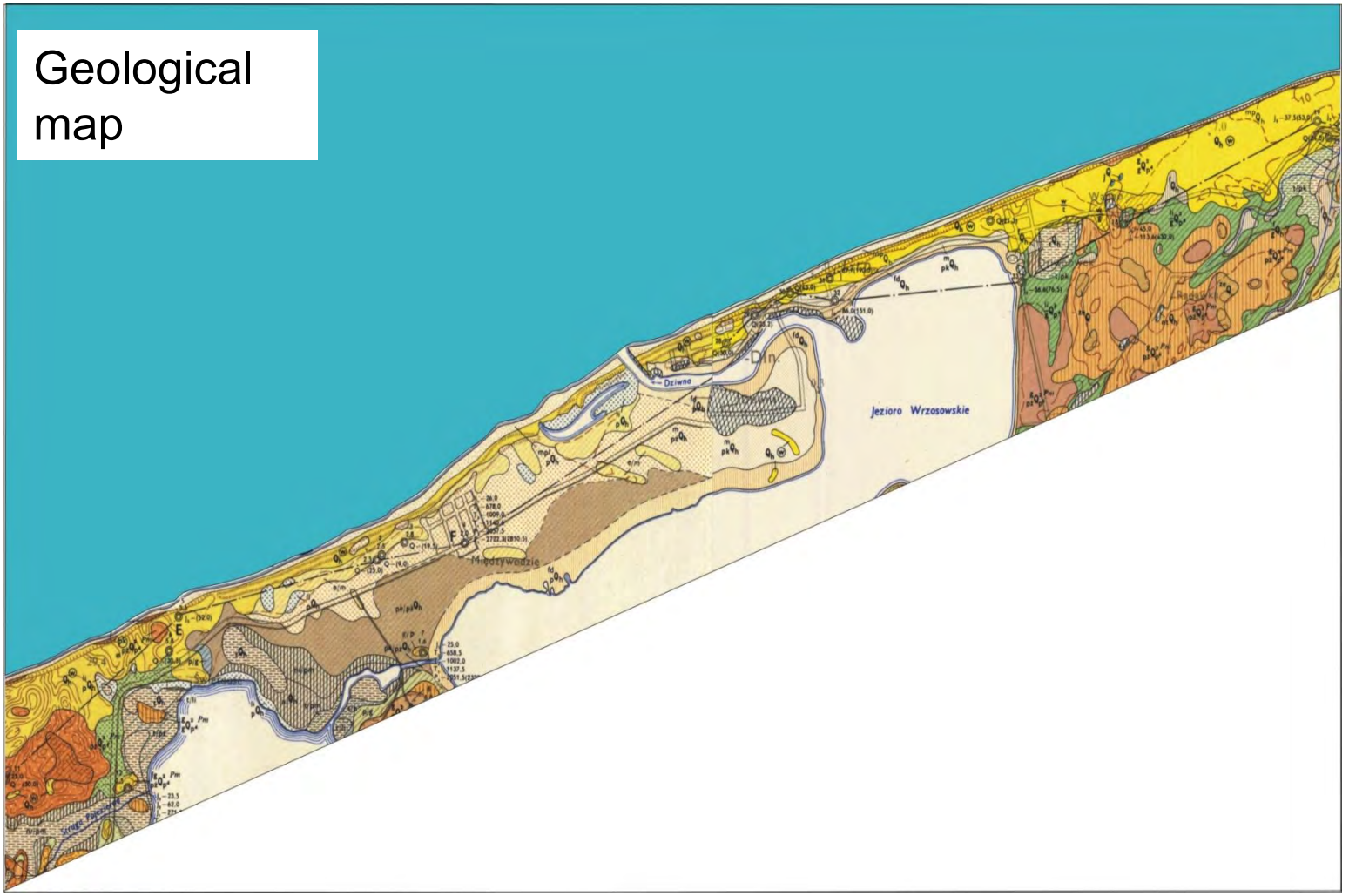
Joanna Dudzińska-Nowak, Kazimierz Furmańczyk, Konrad Furmańczyk, Barbara Paplińska-Swerpel, Natalia Brzezowska



