Memo

To
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Date	**Reference**	**Number of pages**
25 January 2011	1002337-002-ZKS-0001	8
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Subject
Wave look-up table
Building with Nature

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1 Introduction

Within Building with Nature, project HK 3.2, Deltares has developed a wave look-up table. This table is being developed for PhD students within the Building with Nature project, who are interested in nearshore physical processes.

Objective
The purpose of this study is to develop a wave look-up table that will transform wave time series of the IJmuiden, Europlatform and Eierlandse Gat waverider stations to an arbitrary location nearshore, proving nearshore wave time series. The pilot application concerns Vlugtenburg near the province of Zuid Holland (see Figure 1). The wave lookup table covers the entire “Hollandse Kust”, (from Europlatform up to Den Helder; see red box in Figure 1).

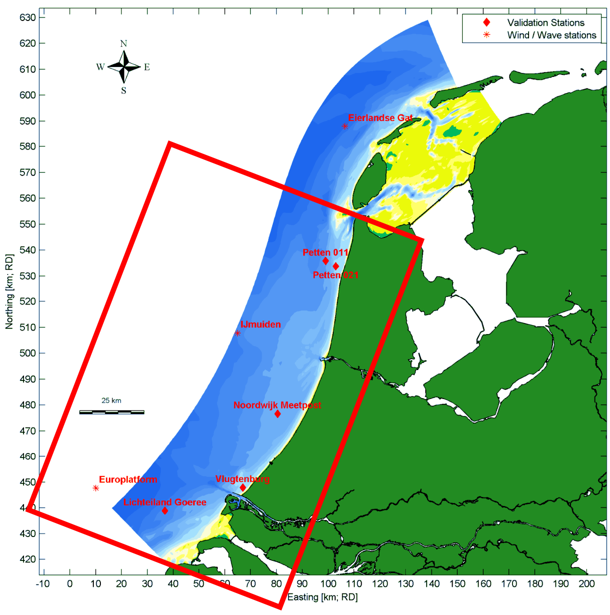

Figure 1: Overview locations with wave information

2 Methodology

The wave table will use and refer to the wave parameter data measured at the IJmuiden waverider measurement station (YM6), the measured data at Eierlandse Gat (ELD), and the measured data at Europlatform 3 (Table 1). Measurement data used in this study, was collected for the period January 1979 to December 2000 (ref 1). The data set includes for this period, the following parameters:

a) wave height (Hm0),
b) mean period (Tm02),
c) wave direction (nautical coordinates),
d) wind speed,
e) wind direction
f) surge

Table 1: Wave station information

	Platform	x-coordinate [km; RD]	y-coordinate [km; RD]	Latitude [deg]	Longitude [deg]	Water Depth [m; NAP]
offshore	IJmuiden munitiestortplaats	64.779	507.673	52º33'00"	4º03'30"	24
	Europlatform 3	10.056	447.687	51º59'55"	3º16'30"	30
	Eierlandse Gat	106.514	587.985	53º16'37"	4º39'42"	26
validation	Noordwijk meetpost	80.443	476.683	52º16'26"	4º17'46"	18
	Lichteiland Goeree	36.870	438.880	51°55'33”	3°40'11”	23
	Vlugtenburg	67.027	447.945	52°00'46”	4°06'20”	10
	Petten 011	99.006	535.831	52°48'25”	4°33'25”	20.2
	Petten 021	102.908	533.840	52°47'22”	4°36'54”	8.0

With this available wave data, a wave transformation matrix is built. To built this matrix, the following steps are taken:

1. Data analysis of the IJmuiden, Eierlandse Gat and Europlatform wave rider buoys to determine the combination of wave conditions that exist
2. Smoothing and binning the wave classification matrices
3. Forcing a SWAN model in stationary mode with the composed set of existing wave conditions
4. Generating transformation tables from the results of the SWAN simulations and the wave conditions at IJmuiden, Europlatform and Europlatform
5. Generating input data for the stations IJmuiden, Europlatfrom and Eierlandse gat from a combination of DONAR data (http://live.waterbase.nl) and MATROOS data (http://matroos.deltares.nl) for timeseries of [Hm0,Hdir,Tm02] until present.
6. Validation of the transformation matrices on the measured data at the locations Lichteiland Goeree, Noordwijk Meetpost and Petten (see Figure 1).
7. Interpolation of the SWAN results to refine the transformation matrix

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8. Making the transformation tool online available for Ecoshape in the Deltares repository

3 Results

3.1 Step 1: Data analysis

Raw data at IJmuiden, Eierlandse Gat and Europlatform is used in this analysis for the period 1979-2001 (ref 1). The wave parameters for this period are shown in Figure 2.

Wind and wave directions

A basic analysis was performed to determine how often the wind direction deviates from the wave direction. From the analysis, it was found that just over 69% of the time the wind direction is within 5 degrees of the wave direction. Therefore, the wind direction will be assumed the same as the wave direction.

The wave roses at the locations IJmuiden, Eierlandse Gat and Europlatform (Figure 3a/b) show that a southwest direction is the main wave direction for both stations. For this study, only waves are considered, propagating from the south through the northerly range, moving in a clockwise direction. This indicates wave directions from 180° to 360°, and from 0° to 30°, to cover the waves propagating from the truly northerly direction.

Classification
The wave data is classified based on wave direction and significant wave height at the offshore location of IJmuiden. The significant wave height is classified in bins of 0.5 m up to a significant wave height to 7.5 m. The wave direction is classified in directional bins of 10°.
As the surge depends on the wind climate parameters, it is chosen to classify the surge on the basis of the wind speed (classes from 0 to 26 m/s) and wind direction (10° bins).

The Figures 4 a-d, show the classification of the parameters Hm0 (a), Tm02 (b), U10(c) and the surge (d) at the location of IJmuiden.

The wave data of Europlatform and Eierlandse Gat is classified based on the wave classification at IJmuiden. Figure 2 shows that the difference in wave characteristics between IJmuiden and Europlatform is negligible. However, the wave period (Tm02) at IJmuiden is slightly higher than it is at the Europlatform measurement station. For this reason, it is chosen to utilize the wave classification on the basis of the IJmuiden station. Figures 4 e-h show the classification of the wave parameters Hm0 (e), Tm02 (f), U10(g) and the surge (h) at the location of Europlatform and Figures 4 i-l show the classification of the wave parameters Hm0 (i), Tm02 (j), U10(k) and the surge (l) at the location of Eierlandse Gat.

3.2 Step 2: Smoothing and binning of classification matrices

3.2.1 Buffer

A vertical buffer is added to each of the classified input matrices. For each bin, in each matrix (Hm0, Tm02, Wind Speed, and Surge), where a Nan value was bordered vertically by a bin where wave data was available, that value was copied to the Nan bin. This buffering (copying) is only applied vertically for each matrix, and not horizontally across the directional classification.

3.2.2 Smoothing

The final step, before making the wave condition file as input for the wave model, is to smooth each of the matrices. A 9-point smoothing routine was applied for each matrix. This means that the binned information directly adjacent to a central bin was averaged to get the smoothed value for the central bin. The Nan-values were retained in each bin that had this value after adding the buffer. Nan values were ignored in the averaging routine, therefore only bin information which included a bin value was retained for the averaging routine.

The results of the smoothing and binning is shown in the Figures 4.5 (a-d for IJmuiden, e-h for Europlatform, i-l for Eierlandse Gat).

3.3 Step 3: SWAN simulations in stationary mode

Wave conditions have been generated based on the smoothed classification matrices. The model that is shown in Figure 1 is forced with the generated wave conditions, to obtain a nearfield wave climate.

A space varying offshore boundary is applied to the model, in which the southern part of the model is forced with the wave conditions of Europlatform, the central part of the model is forced with the wave conditions of IJmuiden and the northern part of the model is forced by the wave conditions of Eierlandse Gat.

A set of 269 stationary SWAN computations are done, to obtain a proper insight in the wave transformation under different hydrodynamic conditions.

3.4 Step 4: Transformation matrix

A transformation matrix is generated using the offshore wave conditions and the generated nearshore wave conditions. The matrix consists of factors, which specify the relation between the offshore wave parameter and the nearshore wave parameter.

For the significant wave height and peak period, the transformation matrix is filled with multiplication factors and for the transformation of the wave direction and surge, an additional factor is used in the transformation matrix.

To indicate which station dominates the offshore wave conditions, waves that have a direction smaller than 280° use the offshore wave information of Europlatform and waves with a direction larger than 280° use the wave information of IJmuiden as offshore wave platform. For the region above IJmuiden, waves with a direction smaller than 300° use the offshore wave information of IJmuiden and waves with a direction larger than 300° use the wave information of Eierlandse Gat as offshore wave platform (see Figure 2).

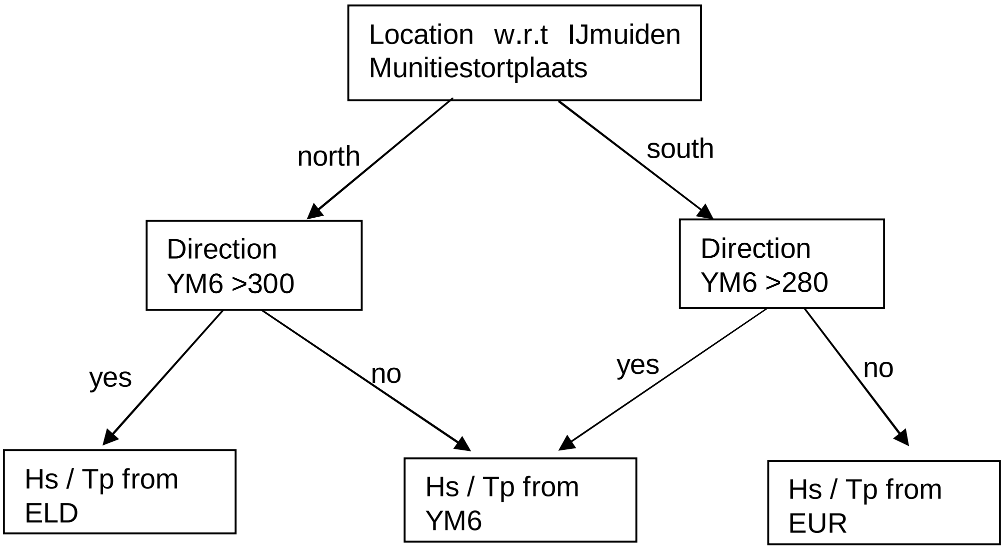


Figure 2: Decision diagram for wave height and wave period

The analysis on the correlation between the wave direction between the three offshore locations showed that the direction of the stations deviates from each other. For this reason it is chosen to do the transformation on the wave direction for the offshore station that is near the location of interest (see Figure 3).

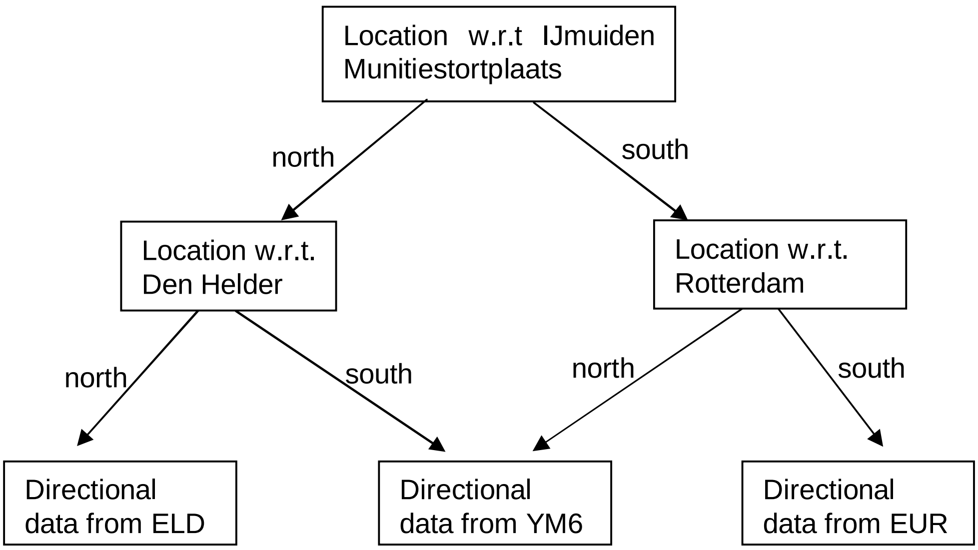


Figure 3: Decision diagram for directional data

3.5 Step 5: Offshore time series

The time series for the offshore stations are automatically generated in the wave transformation tool. The offshore data is generated from a combination of DONAR data (http://live.waterbase.nl) and MATROOS data (http://matroos.deltares.nl). The DONAR data provides the time series for the available period. From this period until present, the data is completed with data from the MATROOS database. Wave height data (Hm0) is included in the tool until tomorrow. For the period where the database is filled with MATROOS data, 2 remarks have to be taken into account:

- For the station of Eierlandse Gat no wave height prediction (now until tomorrow) is available. For this reason, the offshore data is filled with wave height data from IJmuiden.
- When no directional data is present in MATROOS for a station it is filled with directional data from the neighbouring offshore station.

The intervals for the time series of the offshore stations vary over the years, for this reason, the time series are built up from:

- 3-hourly interval data for the period up to 01-Jan-1987
- hourly interval data for the period of 01-Jan-1987 – 01-Jul-2007
- 10 minutes interval for the period of 01-Jul-2007 until tomorrow

3.6 Step 6: Validation against measurements

Four validation stations are present in the model domain: Noordwijk Meetpost, Lichteiland Goeree and two stations near Petten (see Figure 1). For these stations, a validation is done on the parameters Hm0, Hdir (only for Meetpost Noordwijk), Tp and surge (only for Meetpost Noordwijk and Lichteiland Goeree). To obtain nearshore time series from offshore time series, the offshore time series are converted with the use of the transformation matrix, which is derived in step 4.
The results of the validation of Meetpost Noordwijk for the period 1979-2001 are shown in the Figures 4.6 (a-d).

a) Significant wave height (Hs)
b) Wave direction (Hdir)
c) Peak period (Tp)
d) Surge

The results of the validation of Lichteiland Goeree for the period of 1979-2001 are shown in the Figures 4.7 (a-c).

a) Significant wave height (Hs)
b) Peak period (Tp)
c) Surge

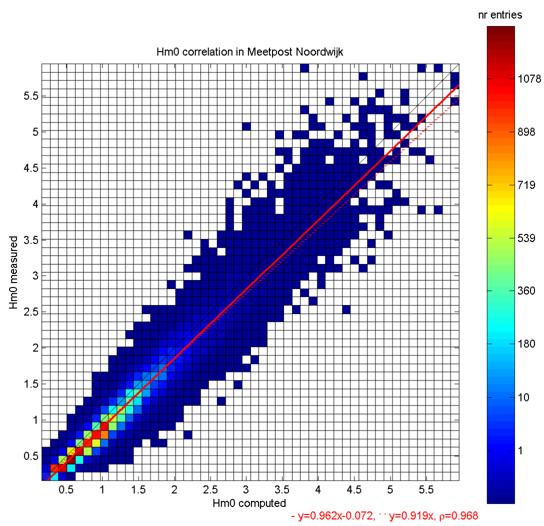


Figure 2: Correlation computed and measured Hs at Meetpost Noordwijk

The results of the validation of station Petten011 and Petten021 for the period of 1995-2001 are shown in the Figures 4.8 and 4.9 (a-c).

a) Significant wave height (Hs)
b) Wave direction (Hdir)
c) Peak period (Tp)

The results show a good correlation for the measured waves versus the observed waves. The correlation factors for the several wave parameters is given in Table 2. The data of the stations Petten011 and Petten021 is used as raw data, which showed some questionable behaviour regarding extreme values.

Table 2: Correlation factor ρ for several wave parameters

	Lichteiland Goeree	Meetpost Noordwijk	Petten011	Petten021
Hm0 [m]	0.94	0.97	0.97	0.97
Hdir [deg N]	×	0.98	0.92	0.94
Tp [s]	0.87	0.90	0.66	0.55
Surge [m]	0.90	0.95	×	×

3.7 Step 7: Refined transformation matrix

To obtain more accurate results regarding the transformation of the offshore wave parameters, the transformation matrices are refined to a directional classification of 4° and a classification of the significant wave height of 0.25 m. This did not result in better results regarding the correlation factor.

4 Conclusions and recommendations

4.1 Conclusions

1. The correlation factors for the significant wave height at the validation stations: Lichteiland Goeree and at Meetpost Noordwijk for a period of 22 years are 0.94 and 0.97, respectively. For the validations stations near Petten, the correlation factores are 0.97.

2. The correlation factors of all relevant wave parameters exceed a value of 0.87 at the validation stations: Lichteiland Goeree (south of the study area) and Meetpost Noordwijk (north of the study area) for a period of 22 years. The transformation matrix showed correlation factors above 0.90 for wave direction near Petten. However, the correlation factors for the wave peak period is less than 0.60.

3. The wave data from the stations near Petten have to be checked on consistency regarding wave periods.

4. A refined matrix has not shown better results than the original transformation matrix, regarding the wave transformation.

4.2 Recommendations

- A new version of Delft3D-WAVE will be available on a short term. In this new version, different wave period parameters (e.g. Tm01, Tm02) can be used to force the model. The results of the transformation matrix will improve by the use of this new version of

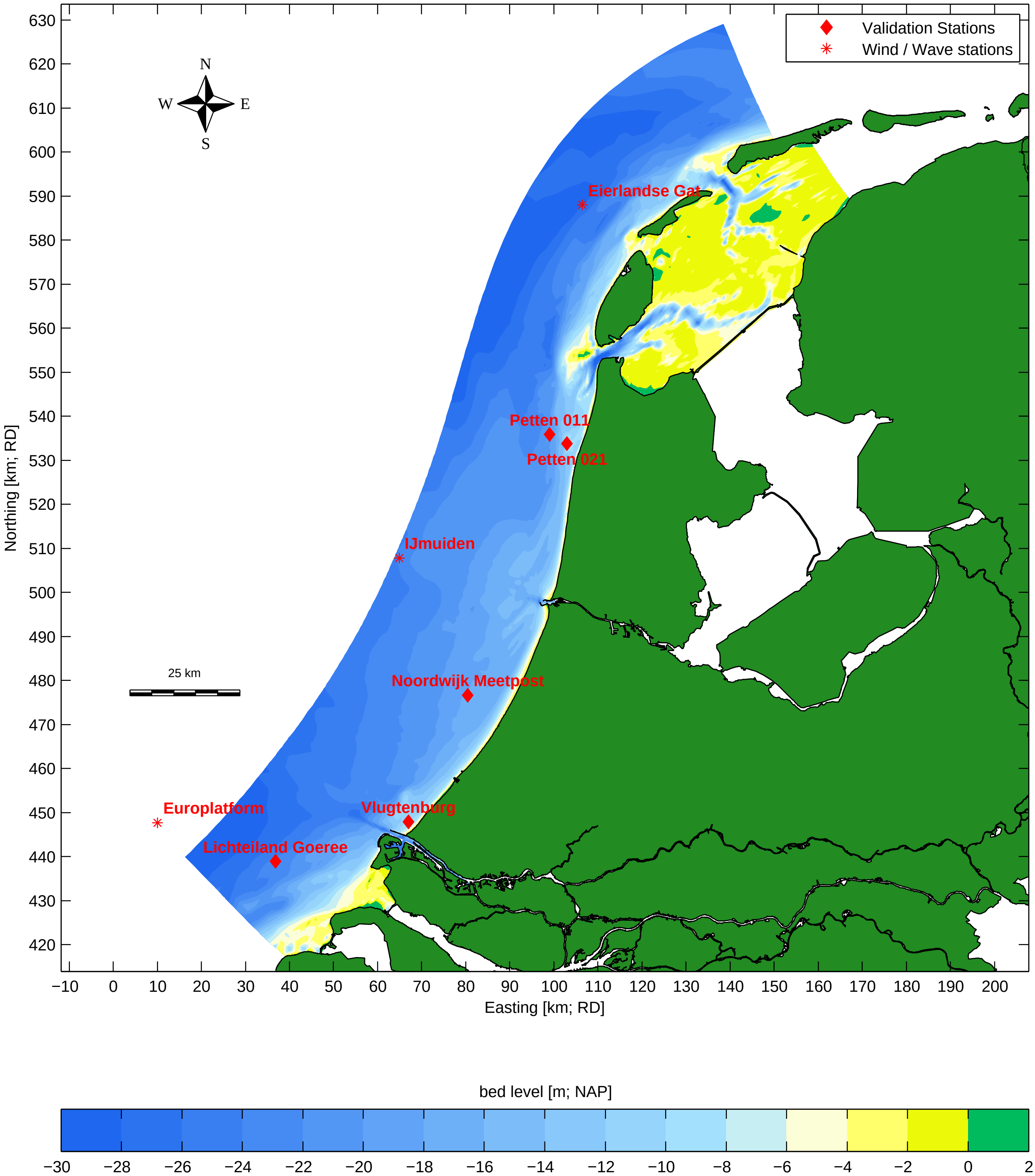
Delft3D-WAVE, as the measured wave data is specified in Tm02. In this study the model is forced with a Tp, which is transformed with a factor from Tm02. It is recommended to allocate one extra day of work, to build this new wave transformation matrix with new simulations by the new Delft3D-WAVE version.

- This method of wave transformation from an offshore platform to a nearshore climate can be applied for an extended area.
- Including tidal water levels and current data in this transformation will lead to better predictions of the hydrodynamic situation nearshore.