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

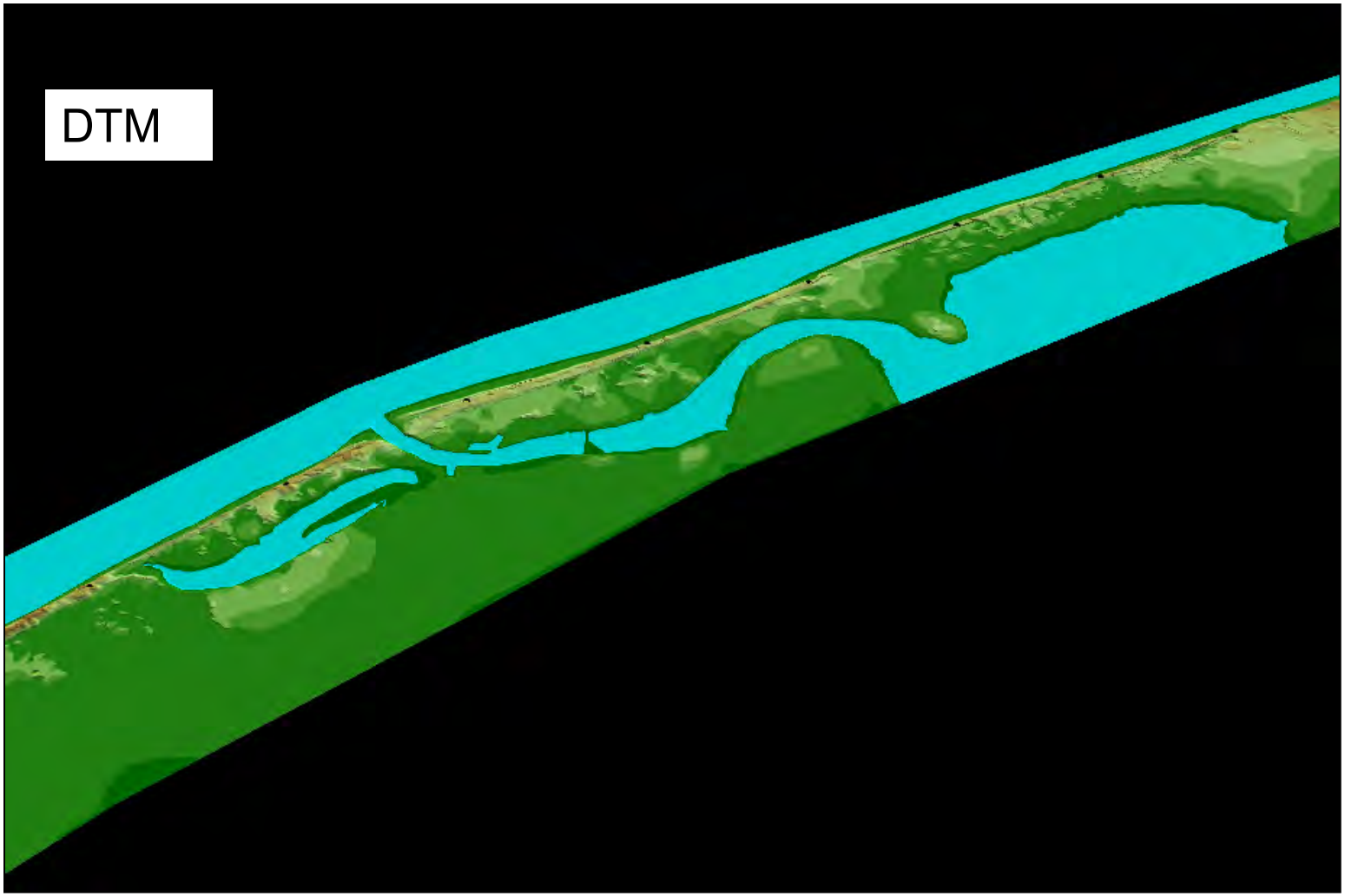
Joanna Dudzińska-Nowak, Kazimierz Furmańczyk, Konrad Furmańczyk, Barbara Paplińska-Swerpel, Natalia Brzezowska

## Geological map



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

Joanna Dudzińska-Nowak, Kazimierz Furmańczyk, Konrad Furmańczyk, Barbara Paplińska-Swerpel, Natalia Brzezowska



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

Joanna Dudzińska-Nowak, Kazimierz Furmańczyk, Konrad Furmańczyk, Barbara Paplińska-Swerpel, Natalia Brzezowska

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

Joanna Dudzińska-Nowak, Kazimierz Furmańczyk, Konrad Furmańczyk, Barbara Paplińska-Swerpel, Natalia Brzezowska

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

Joanna Dudzińska-Nowak, Kazimierz Furmańczyk, Konrad Furmańczyk, Barbara Paplińska-Swerpel, Natalia Brzezowska

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

Joanna Dudzińska-Nowak, Kazimierz Furmańczyk, Konrad Furmańczyk, Barbara Paplińska-Swerpel, Natalia Brzezowska

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

Joanna Dudzińska-Nowak, Kazimierz Furmańczyk, Konrad Furmańczyk, Barbara Paplińska-Swerpel, Natalia Brzezowska

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

Joanna Dudzińska-Nowak, Kazimierz Furmańczyk, Konrad Furmańczyk, Barbara Paplińska-Swerpel, Natalia Brzezowska

## GOAL

The goal of the investigations was probe of defining importancy of the significant storm parameters for the particulary sections of the coast.

Storm occurs when the wind force exceeds 8 Bft.
Storm surge occurs when the mean sea level is exceeded by 70 cm or more (MAJEWSKI *et al.*,1983).

For Dziwnow :
Warning state – 560 cm
Alarm state – 580 cm
(mean sea level – 500 cm)

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

# MATERIALS:

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

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

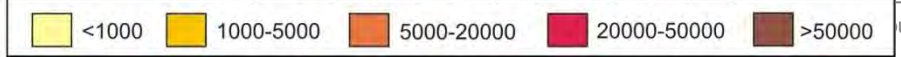
- Estimates of **significant waves height (H)** and **direction of max Hs (A)** were obtained from WAM model, using wind data from COAMPS model provided by the Interdisciplinary Centre for Mathematical and Computational Modeling of Warsaw University (ICM) in the framework of the project HIPOCAS EU (Cieślikiewicz, Paplińska-Swerpel, 2008).
  - storm duration **(T)** Hs > 1 m
  - storm energy **(L)** $\Sigma(T*Hs^2)$

C

| ID | Date | The total dune volume (m3) eroded by every storm 398-385 km (14km) | Storm energy Σ(t*Hs2) | Sea level (cm) | Storm duration (h) | Max Hs (m) | Direction of max Hs (o) |
|---|---|---|---|---|---|---|---|
| | | **D** | **L** | **F** | **T** | **H** | **A** |
| 1 | 30-11-1978 | 72 800 | 205 | 580 | 56 | 2,42 | 204 |
| 2 | 8-11-1981 | 200 | 376 | 597 | 111 | 2,85 | 145 |
| 3 | 26-10-1986 | 615 | 125 | 595 | 24 | 3,6 | 137 |
| 4 | 20-12-1986 | 14 270 | 57 | 613 | 35 | 1,45 | 170 |
| 5 | 6-01-1987 | 700 | 92 | 610 | 29 | 2,18 | 218 |
| 6 | 2-11-1988 | 150 | 96 | 586 | 43 | 1,9 | 147 |
| 7 | 29-11-1988 | 76 925 | 195 | 632 | 45 | 3,21 | 155 |
| 8 | 27-11-1989 | 7 475 | 126 | 607 | 50 | 2,71 | 181 |
| 9 | 9-12-1989 | 650 | 186 | 614 | 54 | 2,89 | 170 |
| 10 | 2-03-1990 | 1 000 | 76 | 586 | 30 | 2,08 | 145 |
| 11 | 24-12-1991 | 1 142 | 202 | 587 | 58 | 2,48 | 166 |
| 12 | 17-01-1992 | 11 085 | 207 | 628 | 86 | 2,49 | 171 |
| 13 | 22-01-1993 | 10 049 | 190 | 582 | 62 | 2,34 | 124 |
| 14 | 21-02-1993 | 73 285 | 571 | 632 | 139 | 3,55 | 194 |
| 15 | 3-01-1995 | 6 061 | 141 | 618 | 86 | 1,77 | 206 |
| 16 | 28-03-1995 | 1 400 | 275 | 585 | 136 | 2,98 | 165 |
| 17 | 7-04-1995 | 22 185 | 153 | 614 | 79 | 2,05 | 167 |
| 18 | 31-08-1995 | 19 195 | 466 | 593 | 88 | 4,72 | 207 |
| 19 | 3-11-1995 | 497 600 | 313 | 650 | 72 | 3,97 | 208 |
| 20 | 11-04-1997 | 113 | 267 | 606 | 61 | 3,72 | 157 |
| 21 | 31-01-1998 | 2 300 | 150 | 585 | 54 | 2,27 | 208 |
| 22 | 21-01-2000 | 3 700 | 497 | 600 | 129 | 2,76 | 176 |
| 23 | 22-11-2001 | 8 920 | 198 | 598 | 61 | 2,67 | 176 |
| 24 | 2-01-2002 | 16 227 | 189 | 613 | 38 | 3,49 | 129 |
| 25 | 21-02-2002 | 21 748 | 60 | 622 | 11 | 3,34 | 207 |
| 26 | 8-10-2002 | 2 100 | 154 | 582 | 72 | 2,24 | 185 |
| 27 | 6-04-2003 | 1 050 | 173 | 590 | 64 | 2,09 | 206 |
| 28 | 6-12-2003 | 7 732 | 128 | 607 | 38 | 2,46 | 163 |
| 29 | 23-11-2004 | 50 045 | 153 | 602 | 43 | 2,44 | 183 |
| 30 | 1-11-2006 | 60 228 | 111 | 633 | 47 | 2,57 | 184 |
| 31 | 31-12-2006 | 6 400 | 54 | 553 | 13 | 3,03 | 116 |
| 32 | 14-10-2009 | 39 297 | 380 | 596 | 92 | 3,2 | 199 |

Dune volume eroded ($m^3$) per 1 km of the coast.

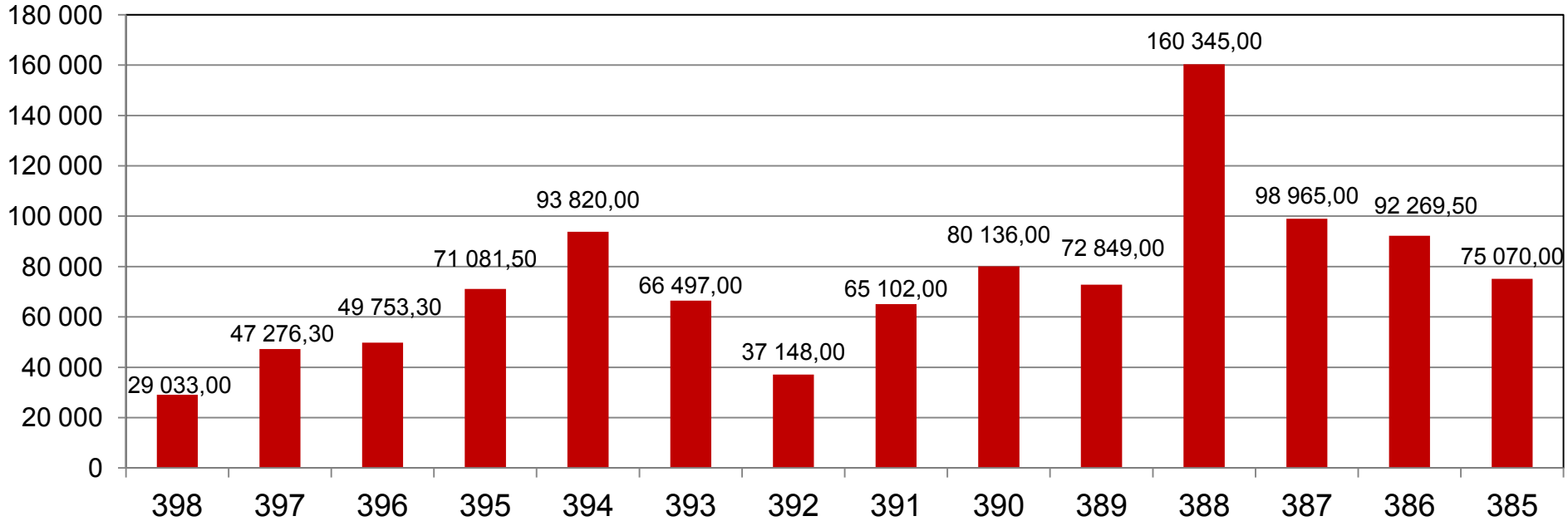
| Storm Surge | The coast length (km) | | | | | | | | | | | | | | The total dune volume ($m^3$) eroded by every storm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 398 | 397 | 396 | 395 | 394 | 393 | 392 | 391 | 390 | 389 | 388 | 387 | 386 | 385 | |
| 30-11-1978 | | | | | | | | | | | | | | | 72 800 |
| 8-11-1981 | | | | | | | | | | | | | | | 200 |
| 26-10-1986 | | | | | | | | | | | | | | | 615 |
| 20-12-1986 | | | | | | | | | | | | | | | 14 270 |
| 6-01-1987 | | | | | | | | | | | | | | | 700 |
| 2-11-1988 | | | | | | | | | | | | | | | 150 |
| 29-11-1988 | | | | | | | | | | | | | | | 76 925 |
| 27-11-1989 | | | | | | | | | | | | | | | 7 475 |
| 9-12-1989 | | | | | | | | | | | | | | | 650 |
| 2-03-1990 | | | | | | | | | | | | | | | 1 000 |
| 24-12-1991 | | | | | | | | | | | | | | | 1 142 |
| 17-01-1992 | | | | | | | | | | | | | | | 11 085 |
| 22-01-1993 | | | | | | | | | | | | | | | 10 049 |
| 21-02-1993 | | | | | | | | | | | | | | | 73 285 |
| 3-01-1995 | | | | | | | | | | | | | | | 6 061 |
| 28-03-1995 | | | | | | | | | | | | | | | 1 400 |
| 7-04-1995 | | | | | | | | | | | | | | | 22 185 |
| 31-08-1995 | | | | | | | | | | | | | | | 19 195 |
| 3-11-1995 | | | | | | | | | | | | | | | 497 600 |
| 11-04-1997 | | | | | | | | | | | | | | | 113 |
| 31-01-1998 | | | | | | | | | | | | | | | 2 300 |
| 21-01-2000 | | | | | | | | | | | | | | | 3 700 |
| 22-11-2001 | | | | | | | | | | | | | | | 8 920 |
| 2-01-2002 | | | | | | | | | | | | | | | 16 227 |
| 21-02-2002 | | | | | | | | | | | | | | | 21 748 |
| 8-10-2002 | | | | | | | | | | | | | | | 2 100 |
| 6-04-2003 | | | | | | | | | | | | | | | 1 050 |
| 6-12-2003 | | | | | | | | | | | | | | | 7 732 |
| 23-11-2004 | | | | | | | | | | | | | | | 50 045 |
| 1-11-2006 | | | | | | | | | | | | | | | 60 228 |
| 31-12-2006 | | | | | | | | | | | | | | | 6 400 |
| 14-10-2009 | | | | | | | | | | | | | | | 39 297 |
| | 398 | 397 | 396 | 395 | 394 | 393 | 392 | 391 | 390 | 389 | 388 | 387 | 386 | 385 | |
| sum total of dune volume eroded ($m^3$) | 29 033 | 47 276 | 49 753 | 71 082 | 93 820 | 66 497 | 37 148 | 65 102 | 80 136 | 72 849 | 160 345 | 98 965 | 92 270 | 75 070 | 1 039 346 |