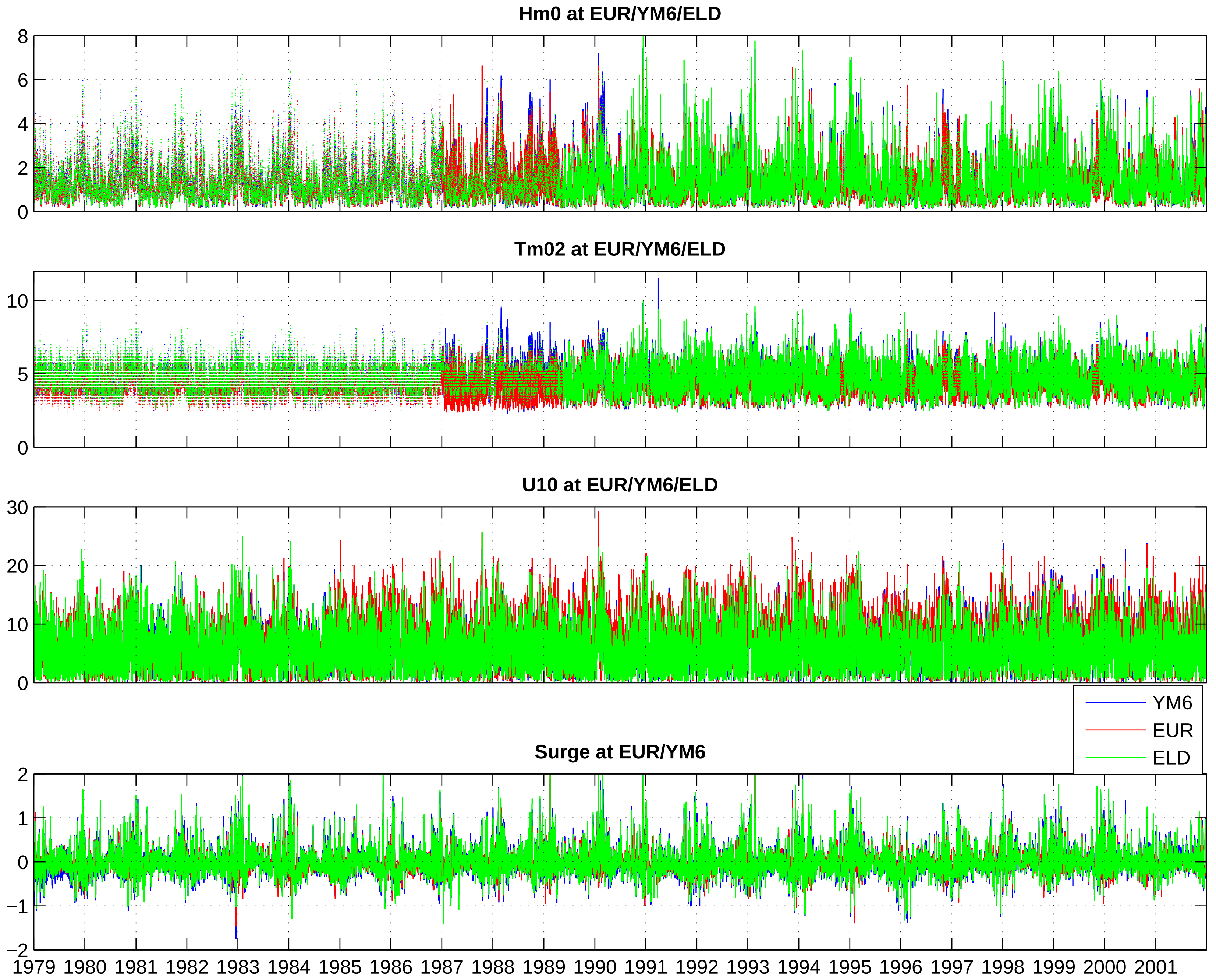
5 References

1 Weerts and Diermanse (2004)
Golfstatistiek op relatief diep water 1979-2002. WL|Delft Hydraulics report: Q3770

Figures



Measurement Stations		
	Building with Nature	
Deltares	1002337.002	Fig 1



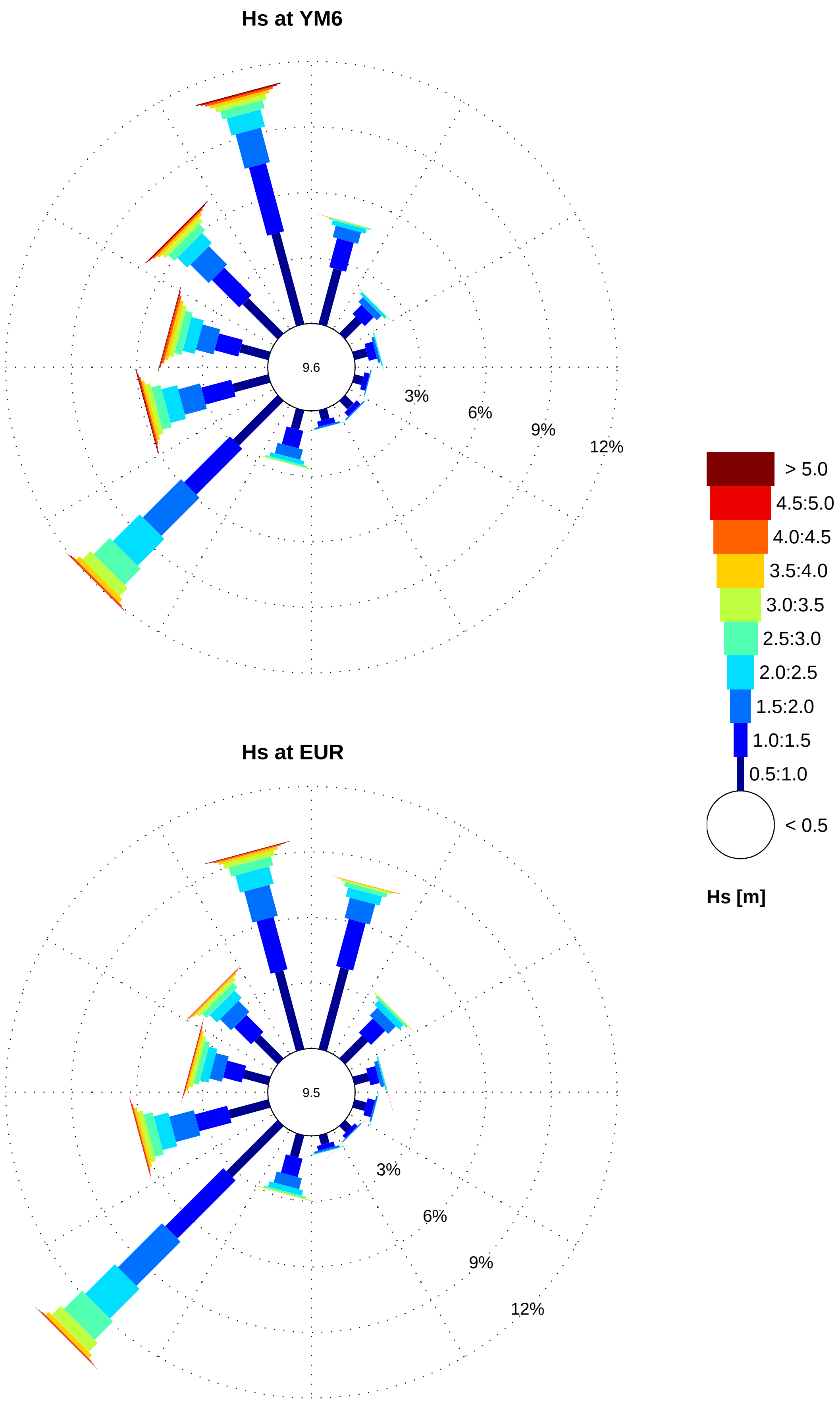
Deltares

wave parameters measured at IJmuiden munitiestortplaats and at Europlatform and Eierlandse gat

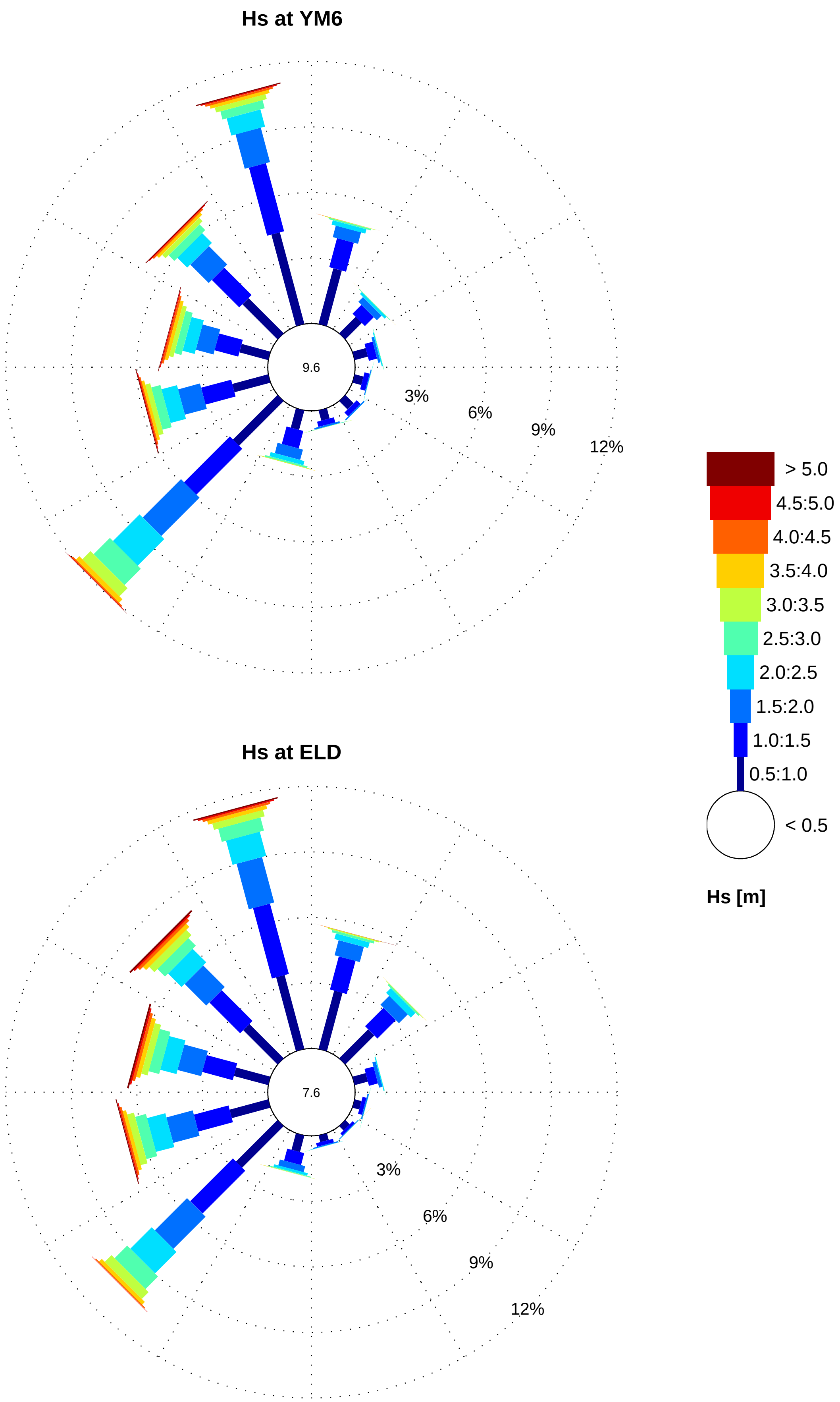
1002337.002

01/01/1979 – 31/12/2001

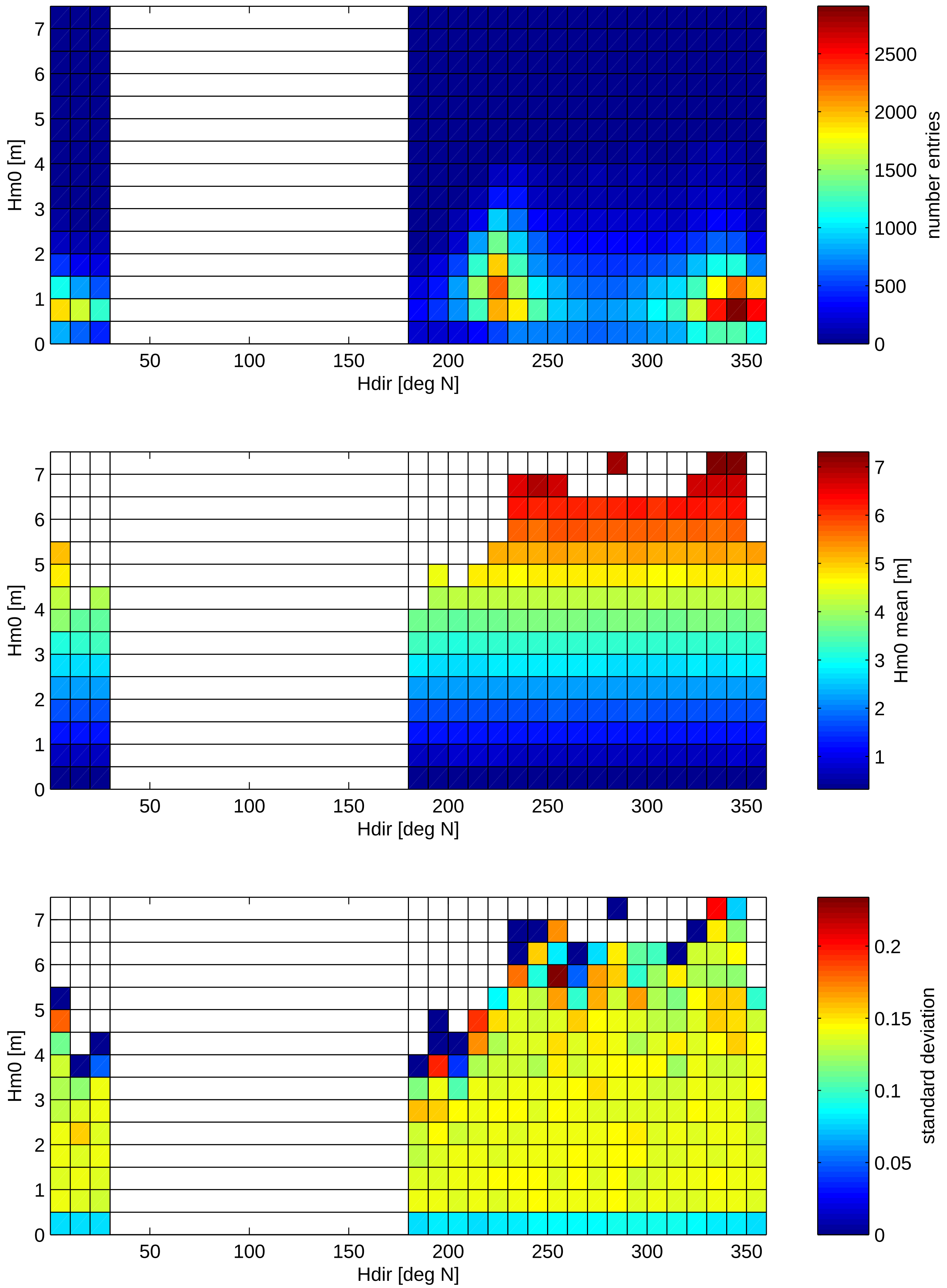
Fig 2



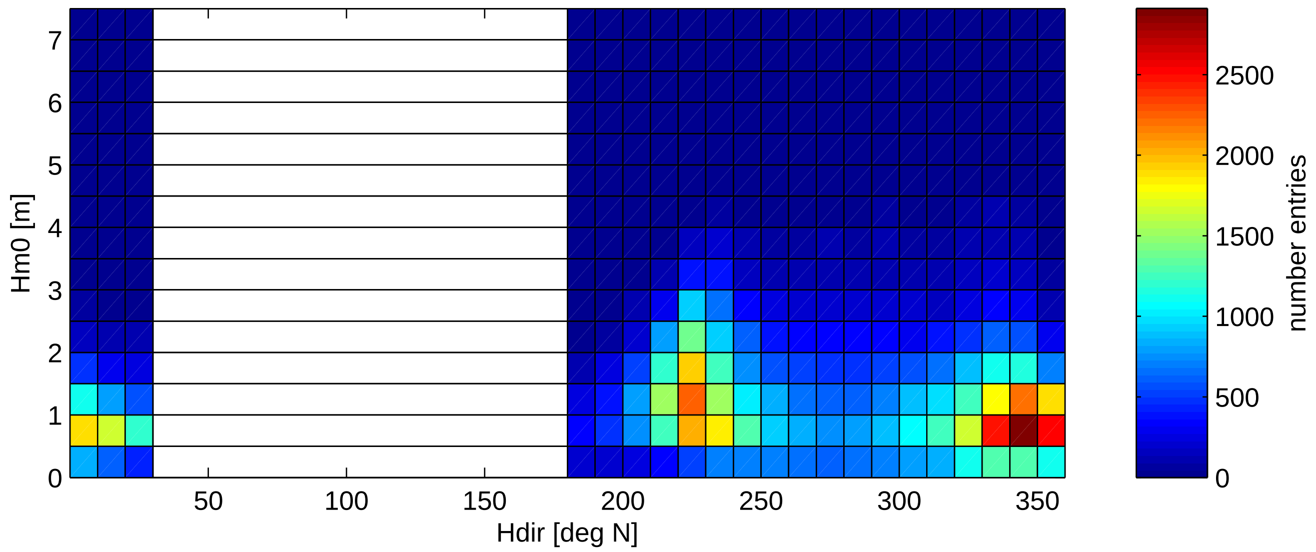
Upperplot: Waverose IJmuiden Lowerplot: Waverose Europlatform	YM6	EUR
	01/01/1979 – 31/12/2001	
Deltares	1002337.002	Fig 3a

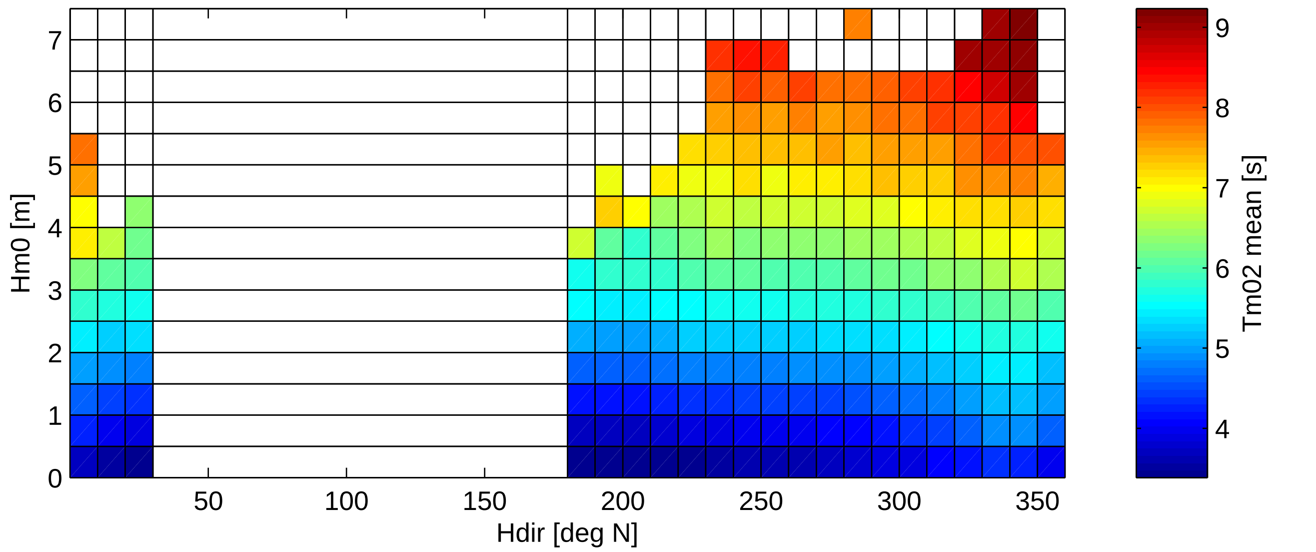


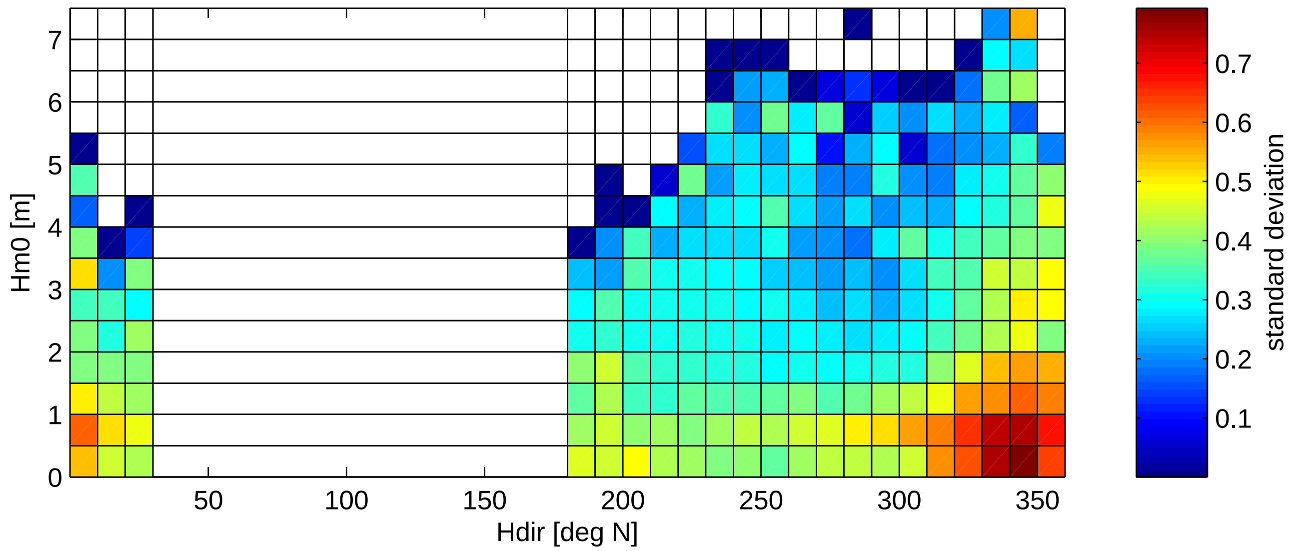
Upperplot: Waverose IJmuiden Lowerplot: Waverose Eierlandse gat	YM6	ELD
	01/01/1979 − 31/12/2001	
Deltares	1002337.002	Fig 3b



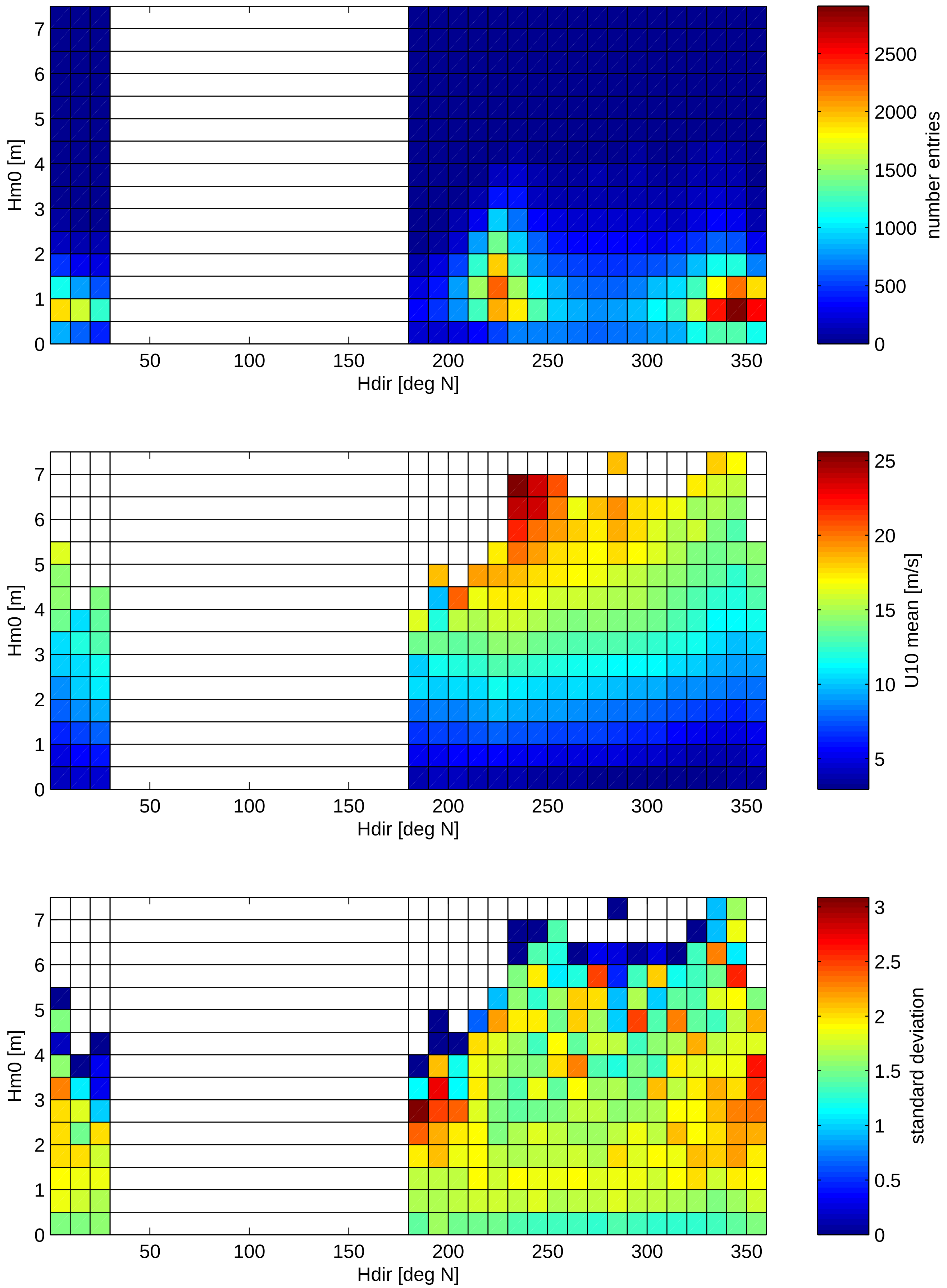
classification matrices on the raw data	Hm0	YM6
	01/01/1979 – 31/12/2001	
Deltares	1002337.002	Fig 4a