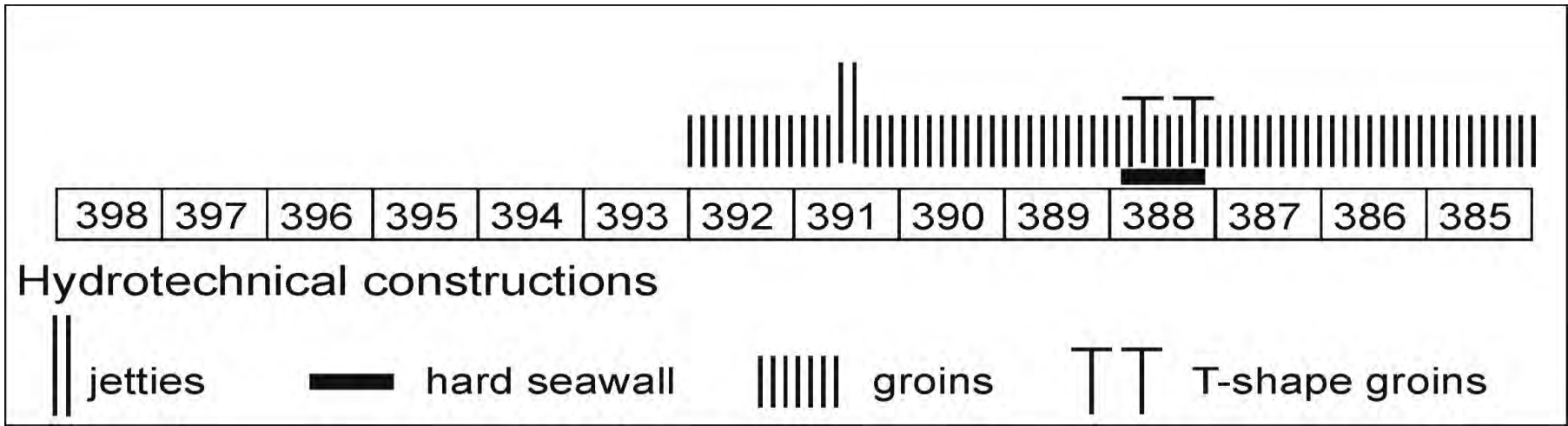


# Dune erosion as a result of the significant storms at the western Polish coast (Dziwnow Spit example).

Joanna Dudzińska-Nowak, Kazimierz Furmańczyk, Konrad Furmańczyk, Barbara Paplińska-Swerpel, Natalia Brzezowska

## Dune volume eroded per 1 km (thou. $m^3$) by all storms (1978-2009).



METHODS:

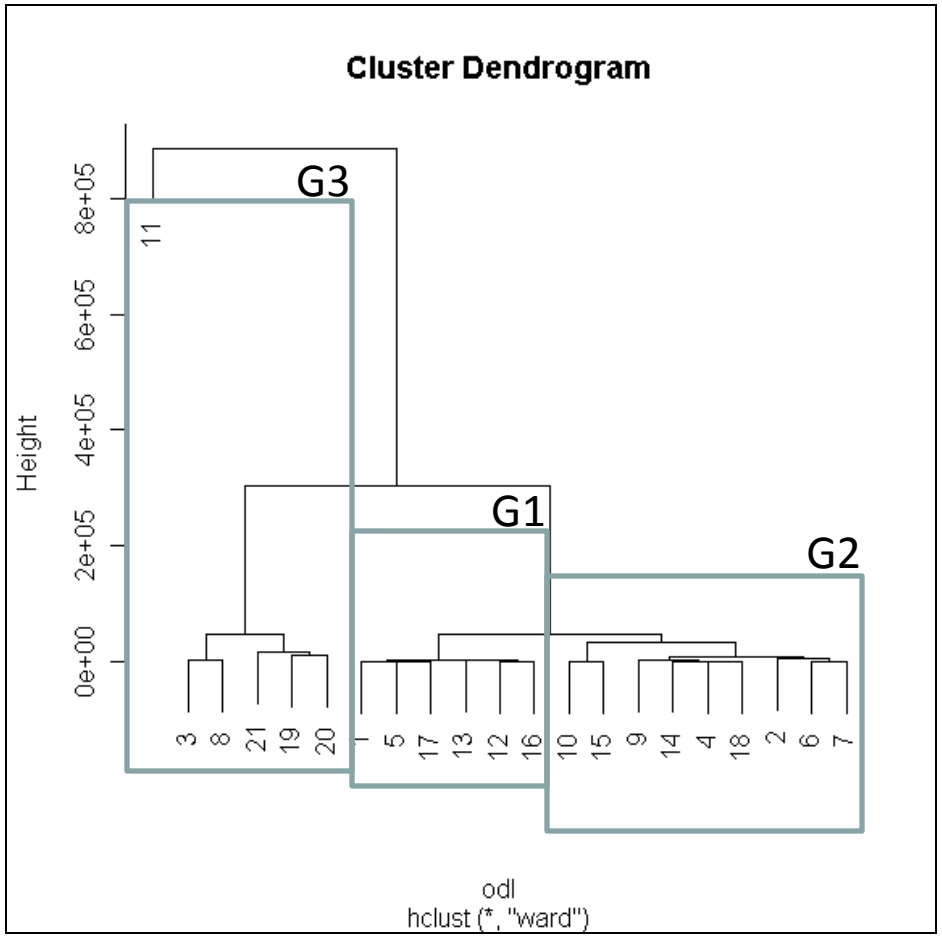
The statistical analysis of the data were performed using **R package**:

▪ **Storms were divided** into groups by **hierarchical cluster analysis** using Ward method for the whole area and for each kilometre of the coast.

•The **threshold values** of dune erosion for the groups of storms identified by the Ward's method were obtained using a **classification tree** for the whole area and for each kilometre of the coast.

▪ The **matrix of the correlation coefficients** of the storm parameters were calculated for every one kilometre section of the coast.

Storms were divided into groups by hierarchical cluster analysis using Ward method.




Groups of storms that cause varying volume of dune erosion:
G1: 1, 5, 17, 13, 12, 16 - small
G2: 10, 15, 9, 14, 4, 18, 2, 6, 7 – medium
G3: 3, 8, 21, 19, 20 (11 dodana) – high

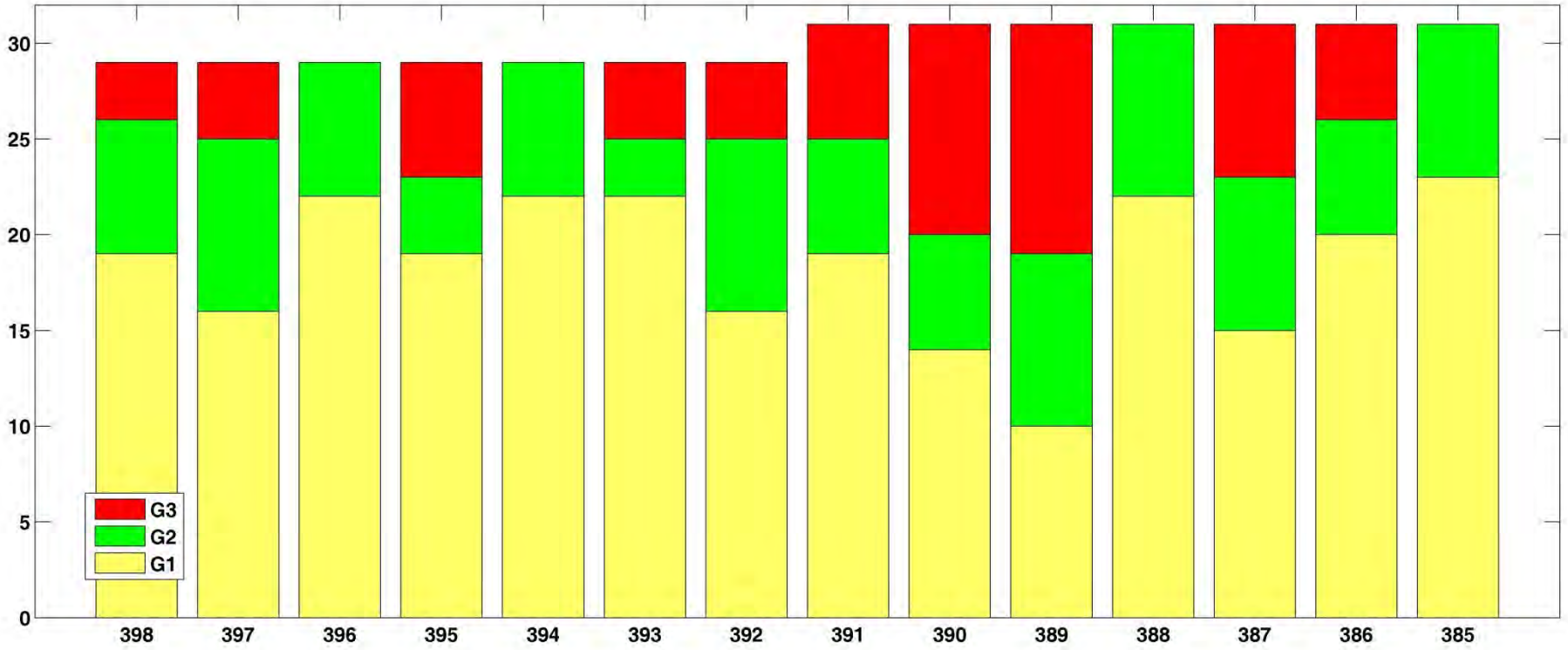
Storms were divided into groups by hierarchical cluster analysis using Ward method.