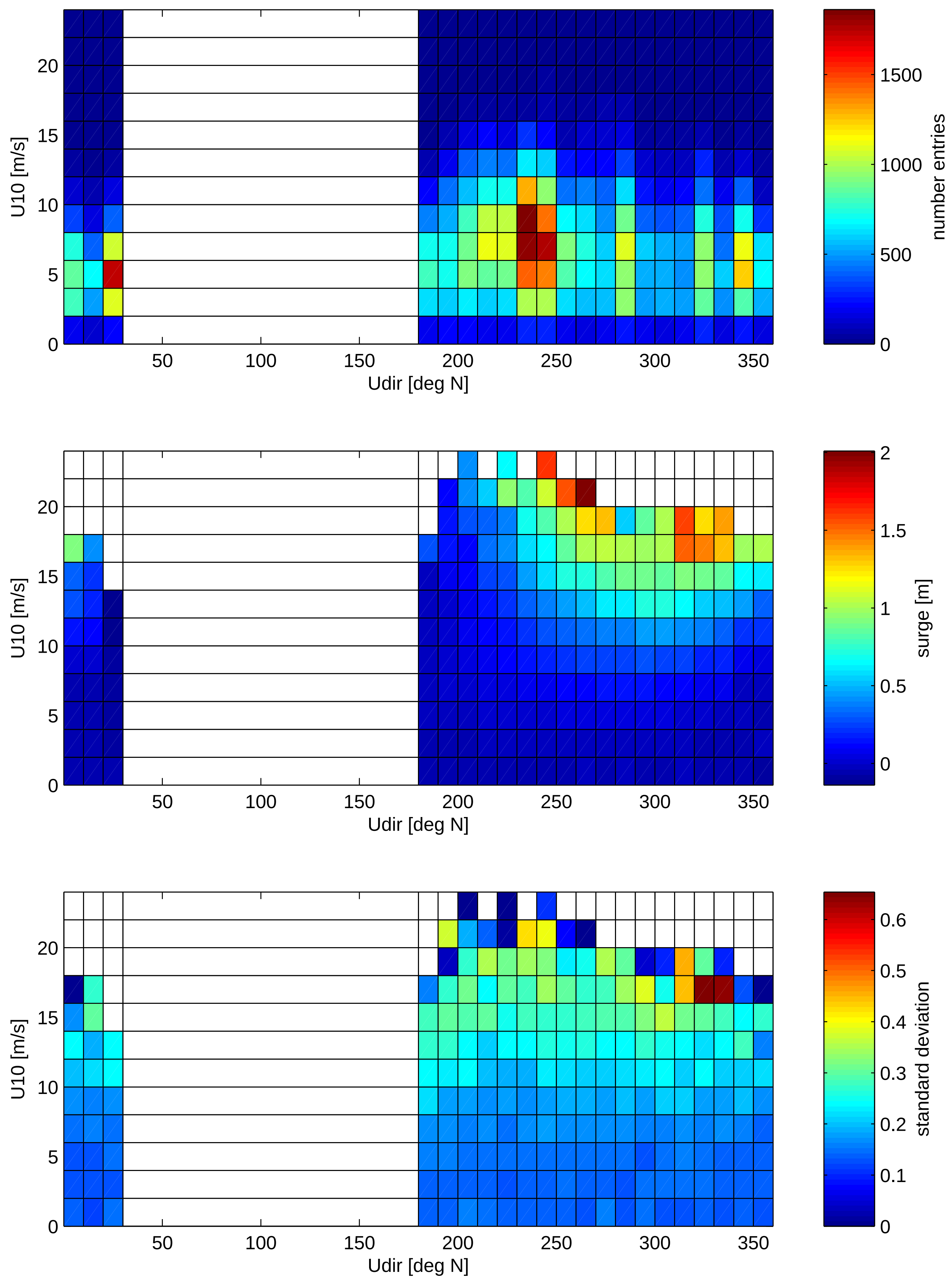




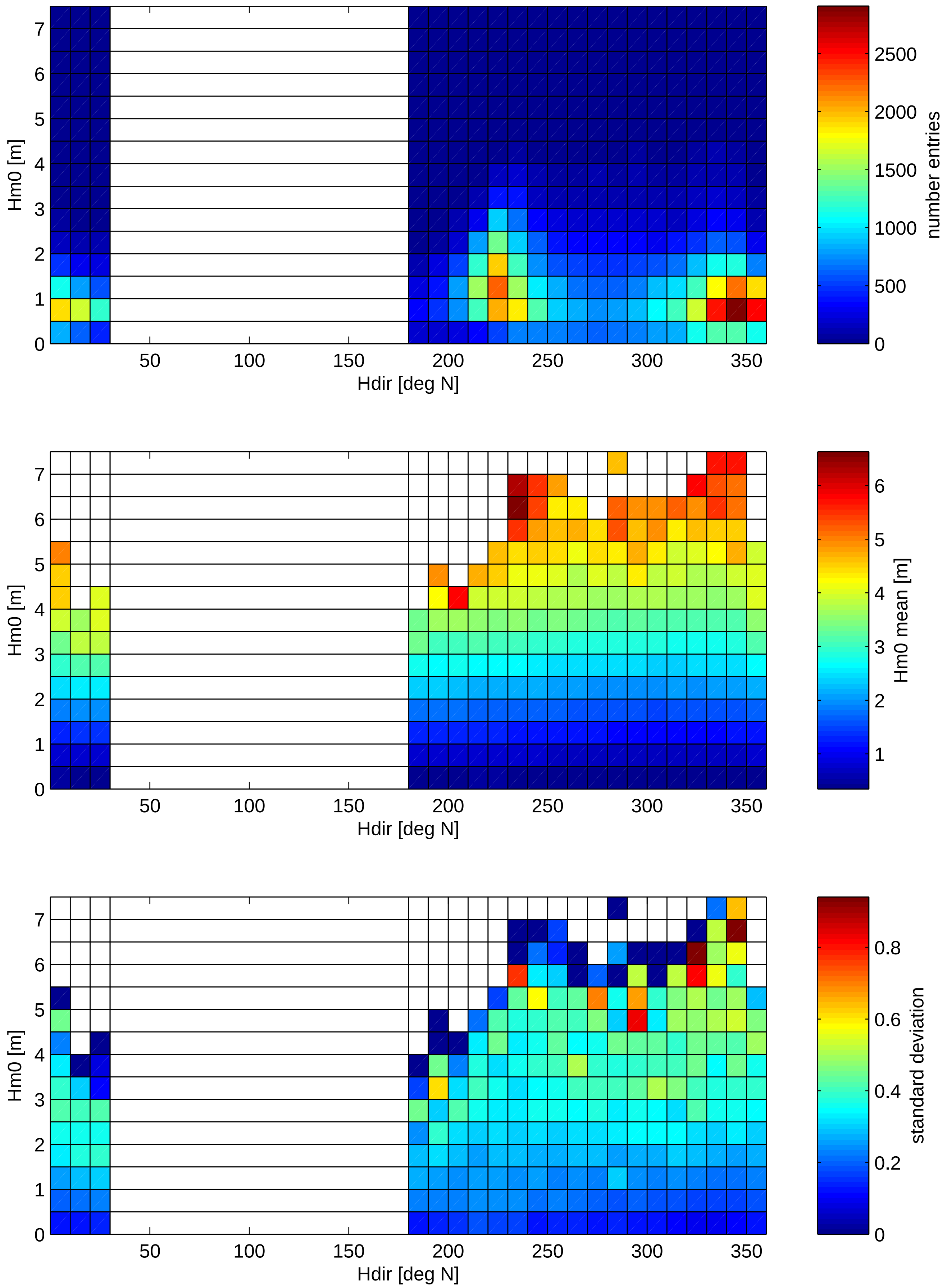
classification matrices on the raw data	Tm02	YM6
	01/01/1979 – 31/12/2001	
Deltares	1002337.002	Fig 4b



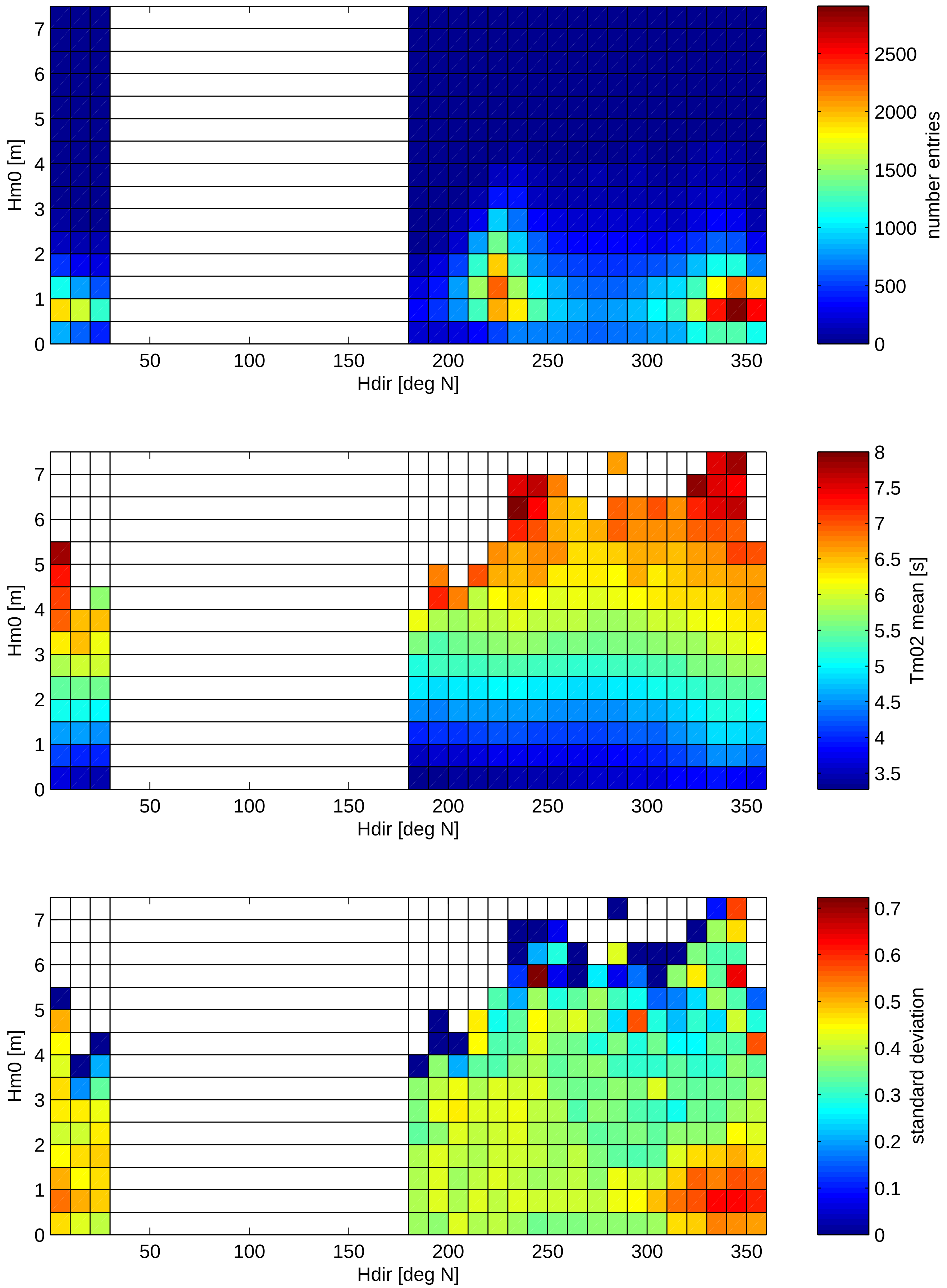
classification matrices on the raw data	U10	YM6
	01/01/1979 – 31/12/2001	
Deltares	1002337.002	Fig 4c



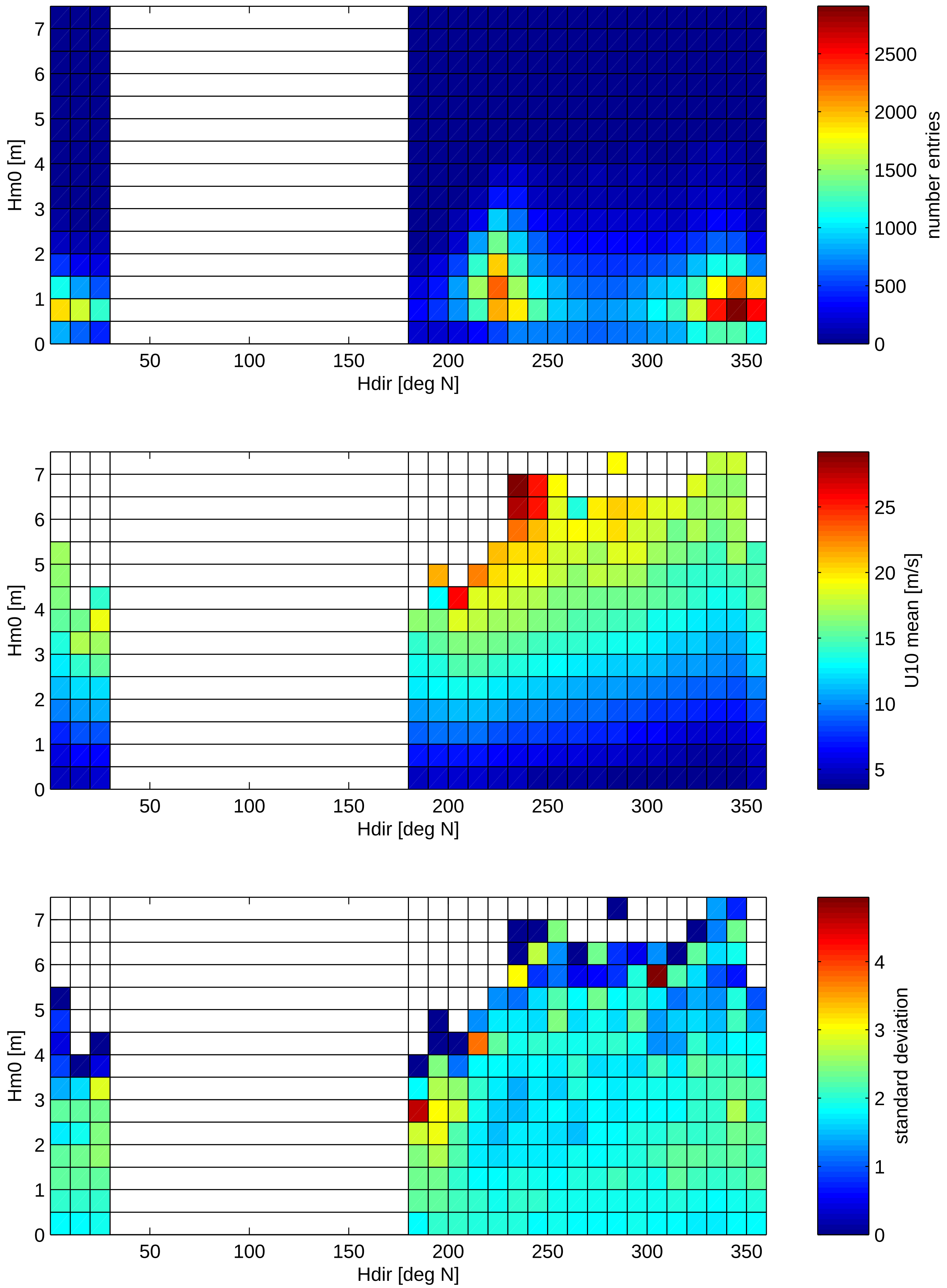
classification matrices on the raw data	surge	YM6
	01/01/1979 − 31/12/2001	
Deltares	1002337.002	Fig 4d



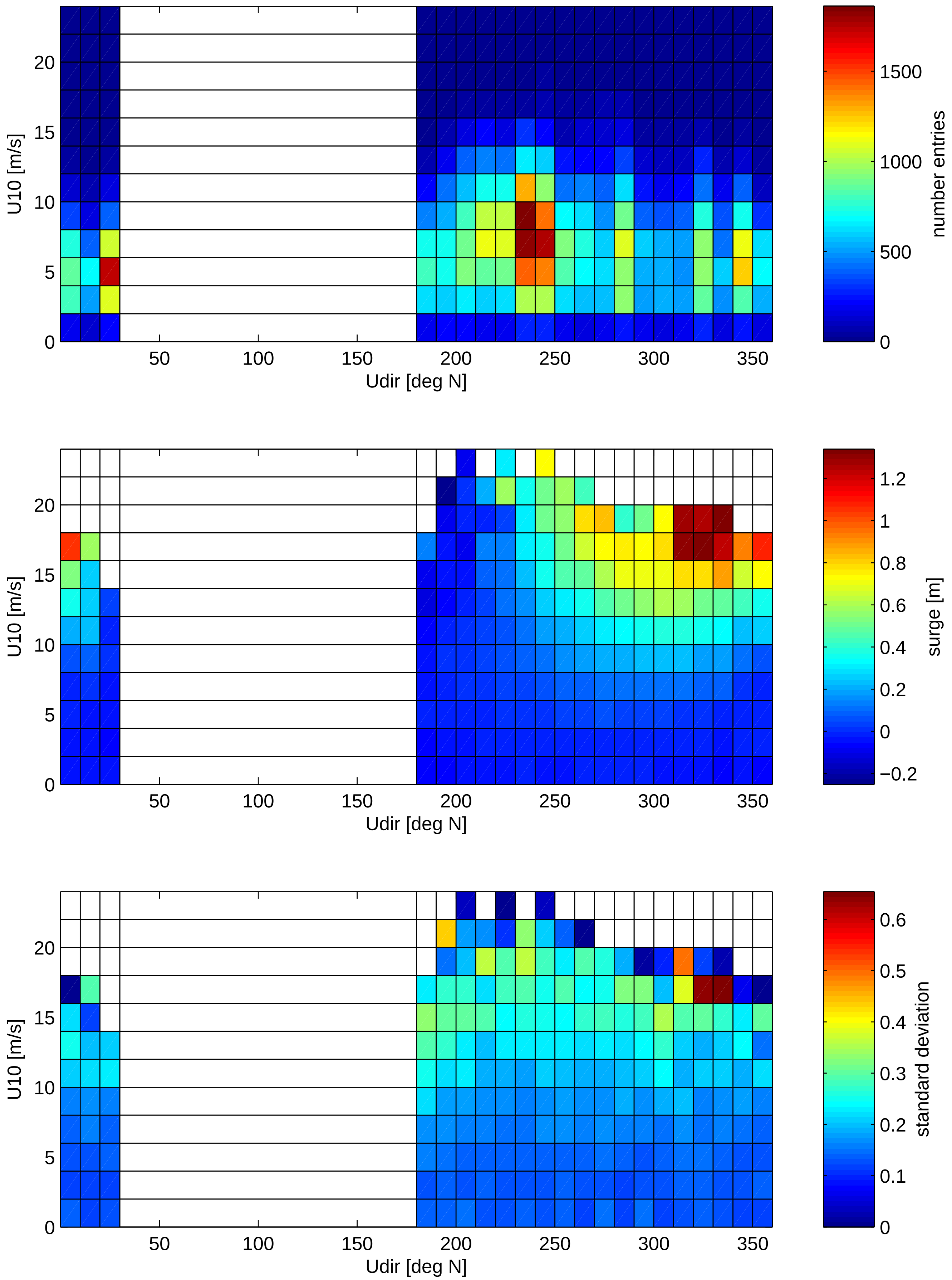
classification matrices on the raw data	Hm0	EUR
	01/01/1979 − 31/12/2001	
Deltares	1002337.002	Fig 4e



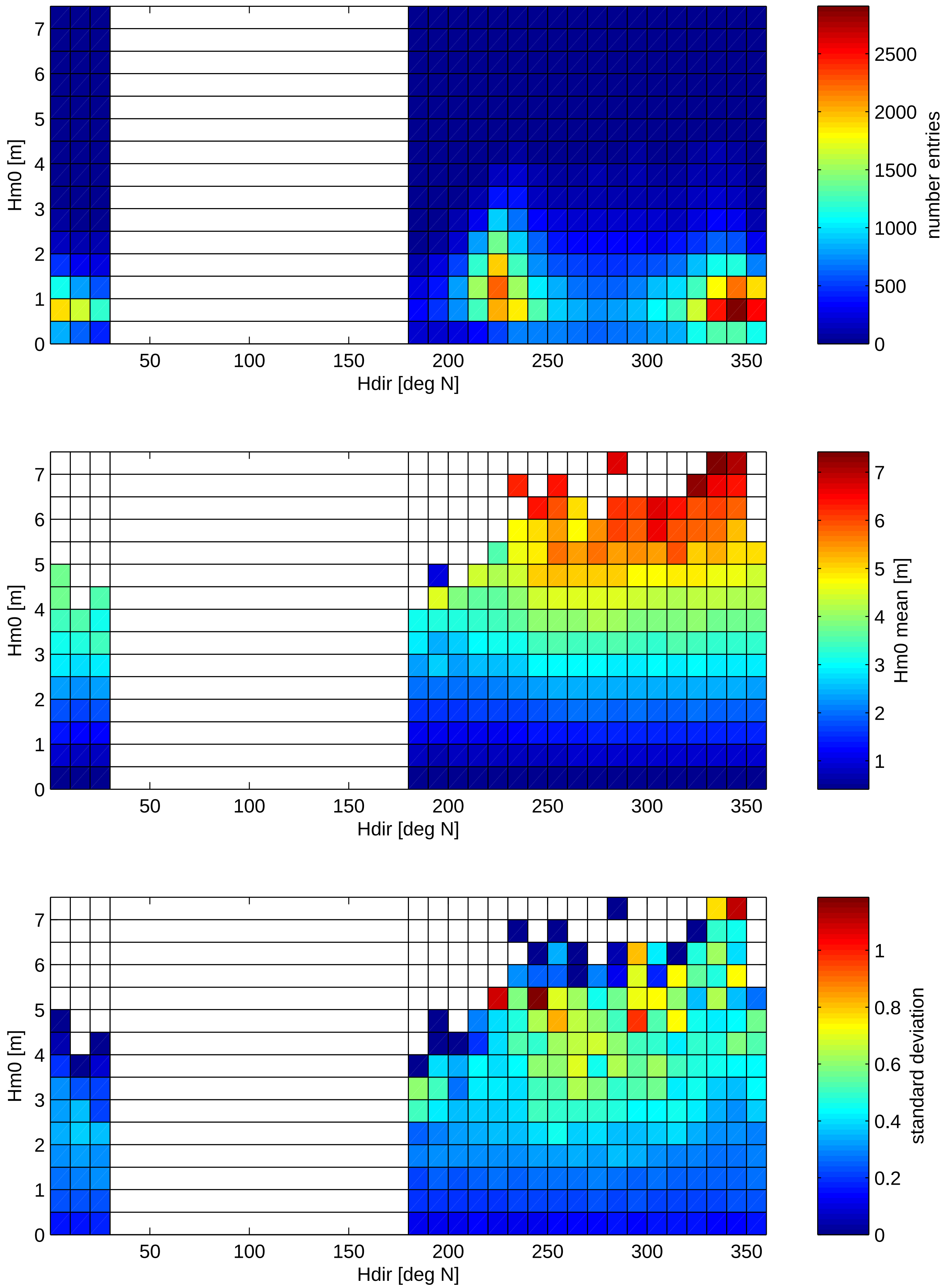
classification matrices on the raw data	Tm02	EUR
	01/01/1979 – 31/12/2001	
Deltares	1002337.002	Fig 4f