## Cluster Dendrogram

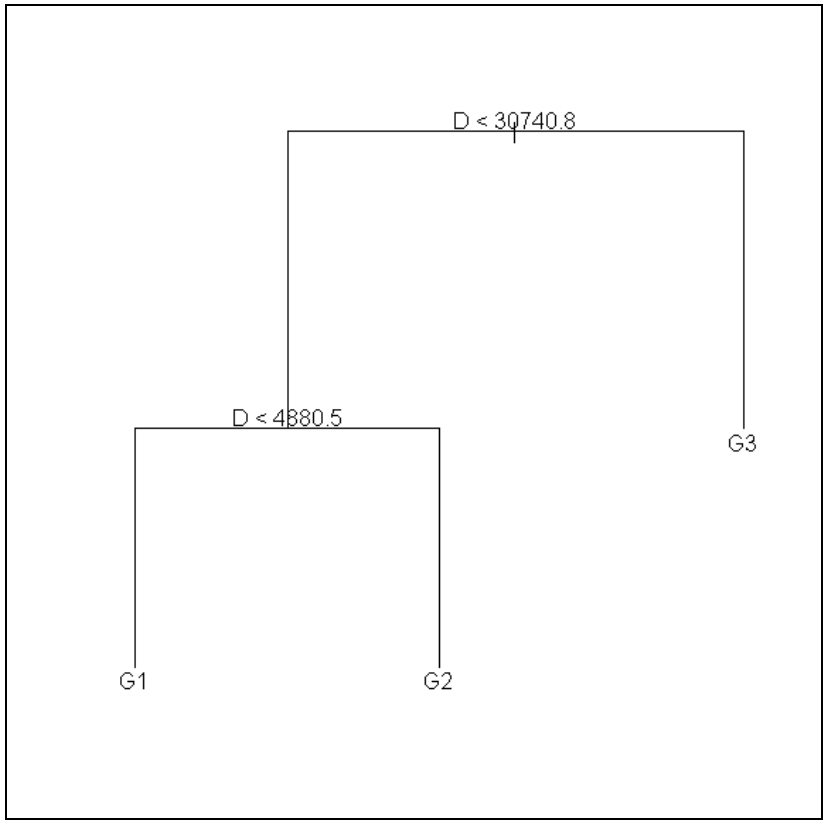
| km | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 398 | | * | * | * | * | * | o | o | * | * | * | o | o | x | o | * | o | x | x | * | * | * | * | | * | * | * | * | * | * | | o |
| 397 | | * | * | * | * | * | o | o | * | * | * | o | * | x | o | * | o | o | x | * | * | * | * | | o | * | * | o | o | x | | x |
| 396 | | * | * | * | * | * | o | * | * | * | * | * | * | o | * | * | * | o | o | * | * | * | * | | * | * | * | * | o | o | | o |
| 395 | | * | * | o | * | * | x | * | * | * | * | o | * | x | o | * | * | x | x | * | * | * | * | | * | * | * | * | o | x | | x |
| 394 | | * | * | * | * | * | o | * | * | * | * | * | * | o | * | * | * | o | o | * | * | * | * | | * | * | * | * | o | o | | o |
| 393 | | * | * | o | * | * | x | * | * | * | * | * | * | o | * | * | * | * | x | * | * | * | * | | * | * | * | * | x | x | | o |
| 392 | | * | * | * | * | * | x | * | * | * | * | * | * | o | * | * | o | * | x | * | o | o | o | | * | o | o | o | x | x | | o |
| 391 | x | * | * | x | * | * | o | * | * | * | * | * | x | x | o | o | x | | x | * | * | * | * | * | * | * | o | * | o | * | * | o |
| 390 | x | * | * | x | o | * | x | x | * | o | o | o | o | x | * | * | * | | x | * | * | * | * | * | x | * | * | x | x | x | o | x |
| 389 | x | * | * | * | * | * | x | o | * | o | o | x | o | x | o | * | x | | x | * | o | o | x | x | x | * | * | o | x | x | o | x |
| 388 | o | * | * | * | * | * | * | * | * | * | * | * | * | o | * | * | o | | o | * | * | * | * | o | o | * | * | * | o | o | * | o |
| 387 | x | * | * | * | * | * | x | o | * | * | * | o | o | x | o | * | o | | x | * | * | * | o | x | x | * | * | * | x | x | o | o |
| 386 | o | * | * | * | * | * | x | * | * | * | * | o | * | x | * | * | * | | x | * | * | * | * | o | o | * | * | * | x | x | o | o |
| 385 | * | * | * | * | * | * | o | * | * | * | * | o | o | o | * | * | o | | o | * | * | * | * | o | o | * | * | * | * | * | * | * |

* - G1 o - G2 x - G3

Storms were divided into groups by hierarchical cluster analysis using Ward method.



The threshold values of dune erosion for the groups of the storms identified by the Ward's method were obtained using a classification tree.



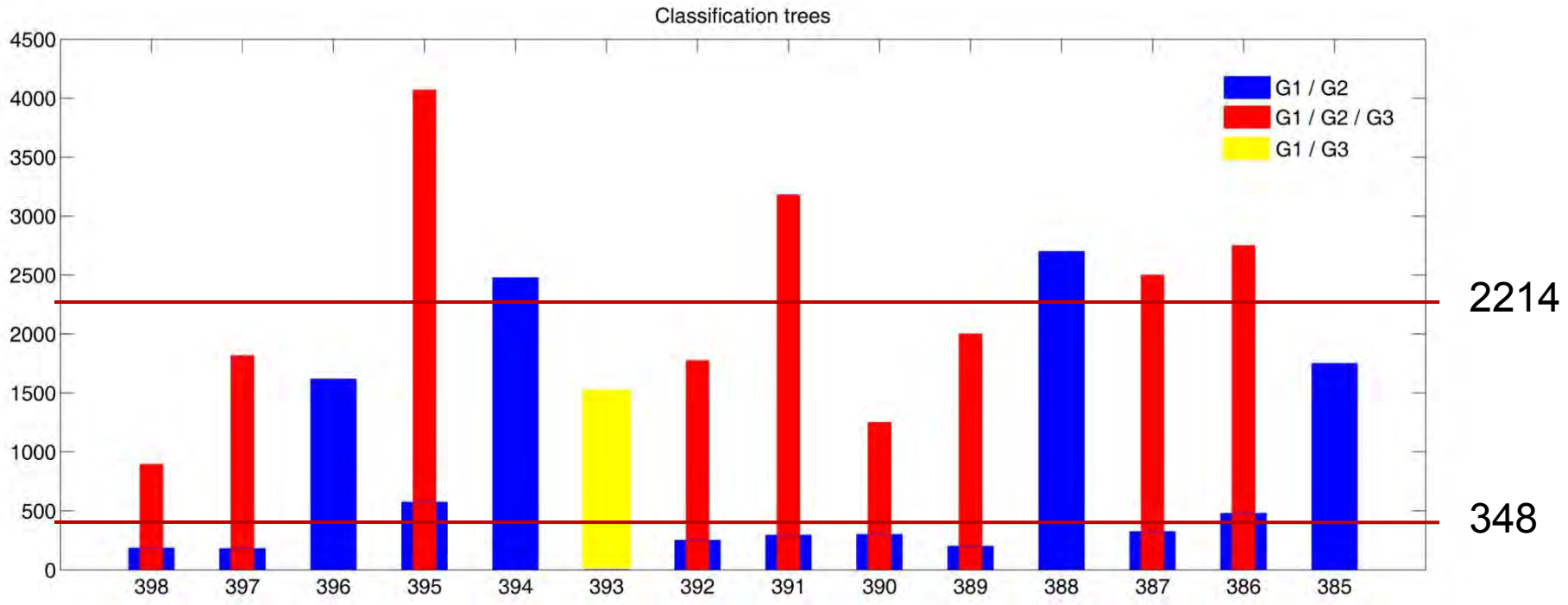

Estimated tresholds:

$D_1 < 5\ 000\ m^3$

$5000\ m^3 \leq D_2 \leq 50000\ m^3$

$D_3 > 50000\ m^3$

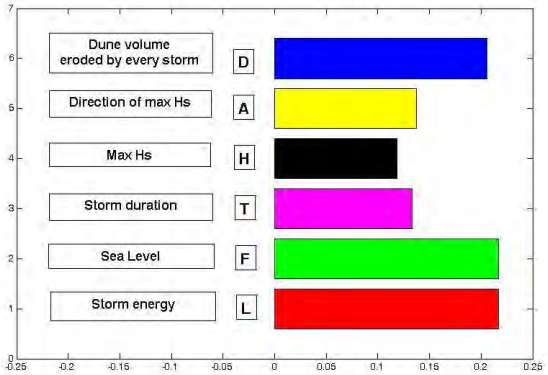
The threshold values of dune erosion for the groups identified by the Ward's method were obtained using a classification tree.

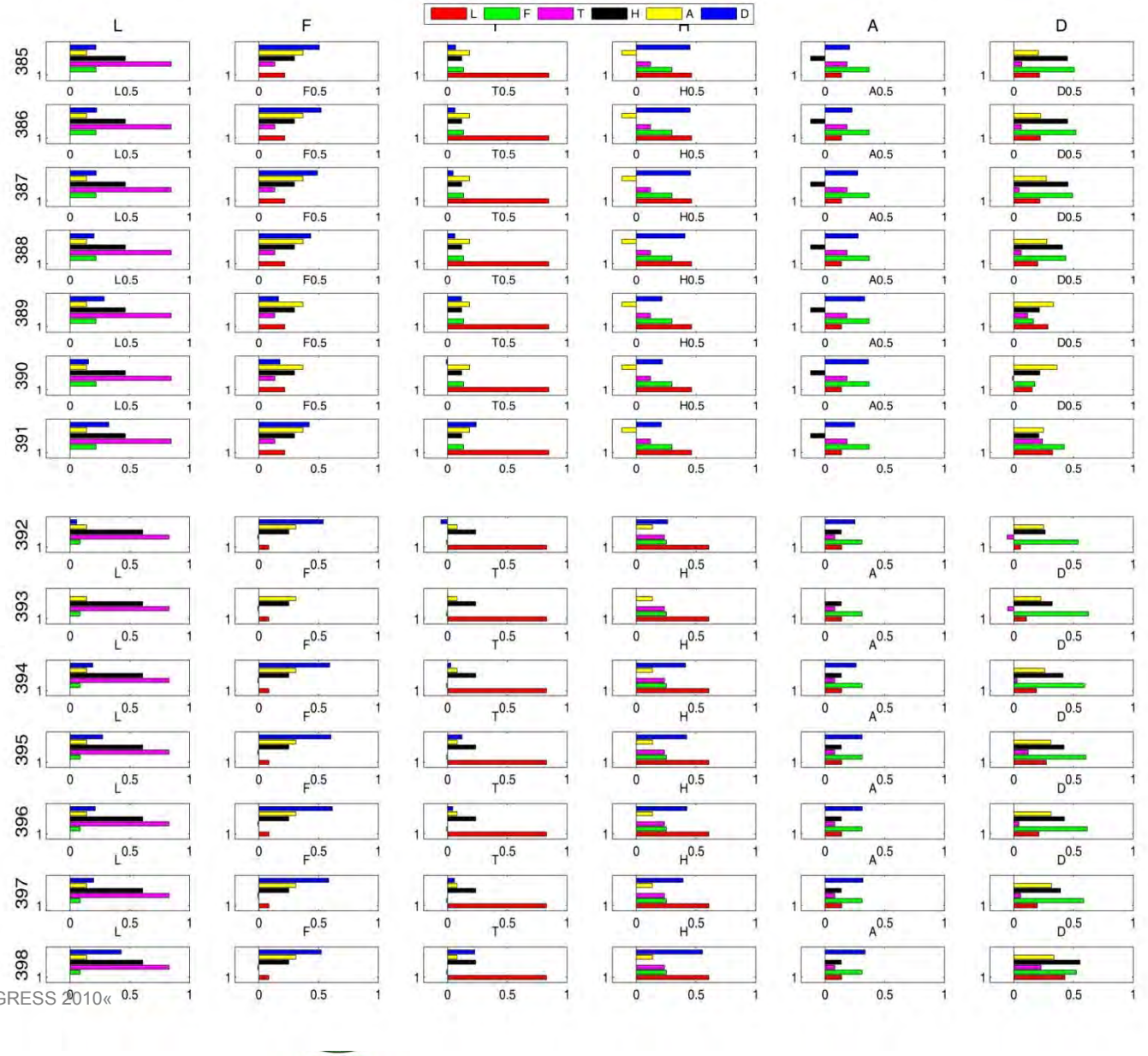


# Dune erosion as a result of the significant storms at the western Polish coast (Dziwnow Spit example).

Joanna Dudzińska-Nowak, Kazimierz Furmańczyk, Konrad Furmańczyk, Barbara Paplińska-Swerpel, Natalia Brzezowska