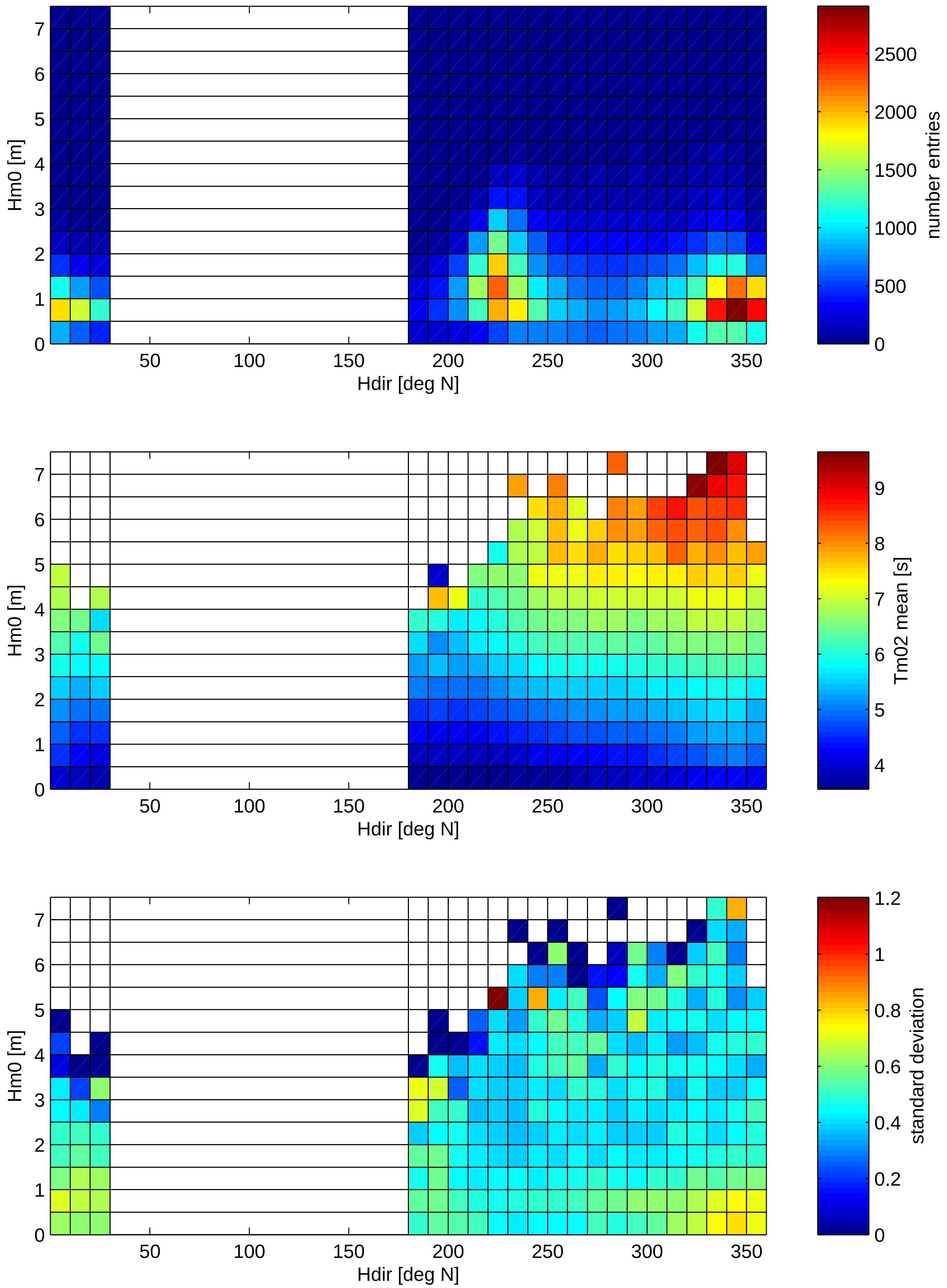
classification matrices on the raw data	U10	EUR
	01/01/1979 − 31/12/2001	
Deltares	1002337.002	Fig 4g



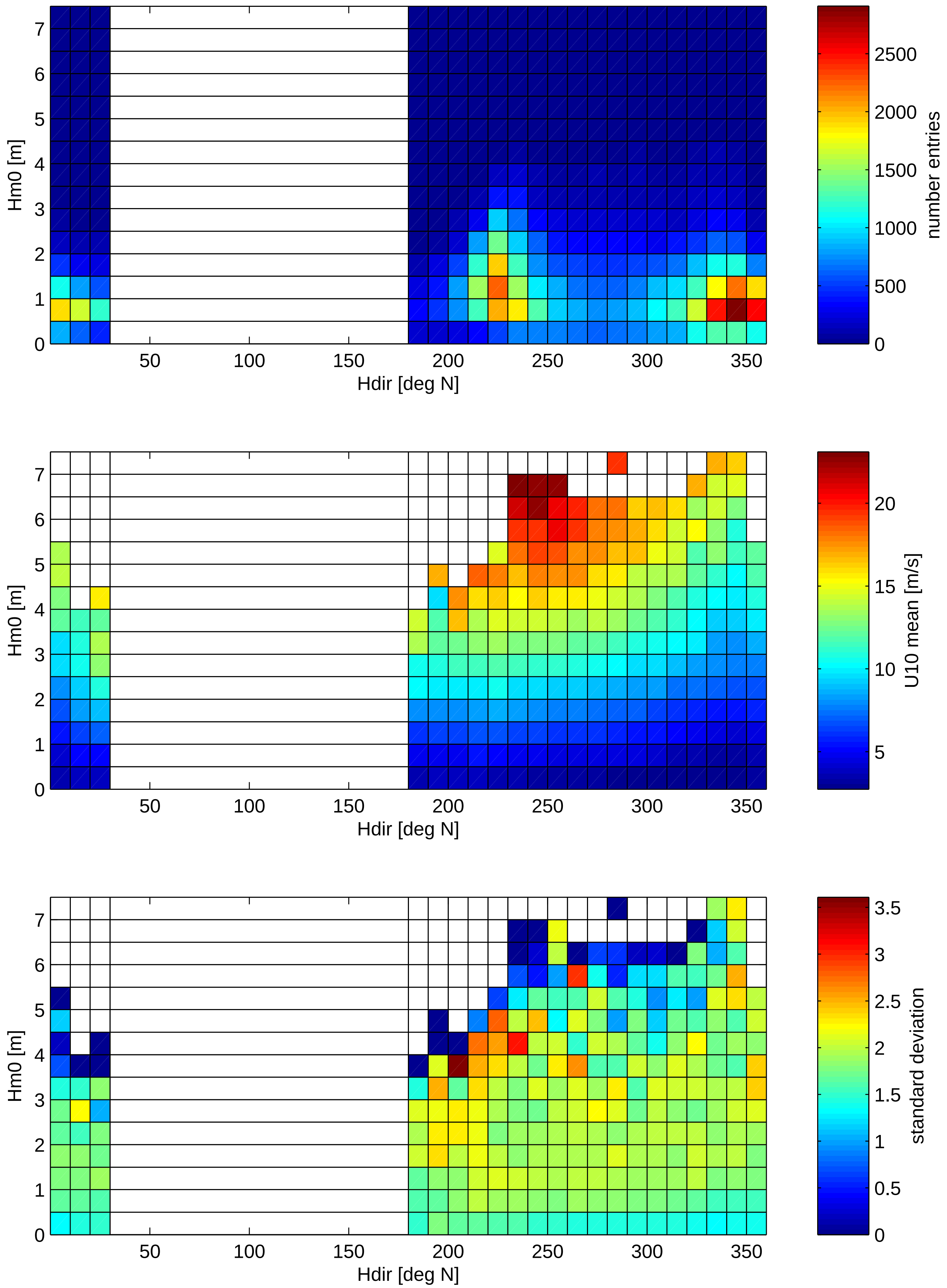
classification matrices on the raw data	surge	EUR
	01/01/1979 − 31/12/2001	
Deltares	1002337.002	Fig 4h



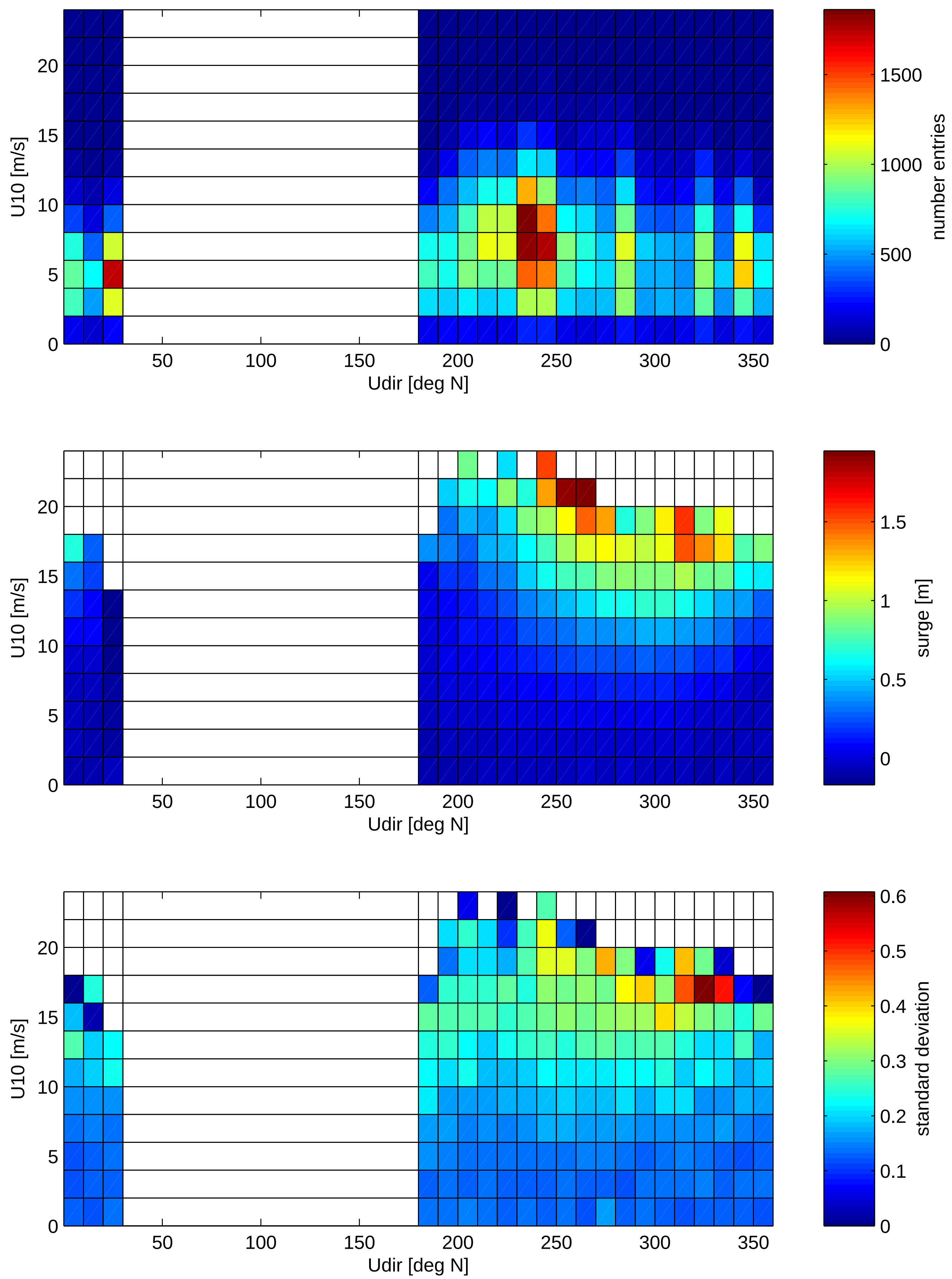
classification matrices on the raw data	Hm0	ELD
	01/01/1979 − 31/12/2001	
Deltares	1002337.002	Fig 4i



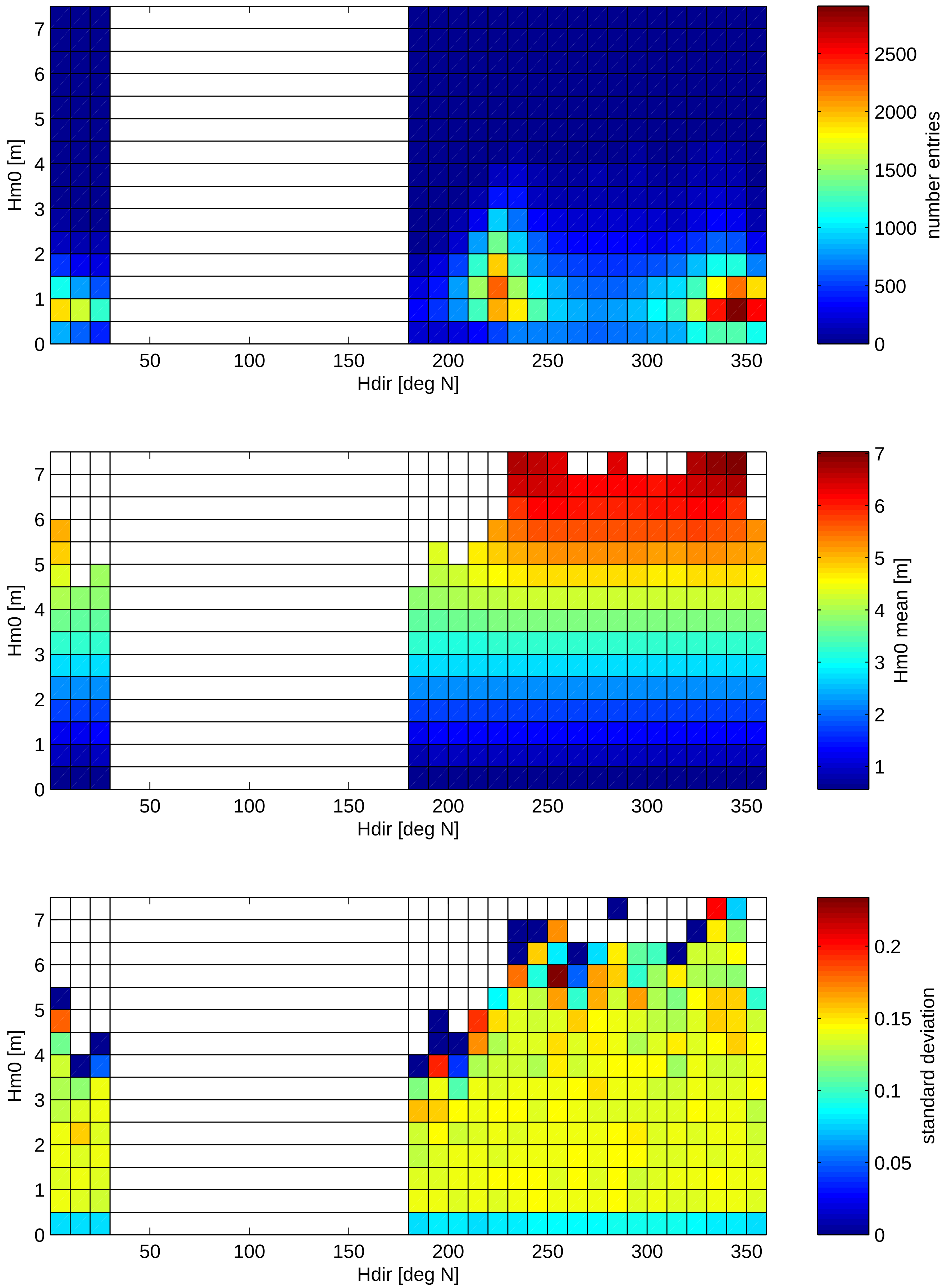
classification matrices on the raw data	Tm02	ELD
	01/01/1979 − 31/12/2001	
Deltares	1002337.002	Fig 4j



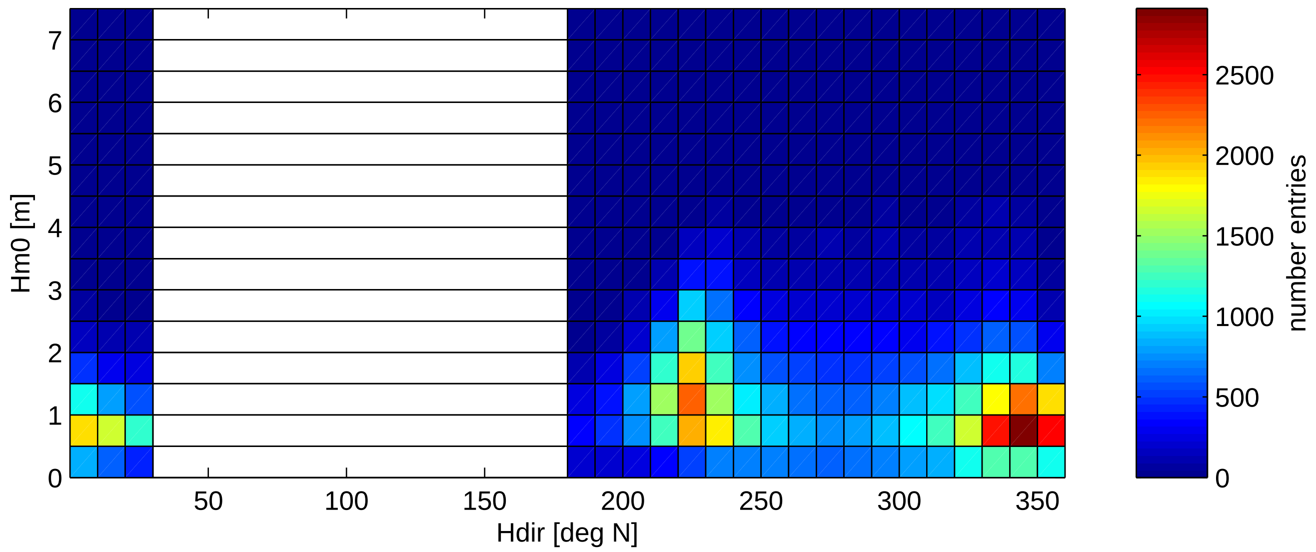
classification matrices on the raw data	U10	ELD
	01/01/1979 − 31/12/2001	
Deltares	1002337.002	Fig 4k

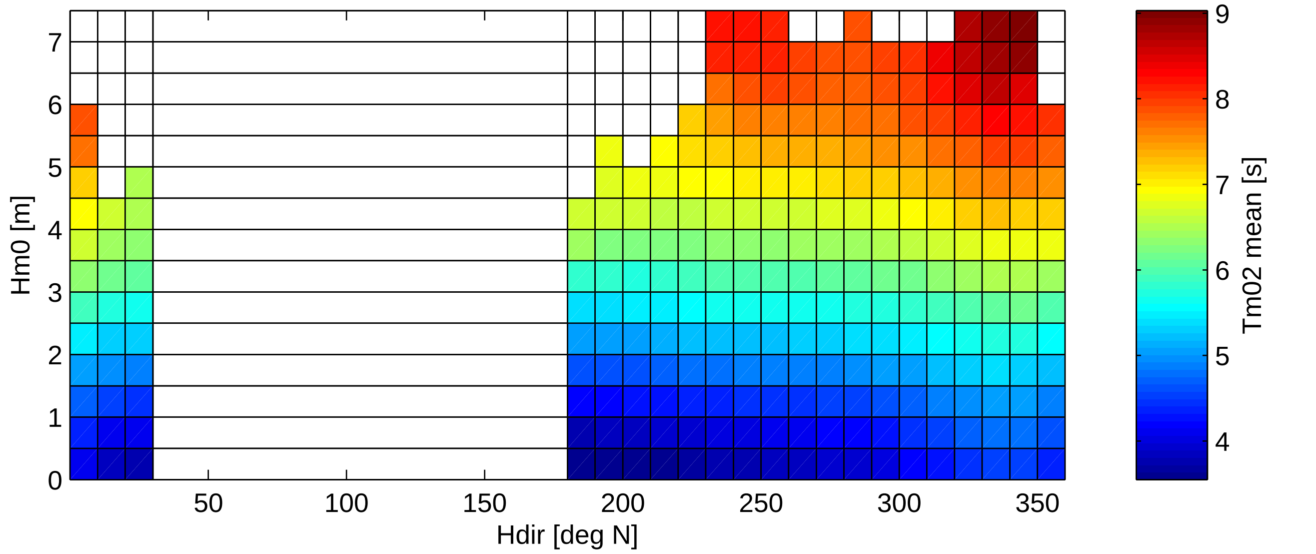


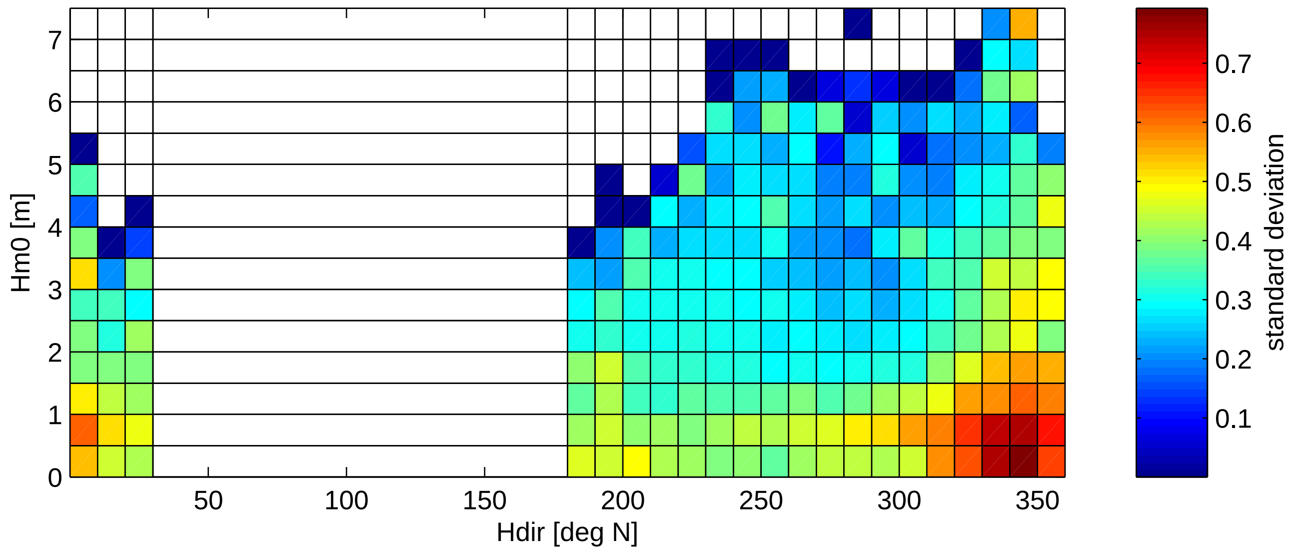
classification matrices on the raw data	surge	ELD
	01/01/1979 − 31/12/2001	
Deltares	1002337.002	Fig 4l



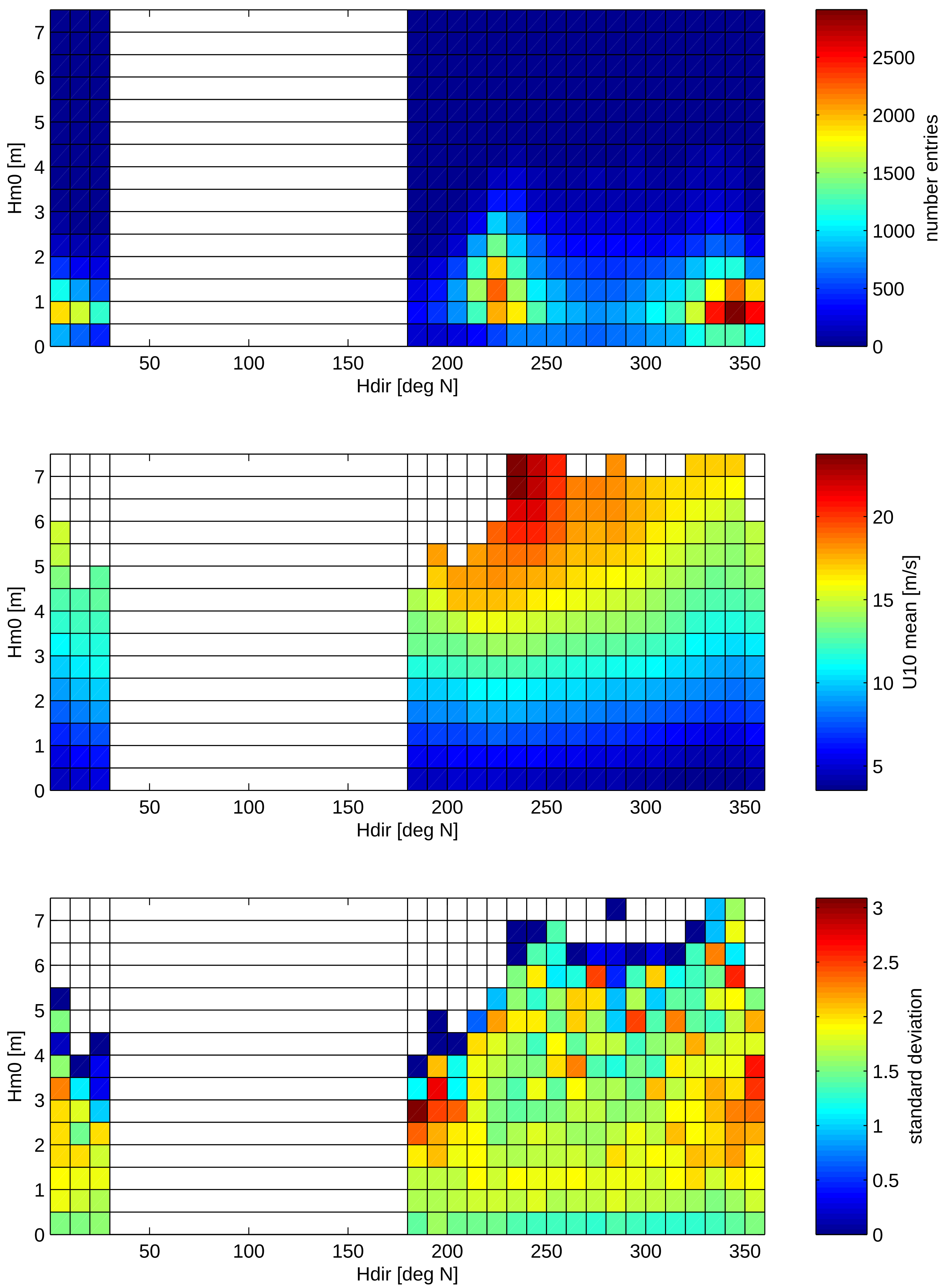
classification matrices on the raw data smoothed data based on 9 points smoothing vertical buffer added per wind/wave direction	Hm0	YM6
	01/01/1979 – 31/12/2001	
Deltares	1002337.002	Fig 5a



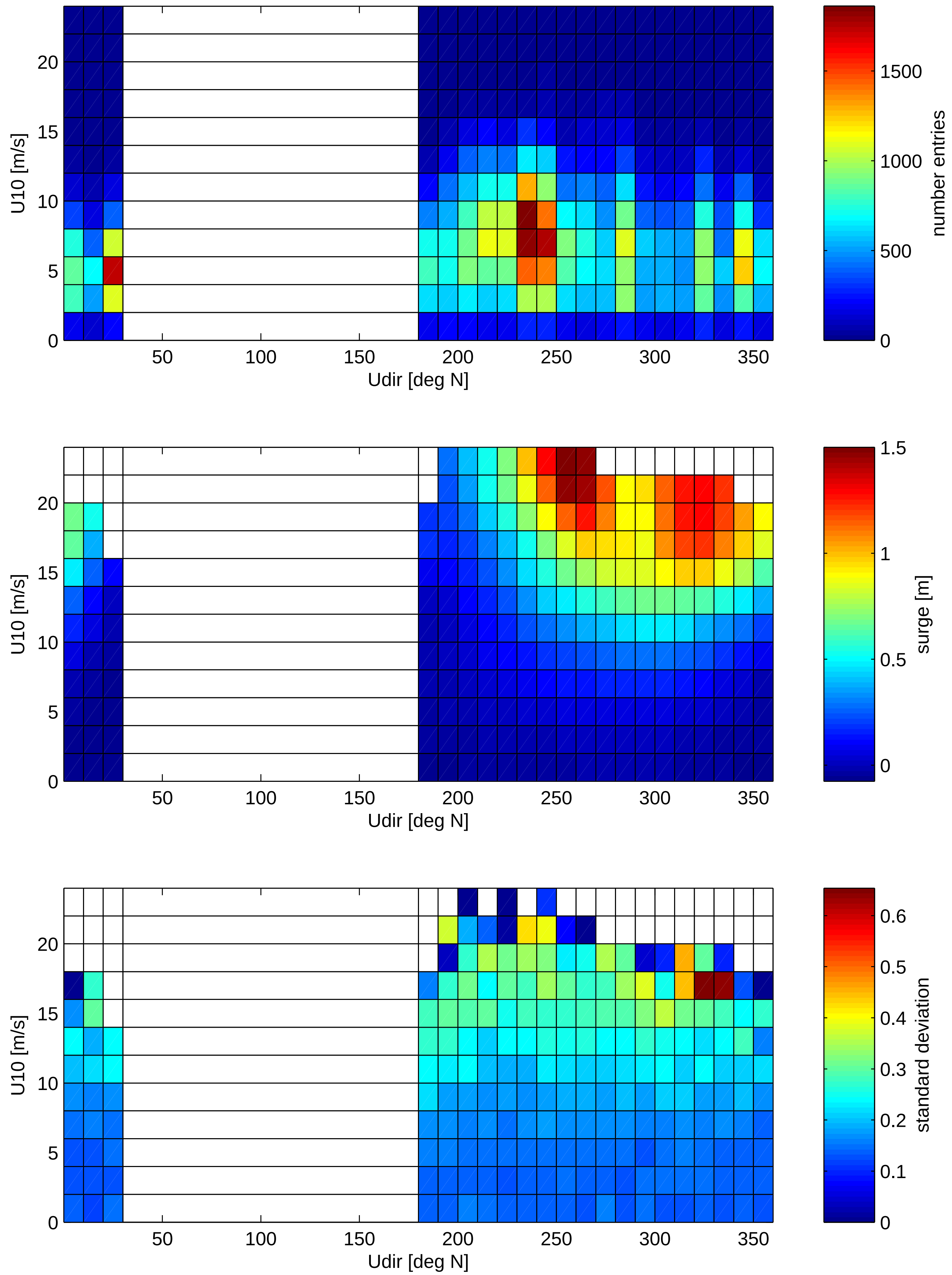




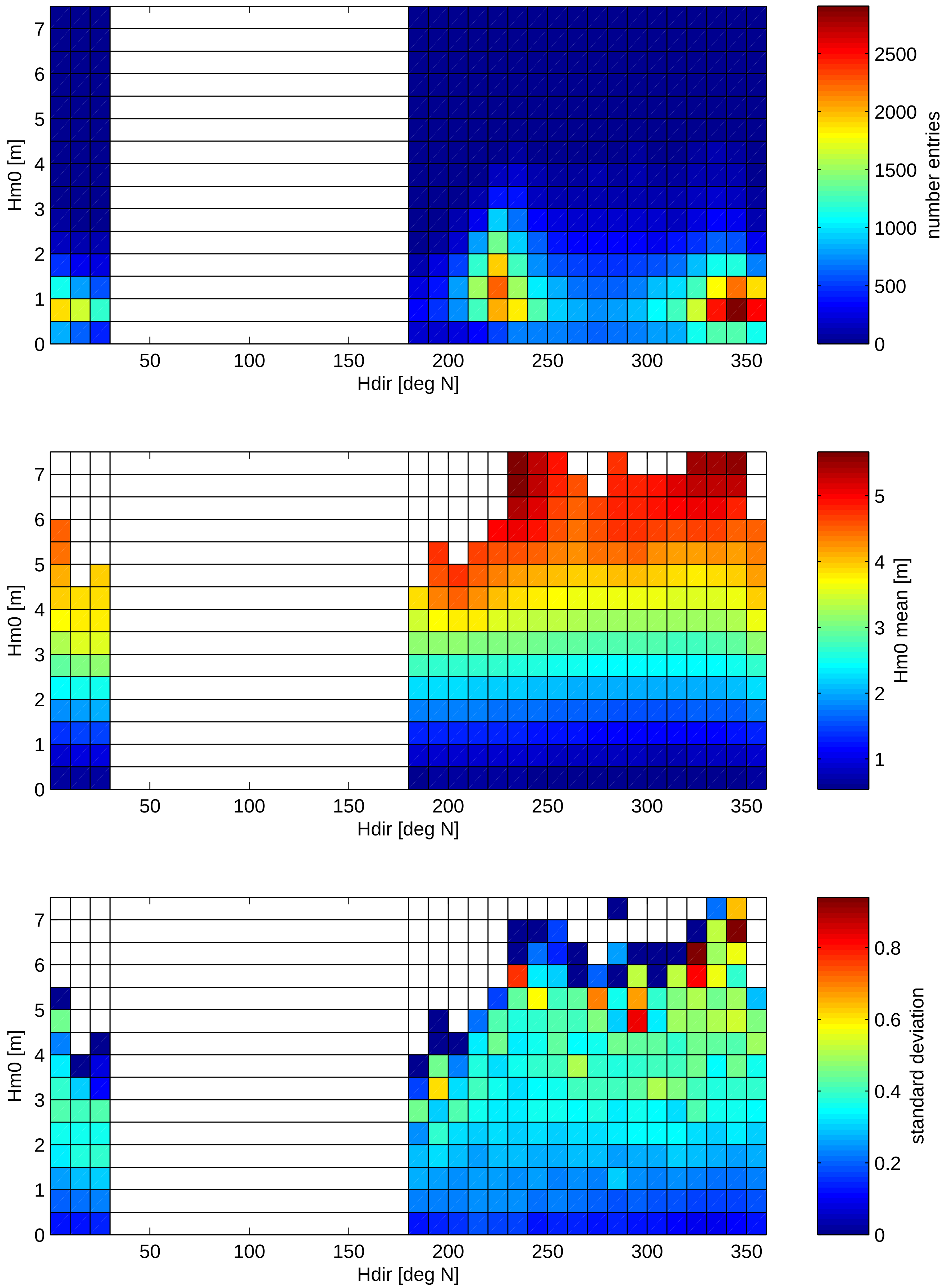
classification matrices on the raw data smoothed data based on 9 points smoothing vertical buffer added per wind/wave direction	Tm02	YM6
	01/01/1979 – 31/12/2001	
Deltares	1002337.002	Fig 5b



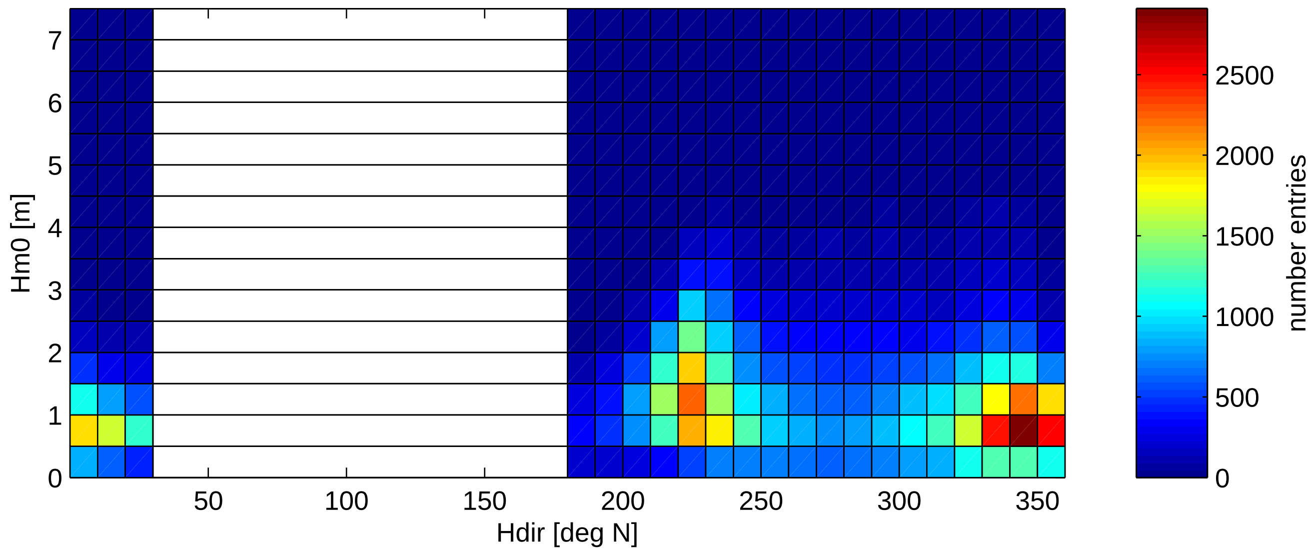
classification matrices on the raw data smoothed data based on 9 points smoothing vertical buffer added per wind/wave direction	U10	YM6
	01/01/1979 − 31/12/2001	
Deltares	1002337.002	Fig 5c

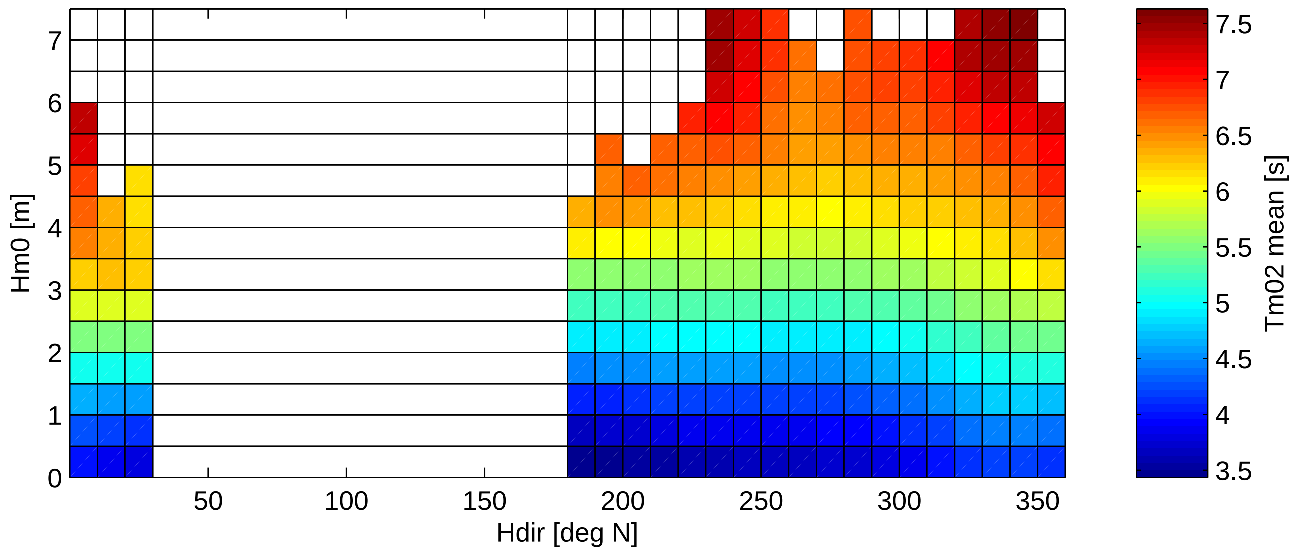


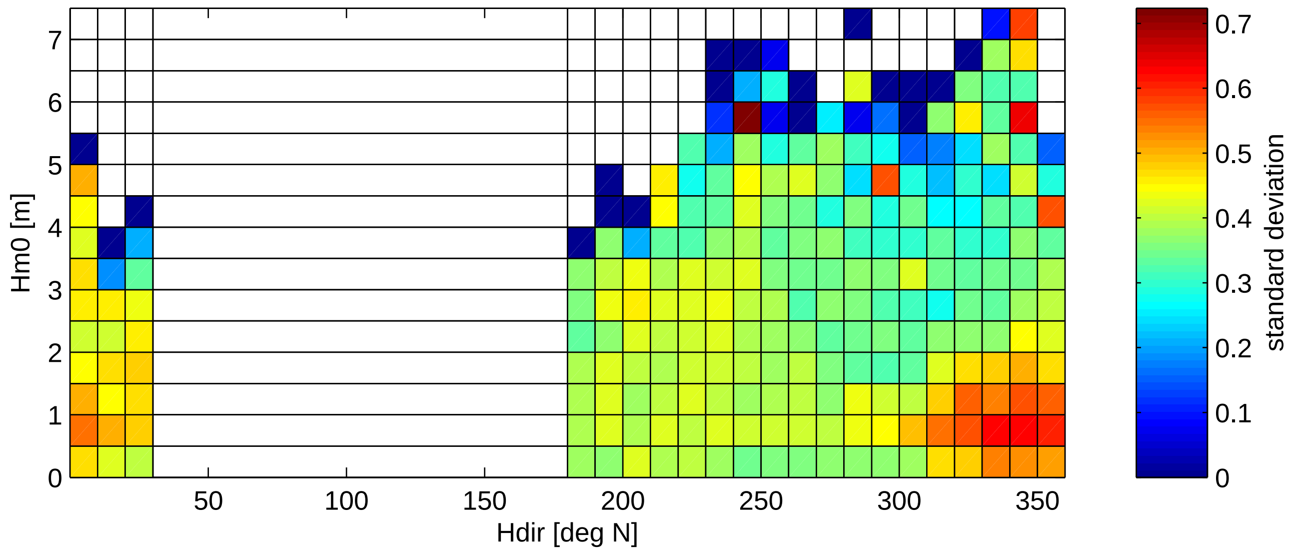
classification matrices on the raw data smoothed data based on 9 points smoothing vertical buffer added per wind/wave direction	surge	YM6
	01/01/1979 − 31/12/2001	
Deltares	1002337.002	Fig 5d



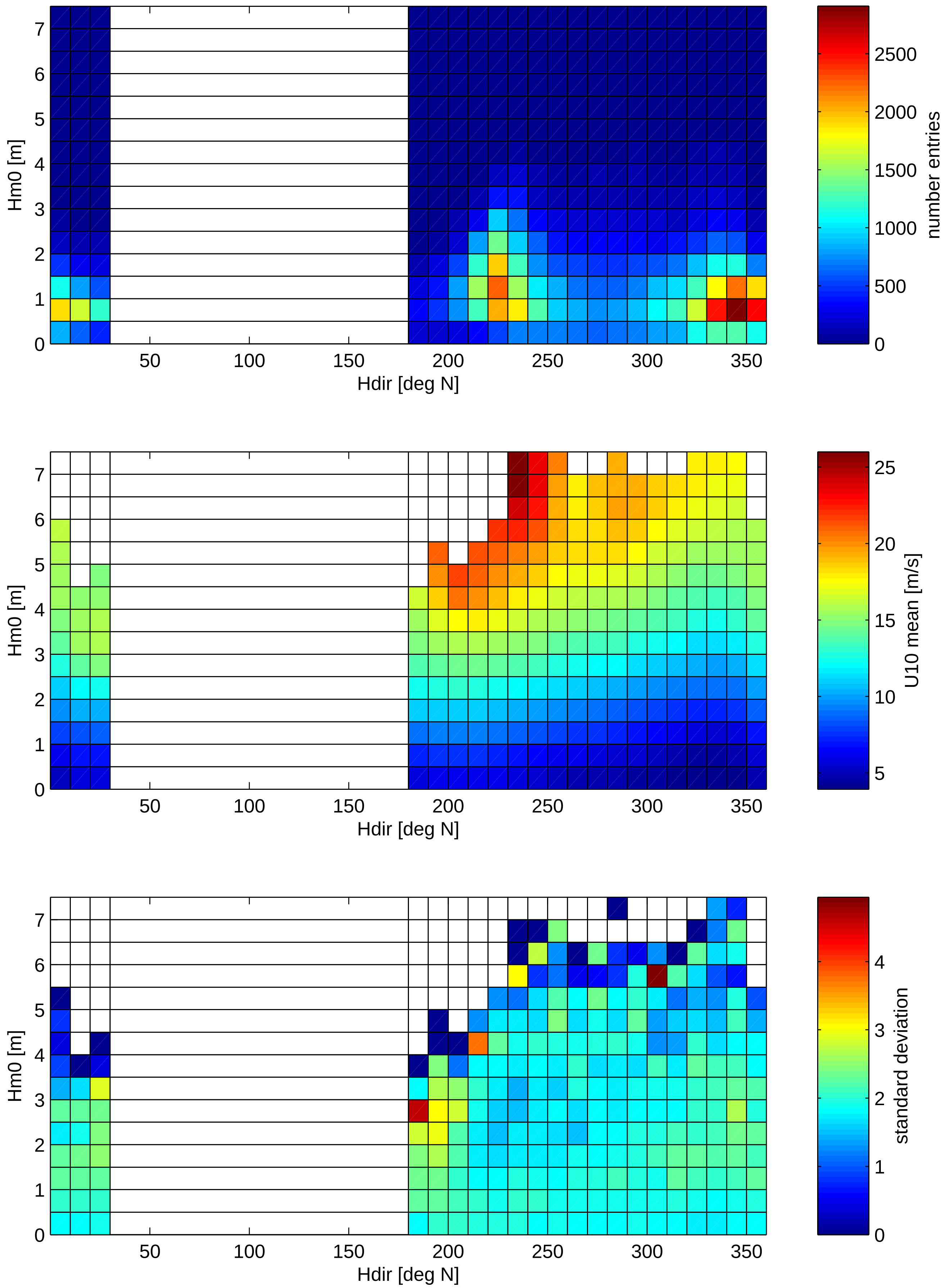
classification matrices on the raw data smoothed data based on 9 points smoothing vertical buffer added per wind/wave direction	Hm0	EUR
	01/01/1979 – 31/12/2001	
Deltares	1002337.002	Fig 5e