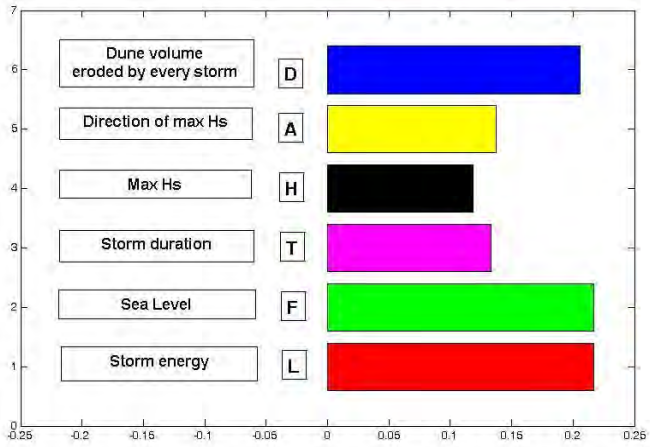
Correlation analysis between each storms parameters for each kilometers of the coast were calculated and presented on diagram.



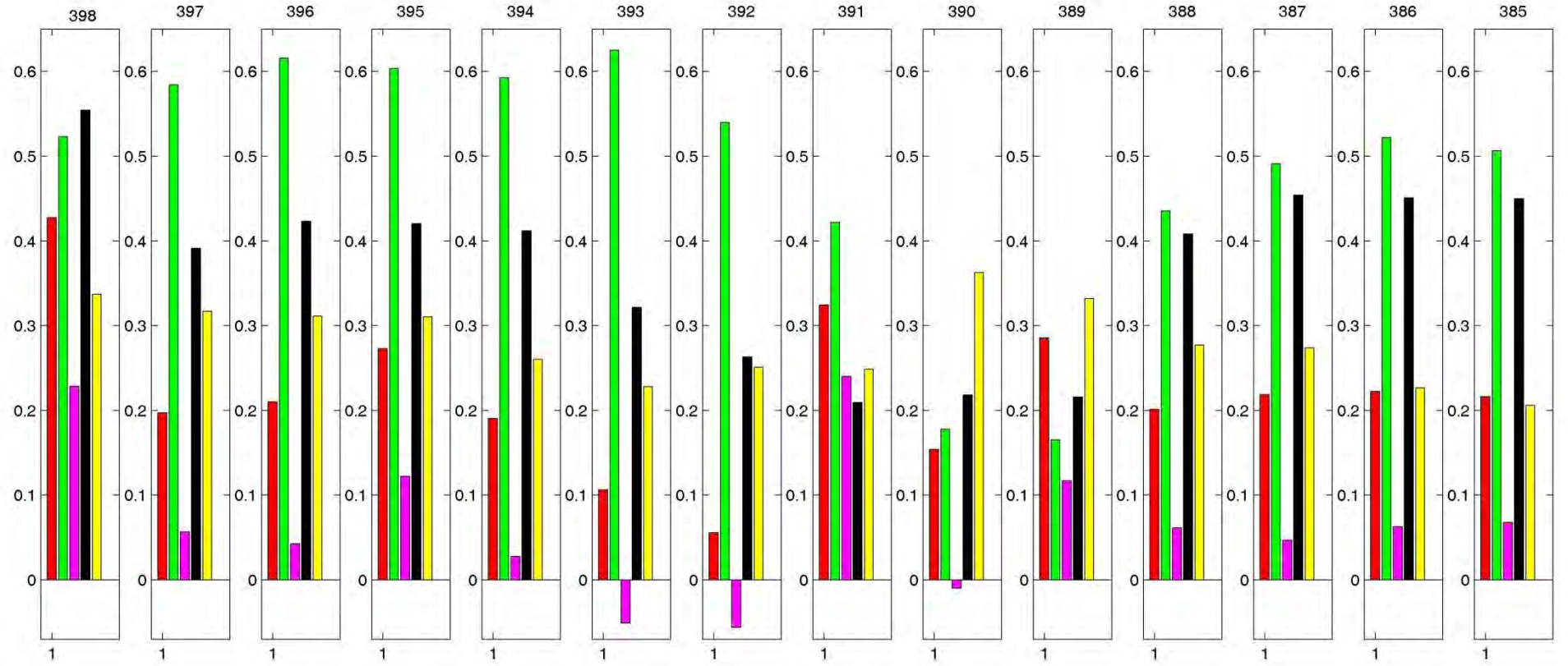



# Dune erosion as a result of the significant storms at the western

Joanna Dudzińska-Nowak, Kazimierz Furmańczyk, Konrad Furmańczyk, Barbara Paplin




Correlation analysis between each storms parameters for each kilometers of the coast.



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

Joanna Dudzińska-Nowak, Kazimierz Furmańczyk, Konrad Furmańczyk, Barbara Paplińska-Swerpel, Natalia Brzezowska

# CONCLUSIONS

In case of significant storms the highest impact to the size of dune erosion (D) have sea level (F), the next significant wave hight (H) and subsequently significant wave direction (A).

On 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 km 389 and 390 located between the river mouth protected by jetties and hard seawall with T-shape groins (km 388), where the highest impact to the size of dune erosion (D) have direction of significant wave (A), the next significant wave height (H) and subsequently level of the sea (F).

# Thank you for the attention

Joanna Dudzińska-Nowak

Laboratory of Remote Sensing
and Marine Cartography
Institute of Marine Sciences
University of Szczecin
jotde@univ.szczecin.pl