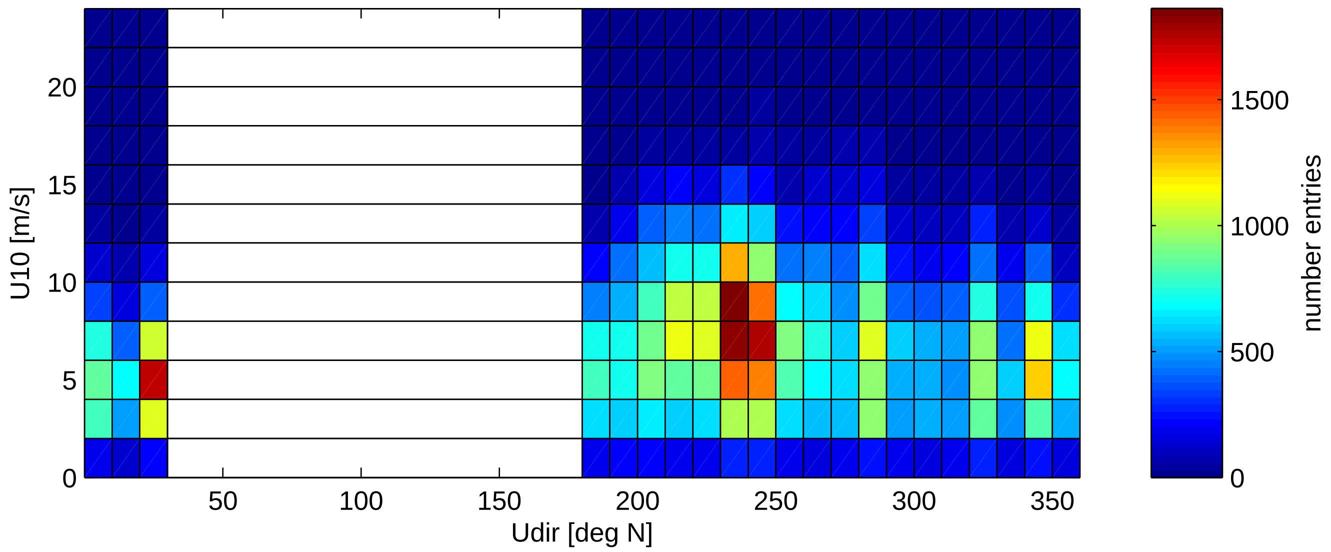


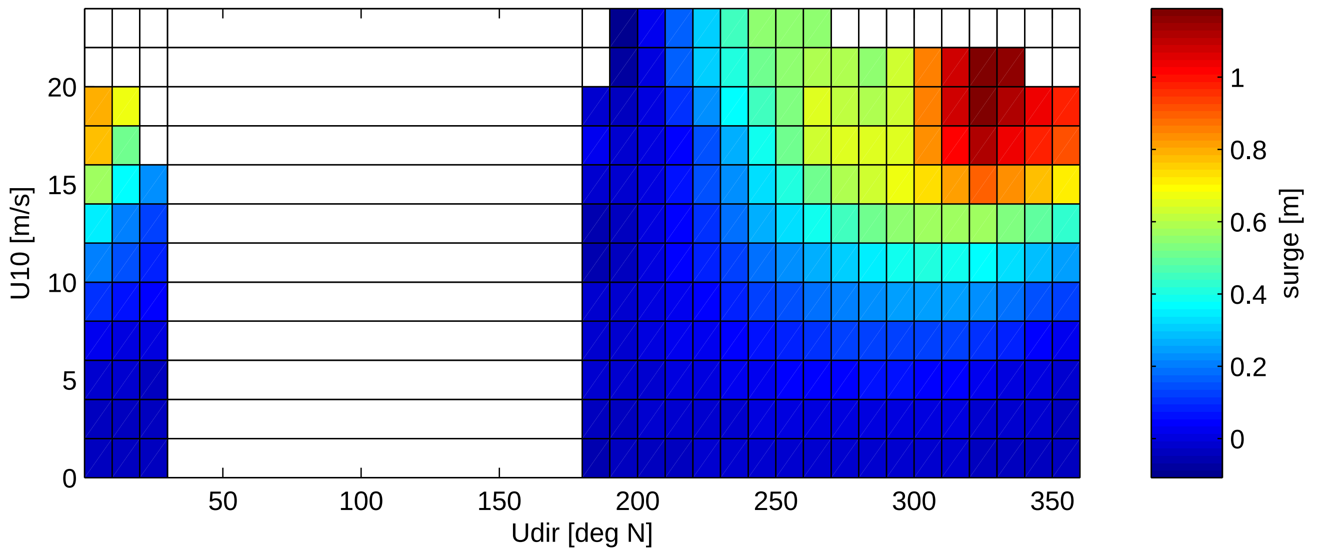


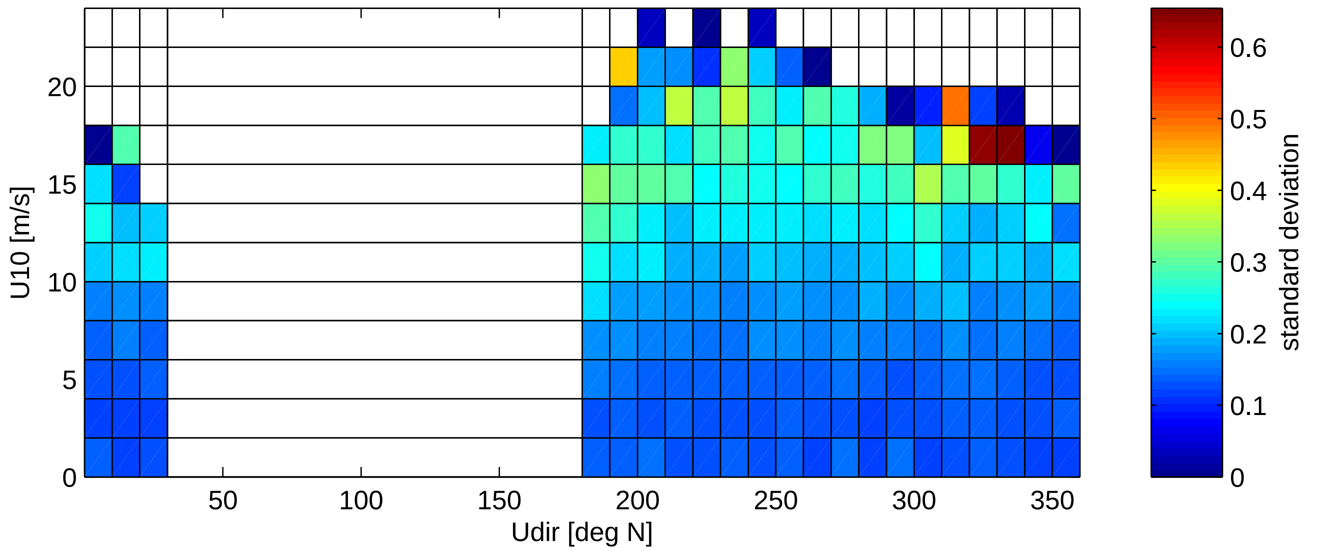
classification matrices on the raw data smoothed data based on 9 points smoothing vertical buffer added per wind/wave direction	Tm02	EUR
	01/01/1979 – 31/12/2001	
Deltares	1002337.002	Fig 5f



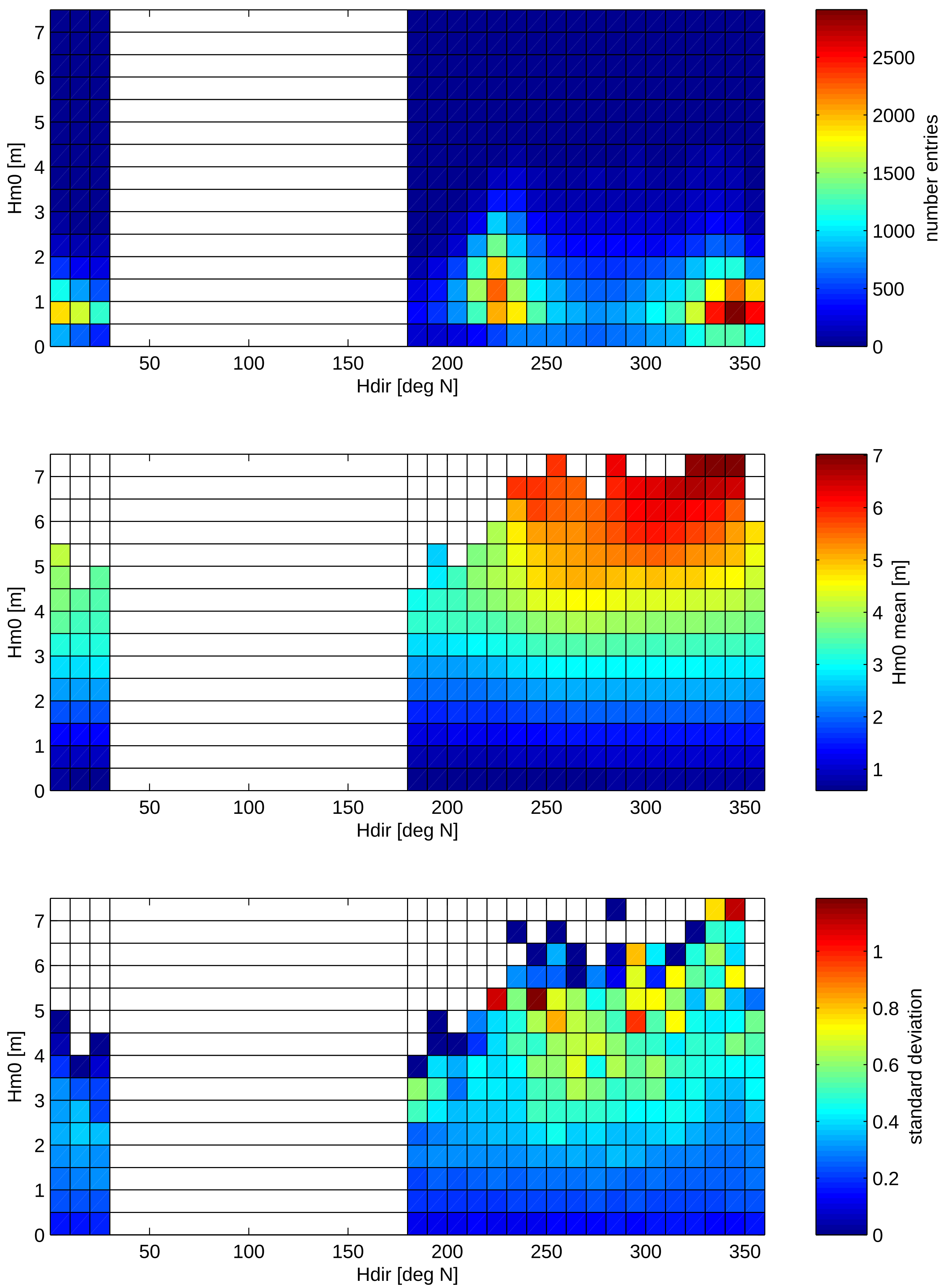
classification matrices on the raw data smoothed data based on 9 points smoothing vertical buffer added per wind/wave direction	U10	EUR
	01/01/1979 − 31/12/2001	
Deltares	1002337.002	Fig 5g



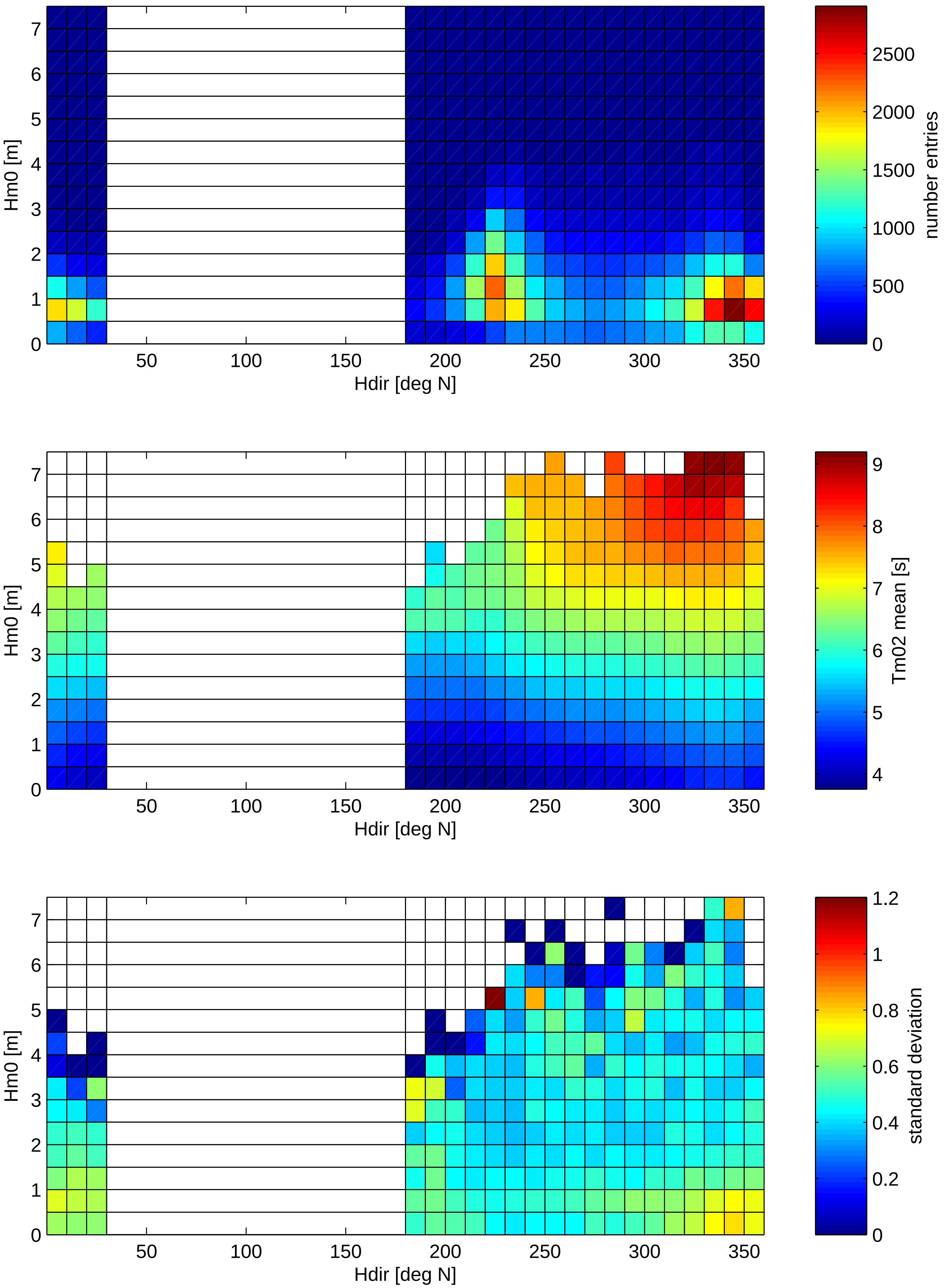




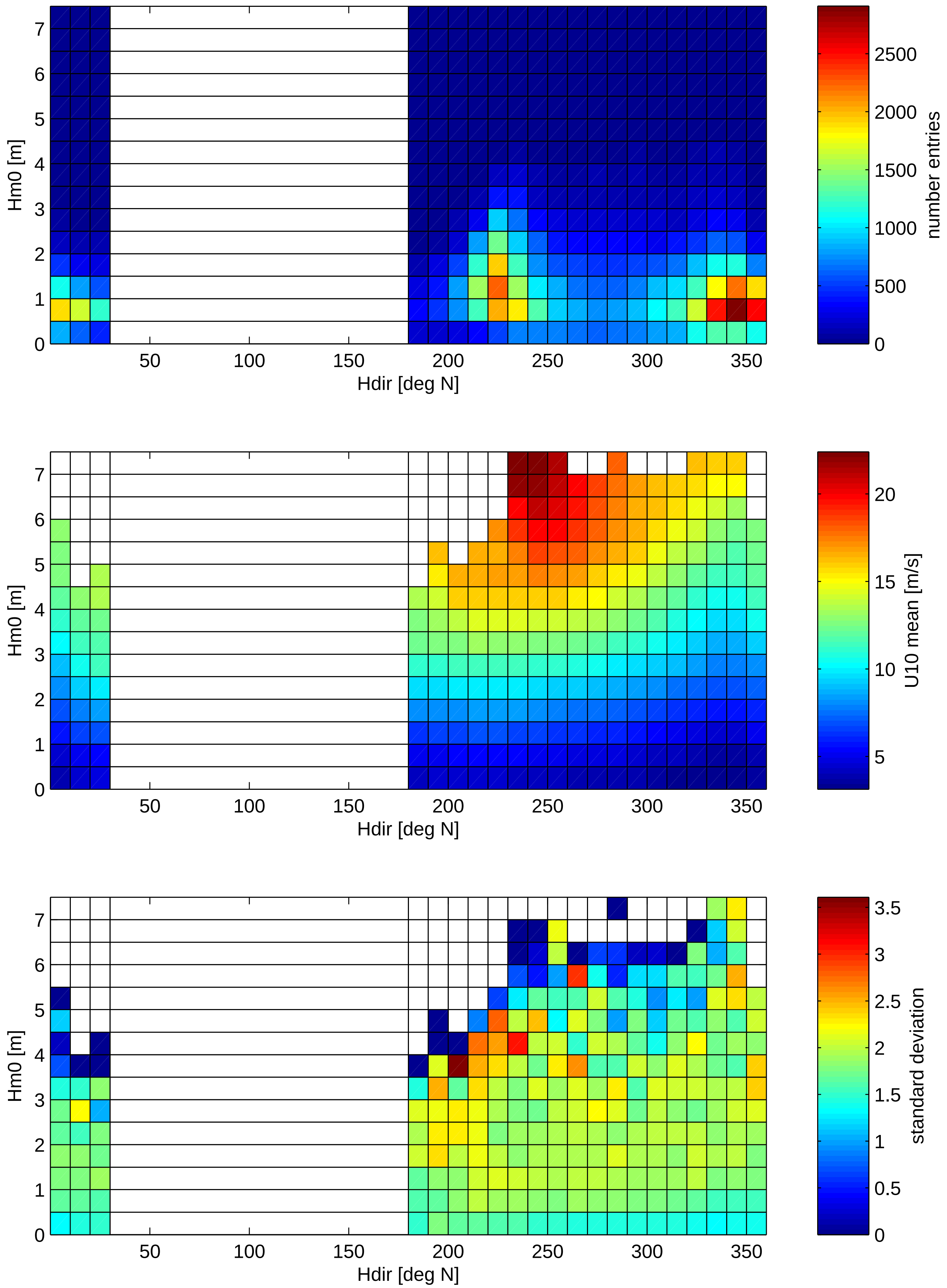
classification matrices on the raw data smoothed data based on 9 points smoothing vertical buffer added per wind/wave direction	surge	EUR
	01/01/1979 – 31/12/2001	
Deltares	1002337.002	Fig 5h



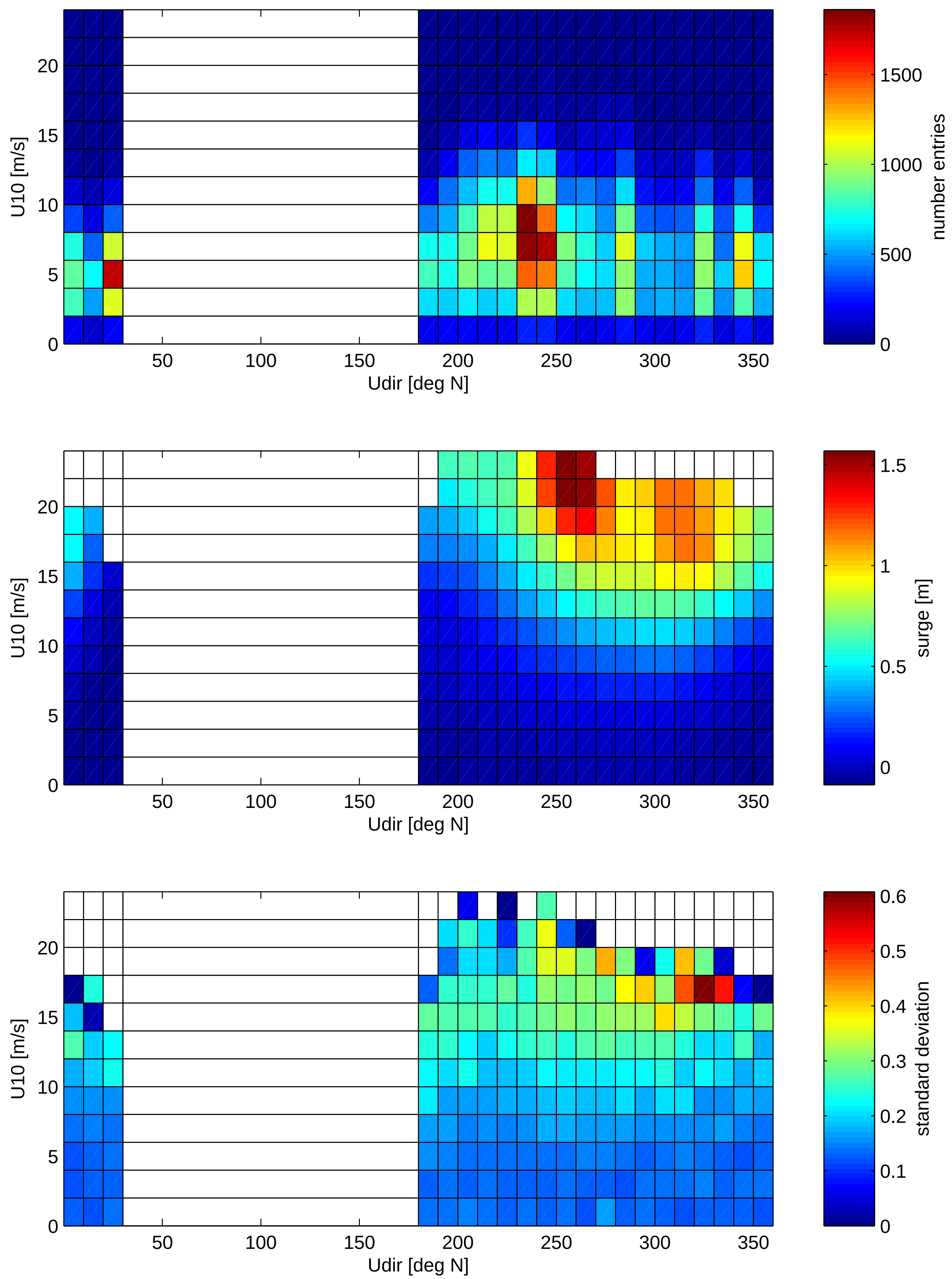
classification matrices on the raw data smoothed data based on 9 points smoothing vertical buffer added per wind/wave direction	Hm0	ELD
	01/01/1979 – 31/12/2001	
Deltares	1002337.002	Fig 5i



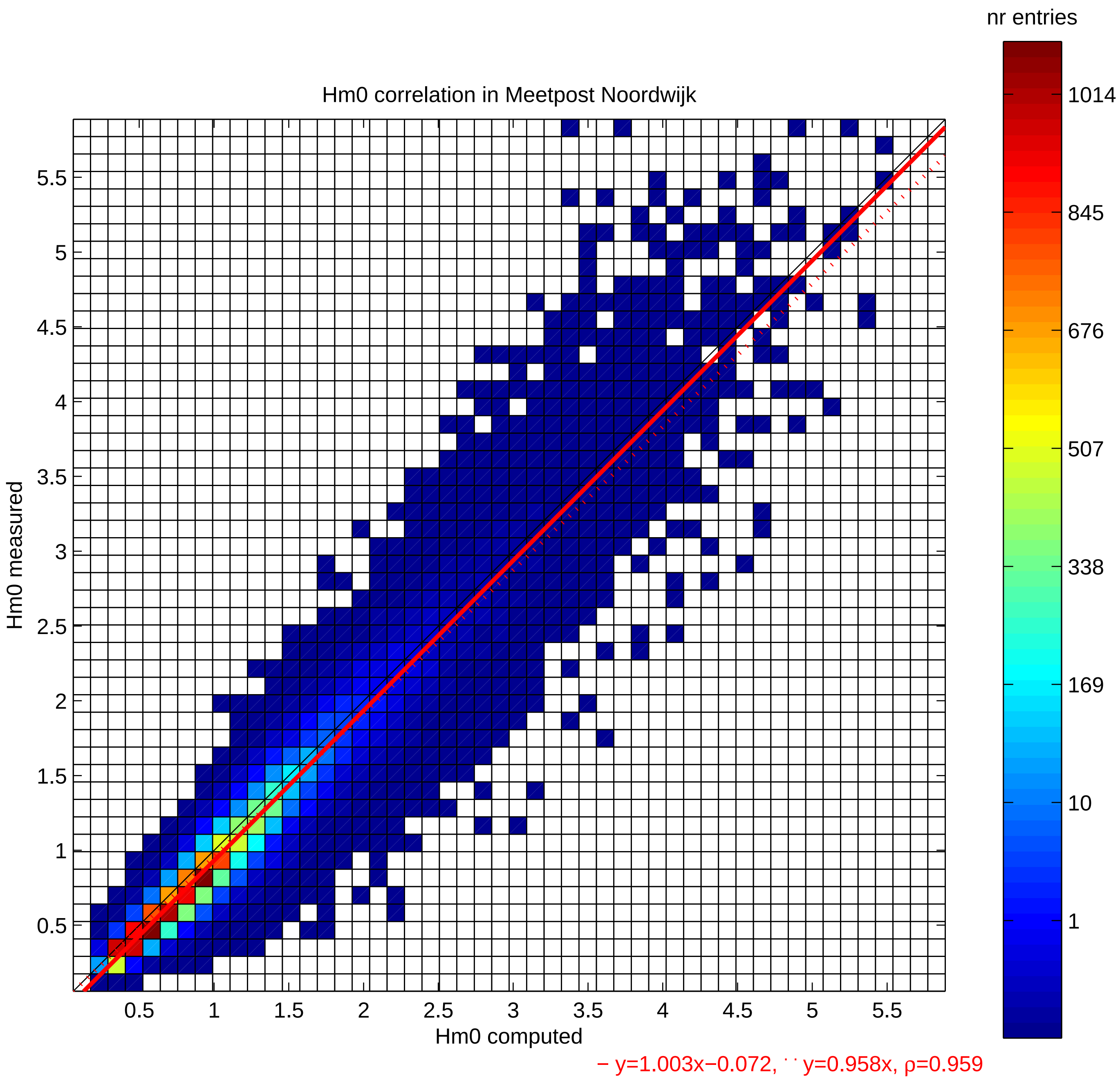
classification matrices on the raw data smoothed data based on 9 points smoothing vertical buffer added per wind/wave direction	Tm02	ELD
	01/01/1979 − 31/12/2001	
Deltares	1002337.002	Fig 5j



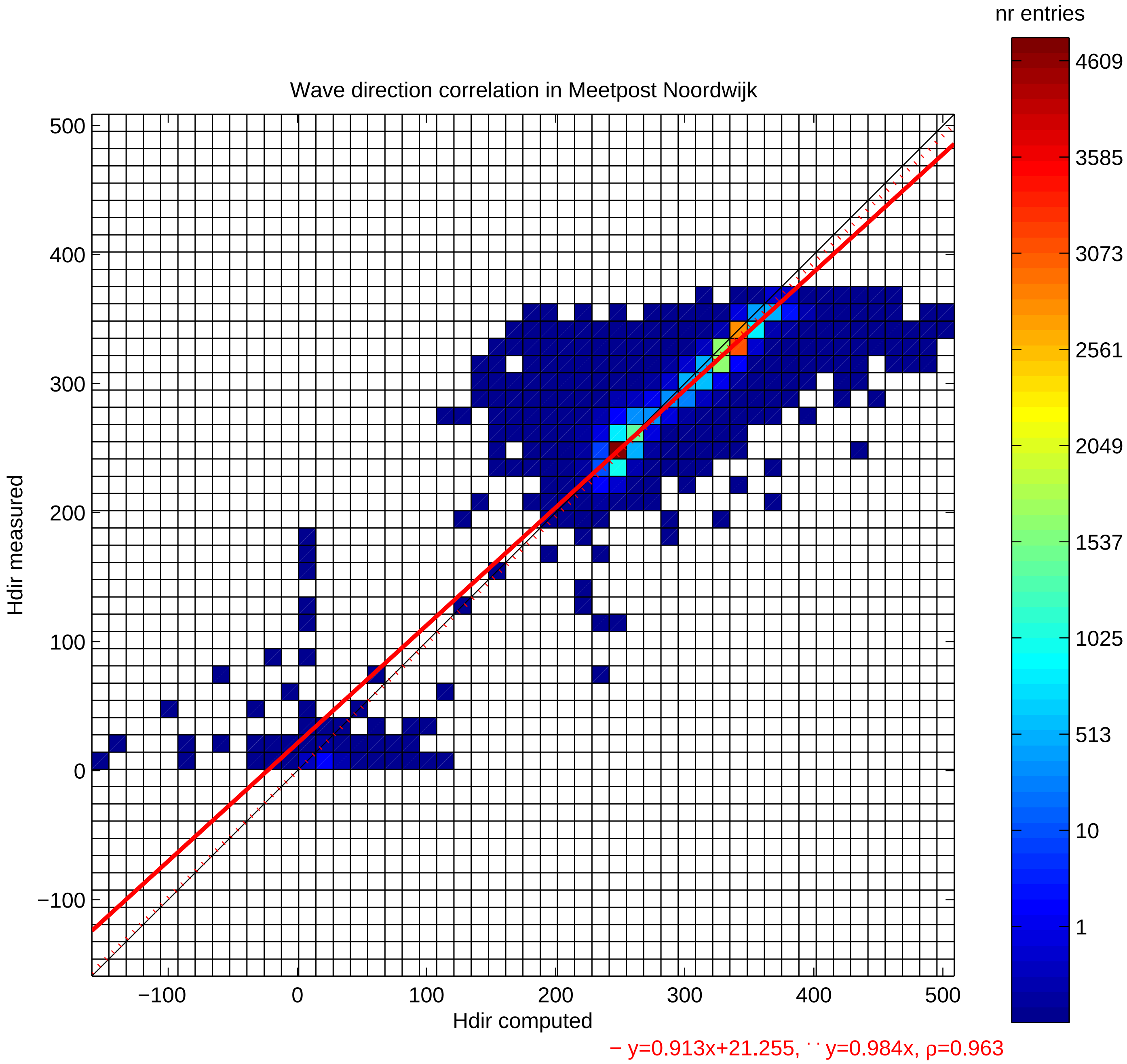
classification matrices on the raw data smoothed data based on 9 points smoothing vertical buffer added per wind/wave direction	U10	ELD
	01/01/1979 – 31/12/2001	
Deltares	1002337.002	Fig 5k



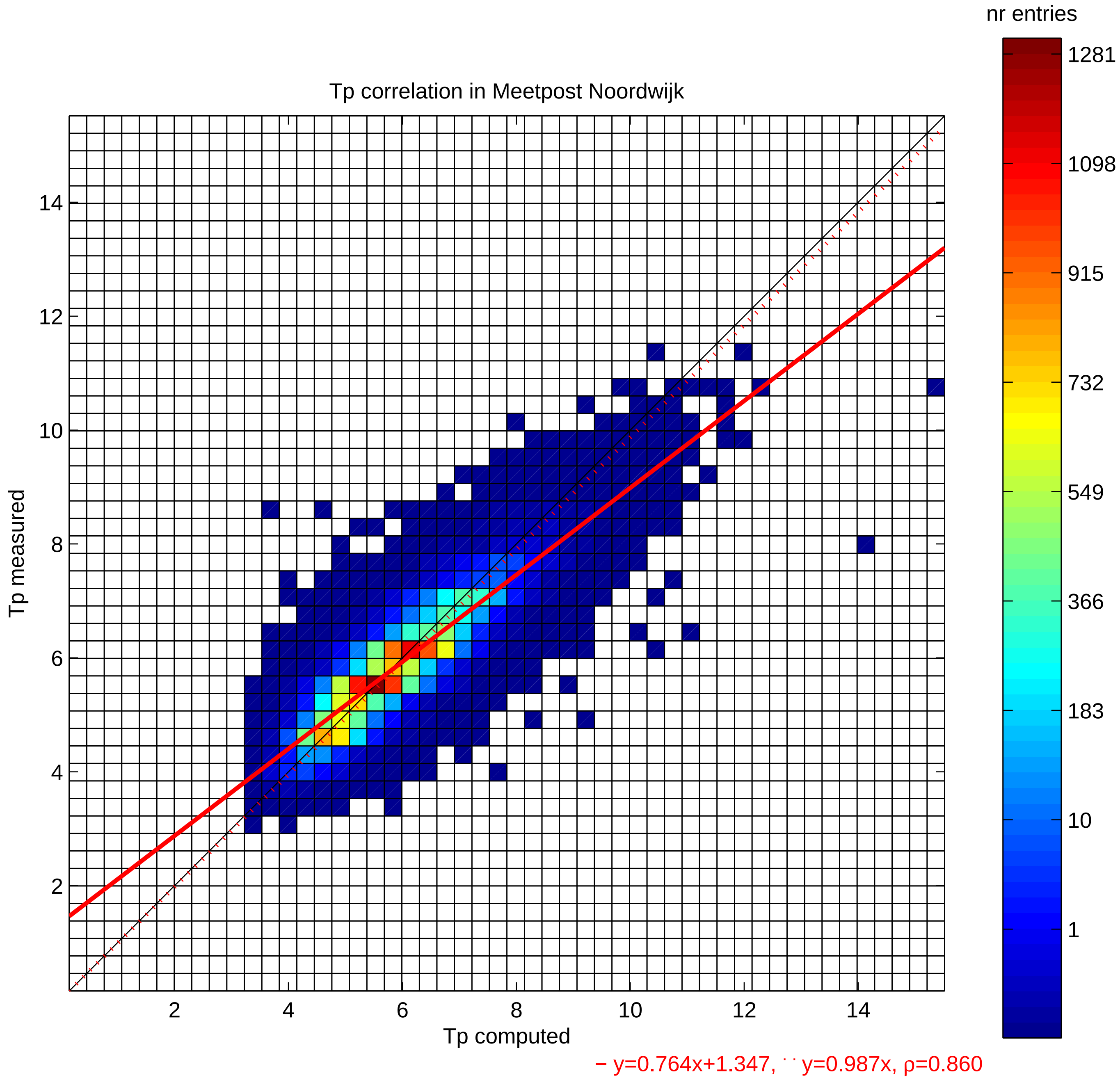
classification matrices on the raw data smoothed data based on 9 points smoothing vertical buffer added per wind/wave direction	surge	ELD
	01/01/1979 − 31/12/2001	
Deltares	1002337.002	Fig 5l



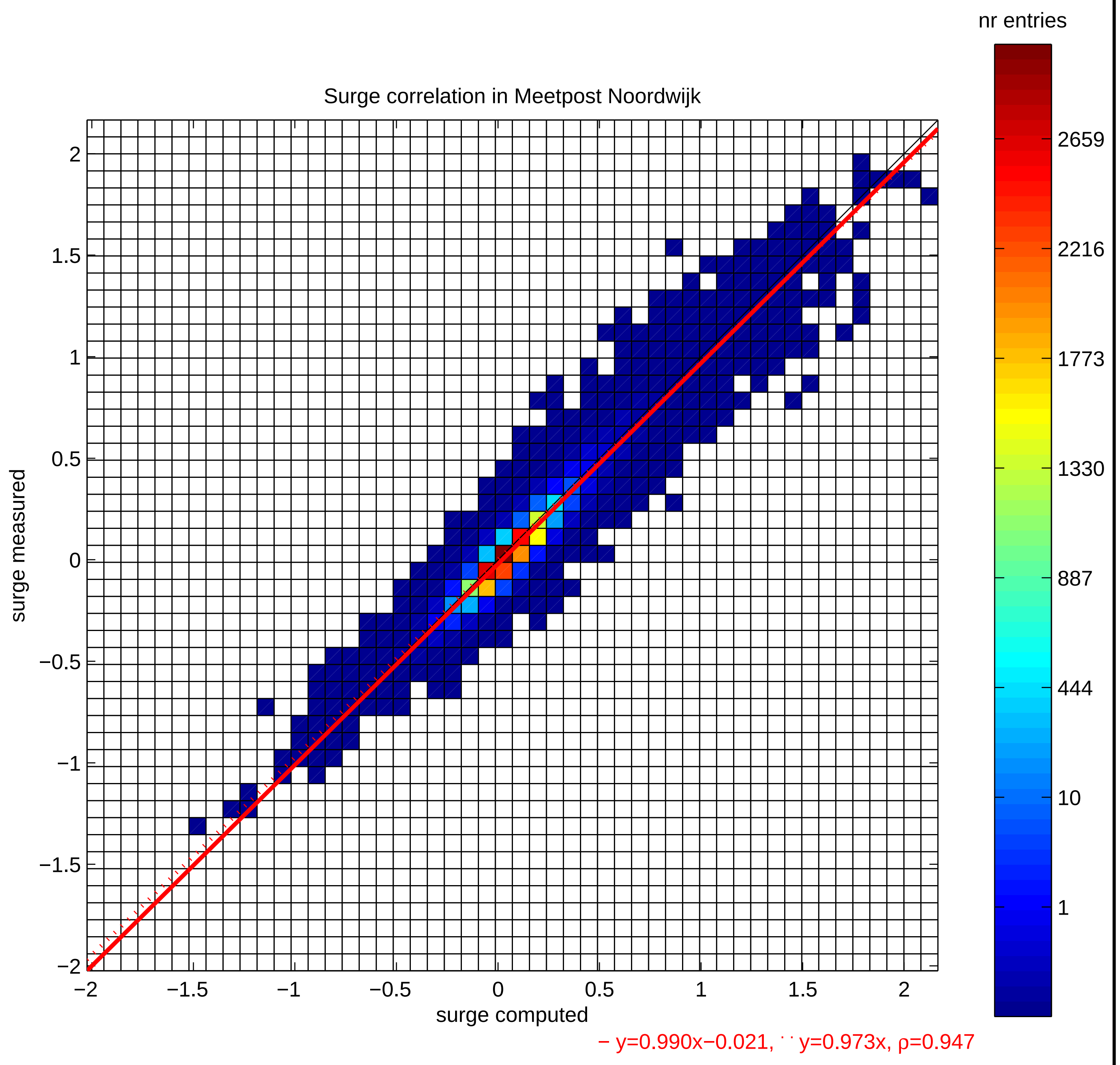
Density scatter significant wave heigth Hm0 computed vs Hm0 measured at Meetpost Noordwijk number of datapoints = 56256		MPN
	01/01/1979 − 30/12/2001	
Deltares	1002337.002	Fig 6a



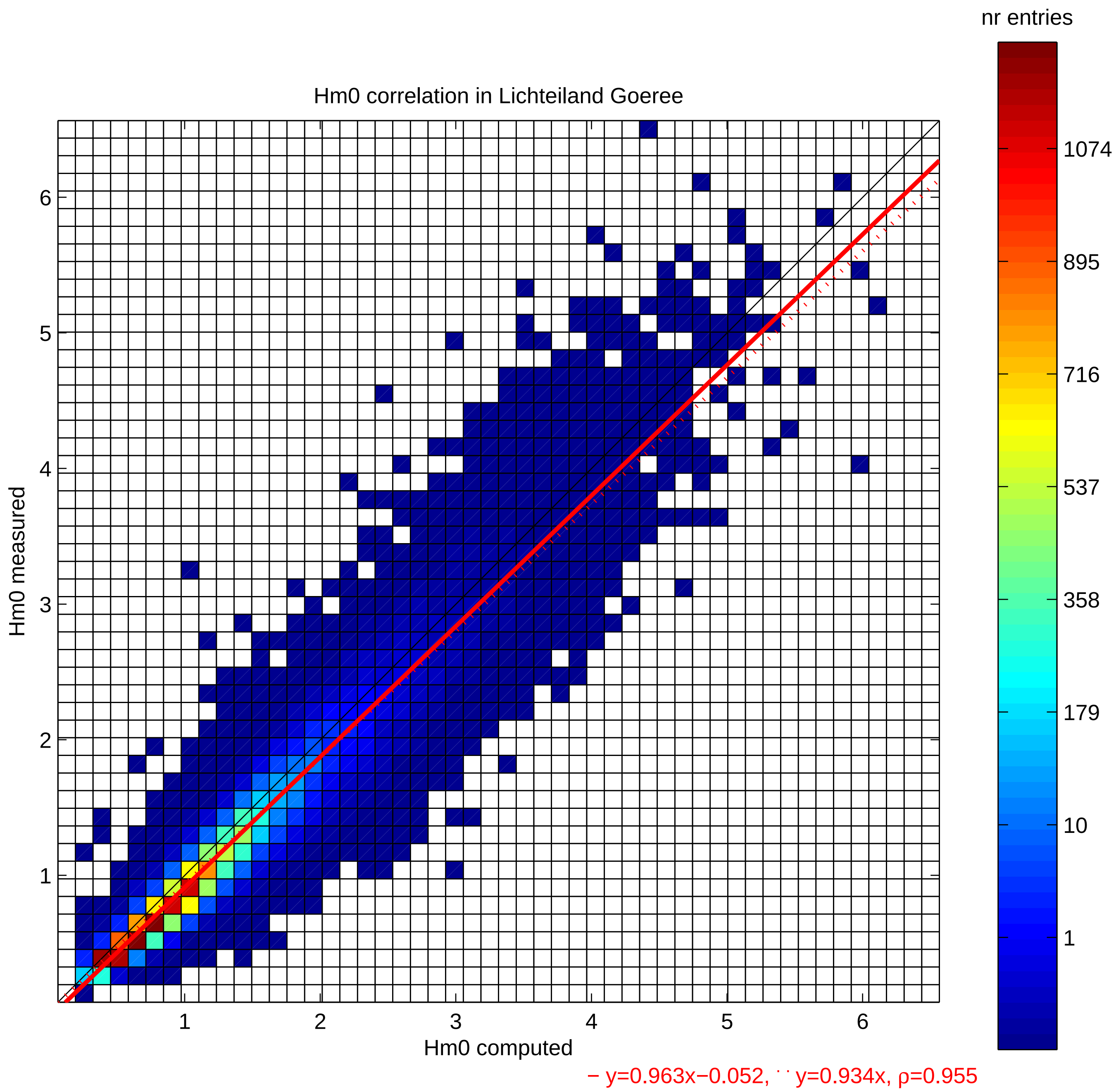
Density scatter mean wave direction Hdir computed vs Hdir measured at Meetpost Noordwijk number of datapoints = 56256		MPN
	01/01/1979 − 30/12/2001	
Deltares	1002337.002	Fig 6b



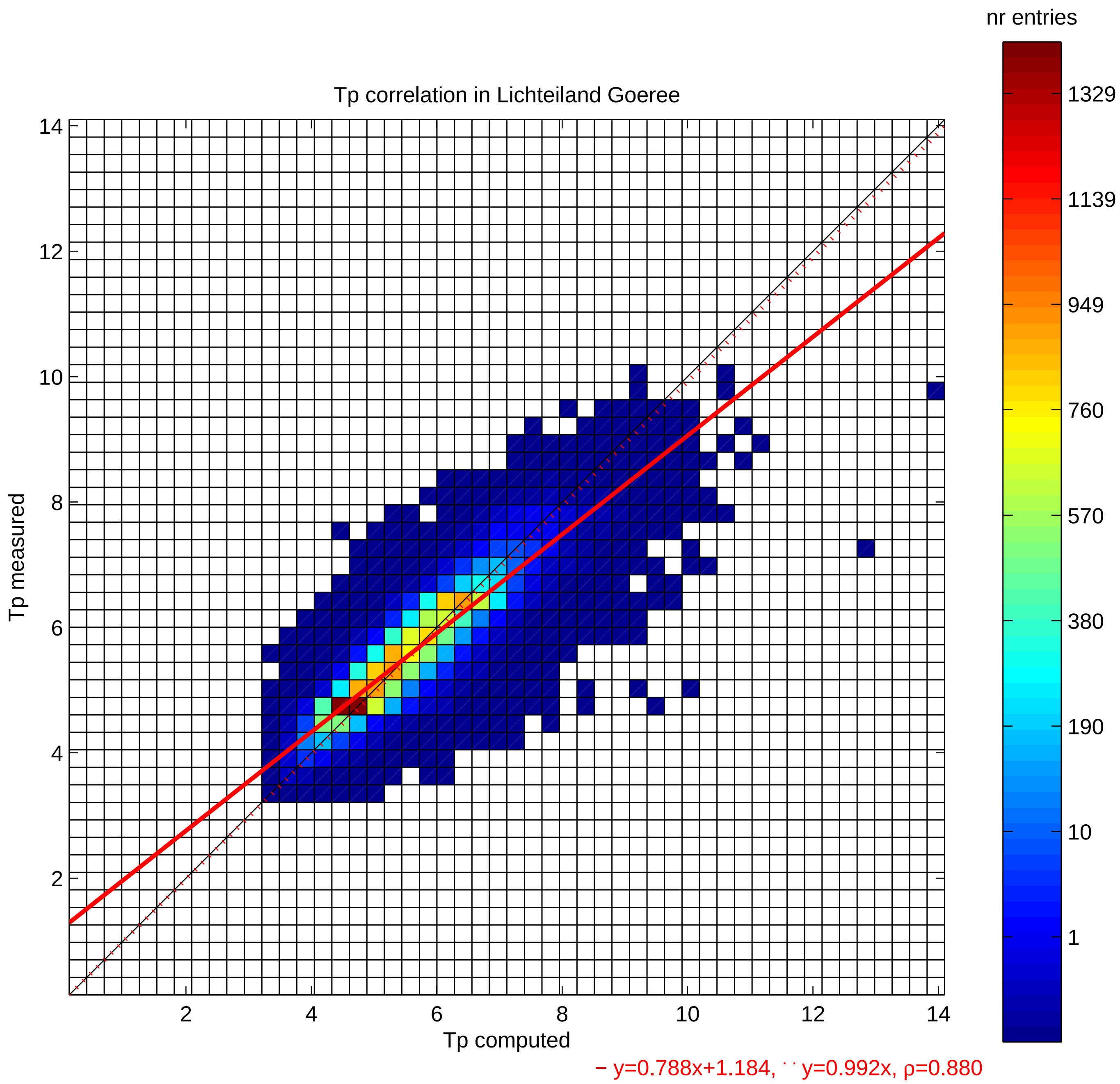
Density scatter mean wave period Tp computed vs Tp measured at Meetpost Noordwijk number of datapoints = 56256		MPN
	01/01/1979 − 30/12/2001	
Deltares	1002337.002	Fig 6c



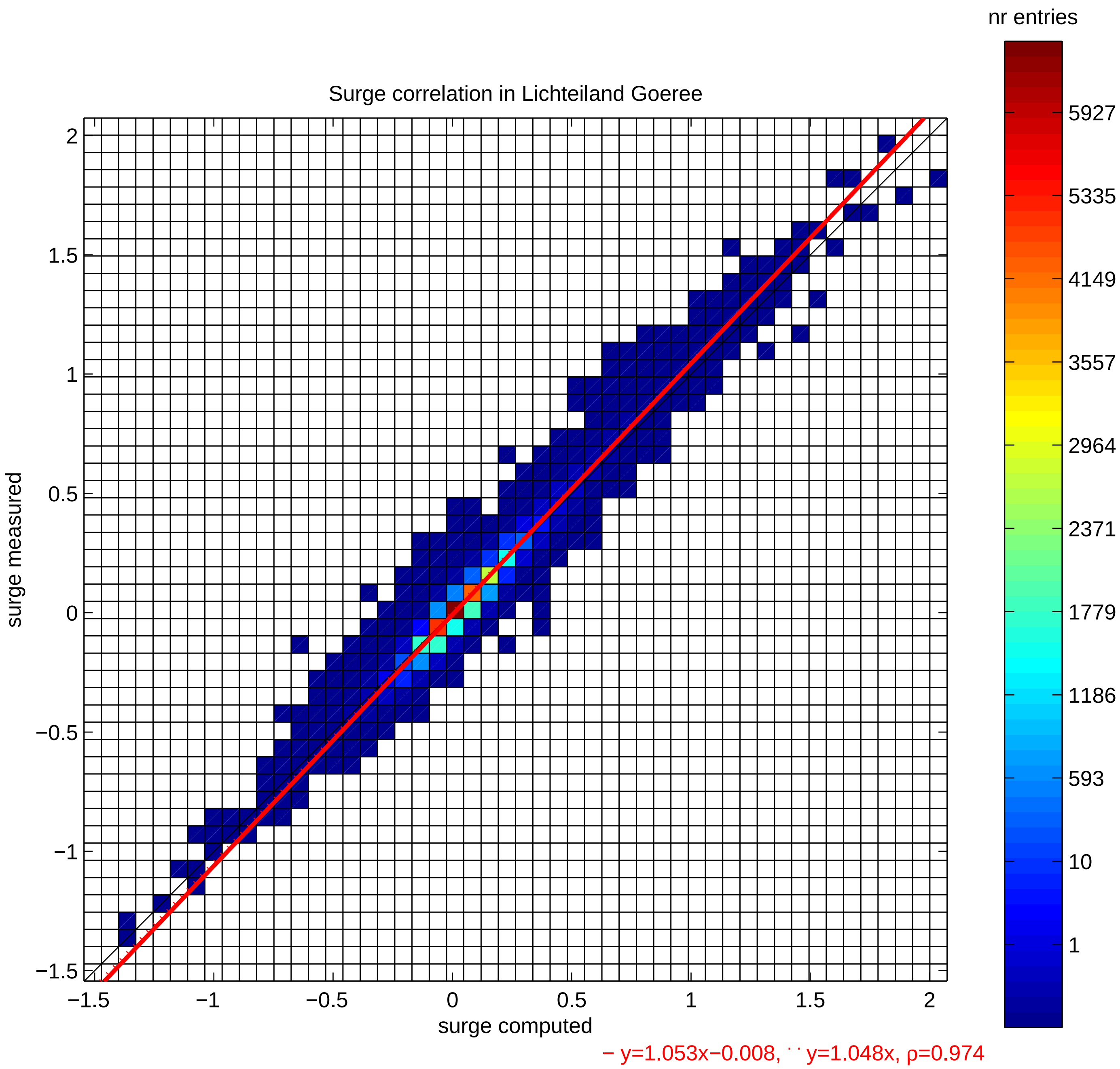
Density scatter for surge Surge computed vs Surge measured at Meetpost Noordwijk number of datapoints = 56256		MPN
	01/01/1979 − 30/12/2001	
Deltares	1002337.002	Fig 6d



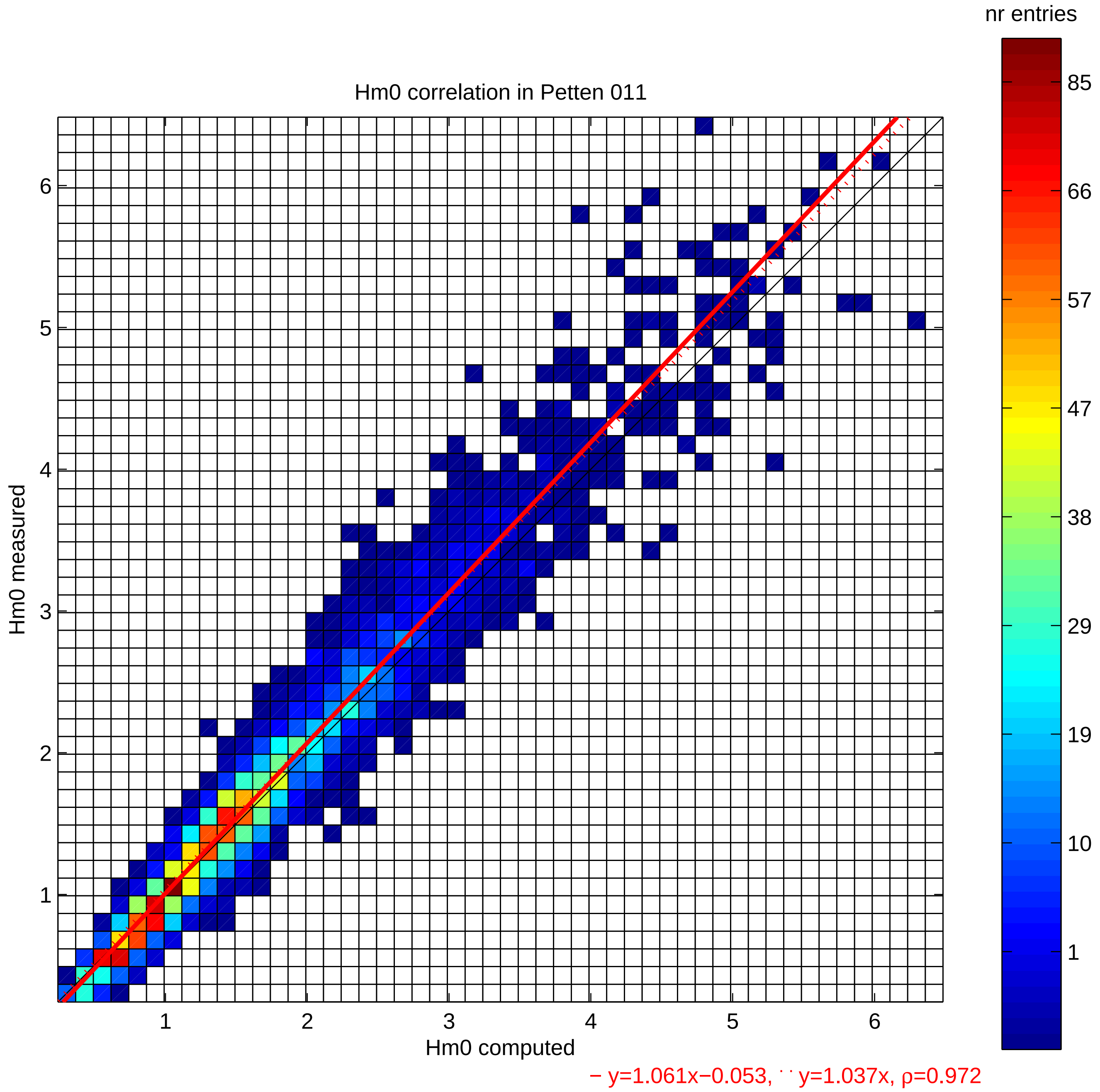
Density scatter significant wave heigth Hm0 computed vs Hm0 measured at Lichteiland Goeree number of datapoints = 56256		LEG
	01/01/1979 − 30/12/2001	
Deltares	1002337.002	Fig 7a



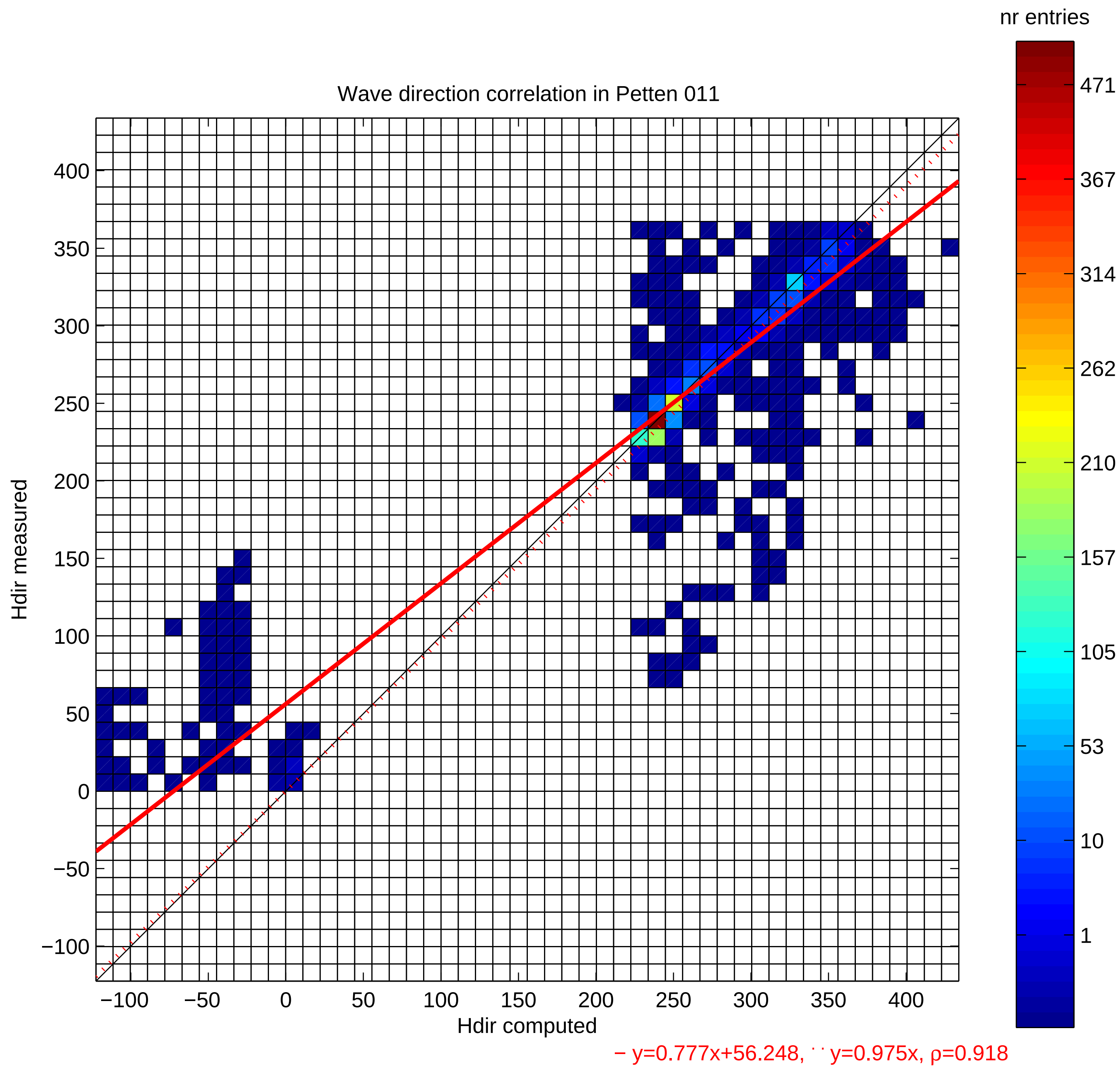
Density scatter mean wave period Tp computed vs Tp measured at Lichteiland Goeree number of datapoints = 56256		LEG
	01/01/1979 − 30/12/2001	
Deltares	1002337.002	Fig 7c



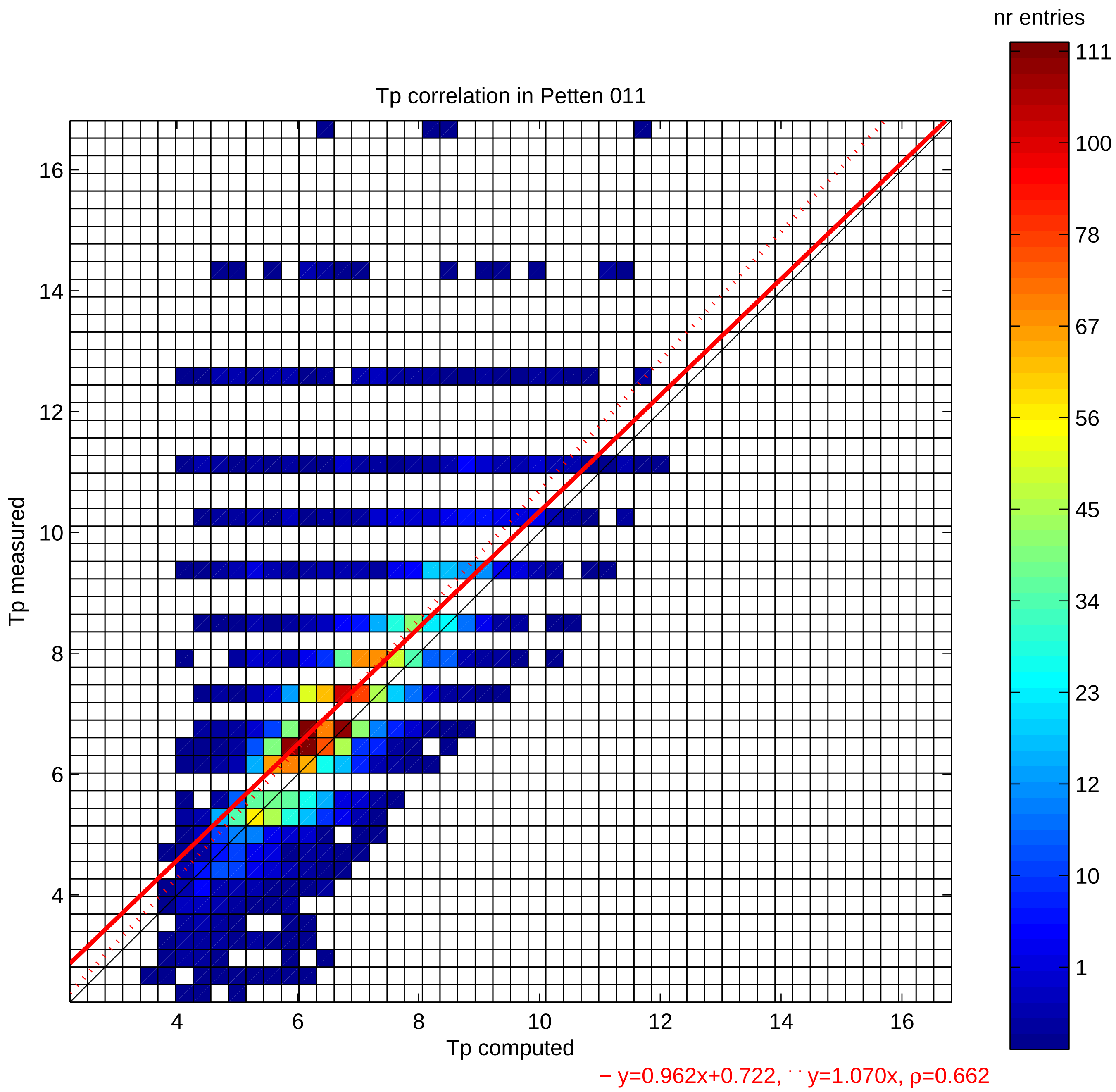
Density scatter for surge Surge computed vs Surge measured at Lichteiland Goeree number of datapoints = 56256		LEG
	01/01/1979 − 30/12/2001	
Deltares	1002337.002	Fig 7d



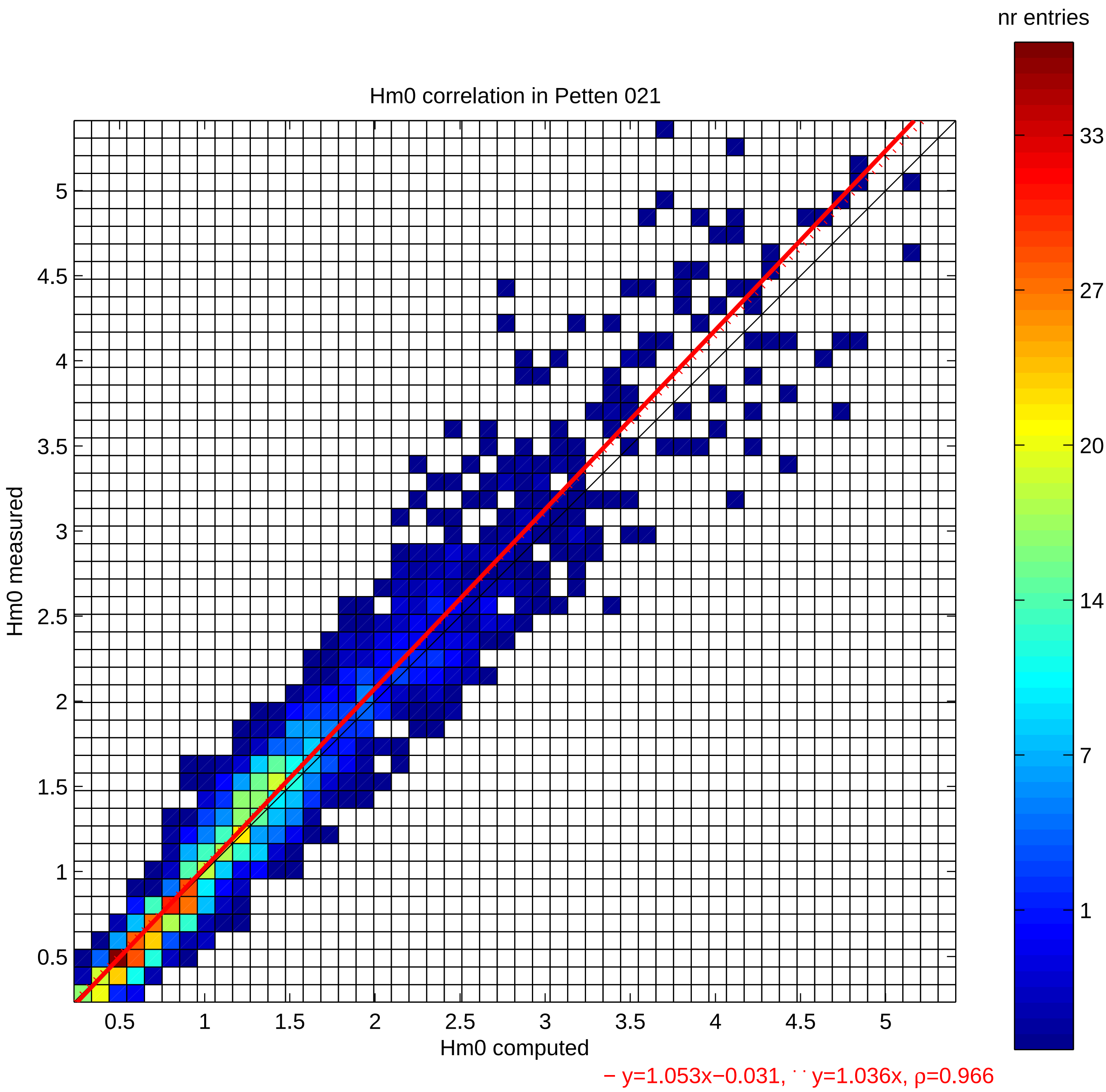
Density scatter significant wave heigth Hm0 computed vs Hm0 measured at Petten 011 number of datapoints = 4486		PET011
	01/01/1995 − 28/12/2001	
Deltares	1002337.002	Fig 8a



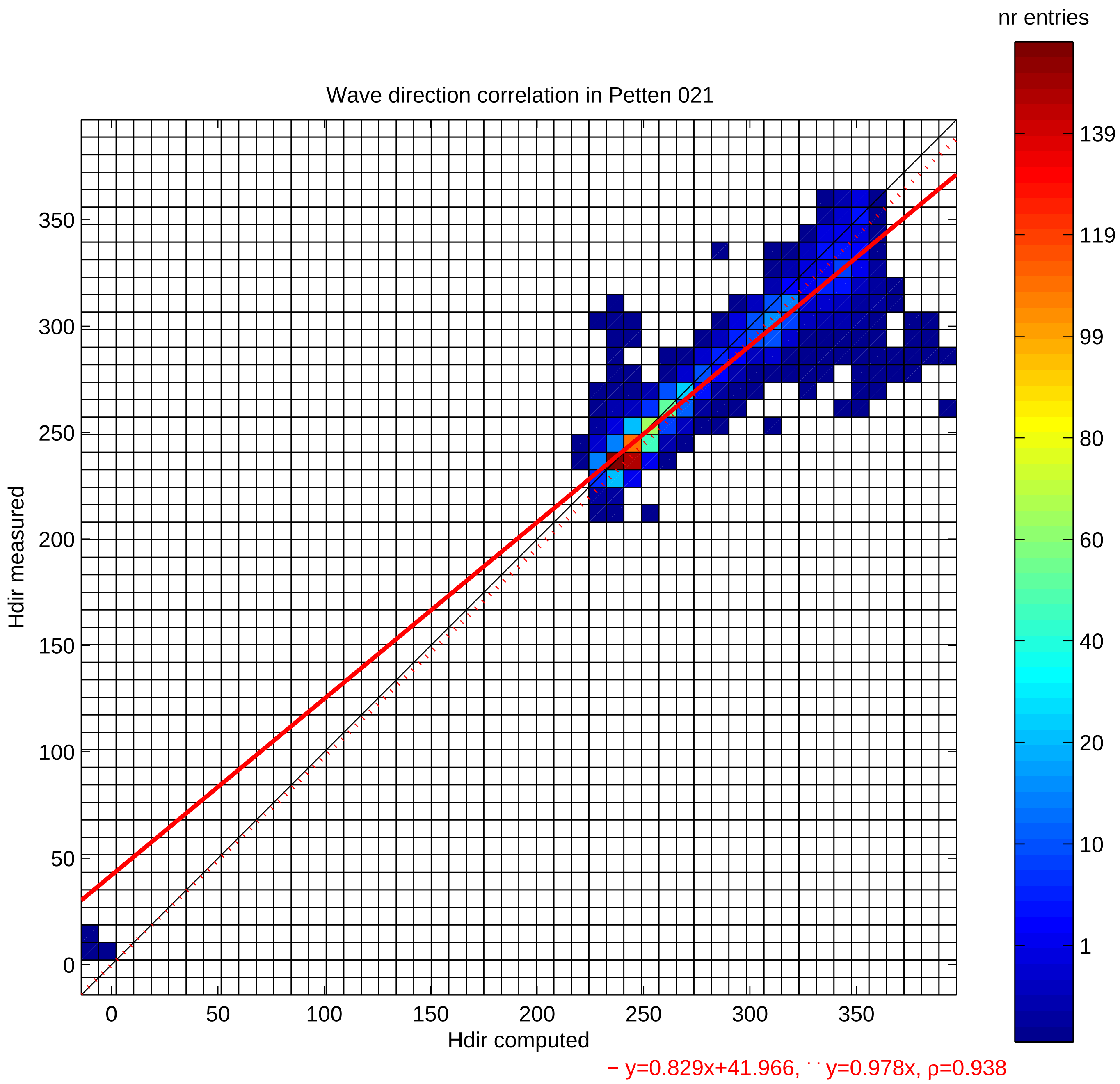
Density scatter mean wave direction Hdir computed vs Hdir measured at Petten 011 number of datapoints = 4484		PET011
	01/01/1995 − 28/12/2001	
Deltares	1002337.002	Fig 8b



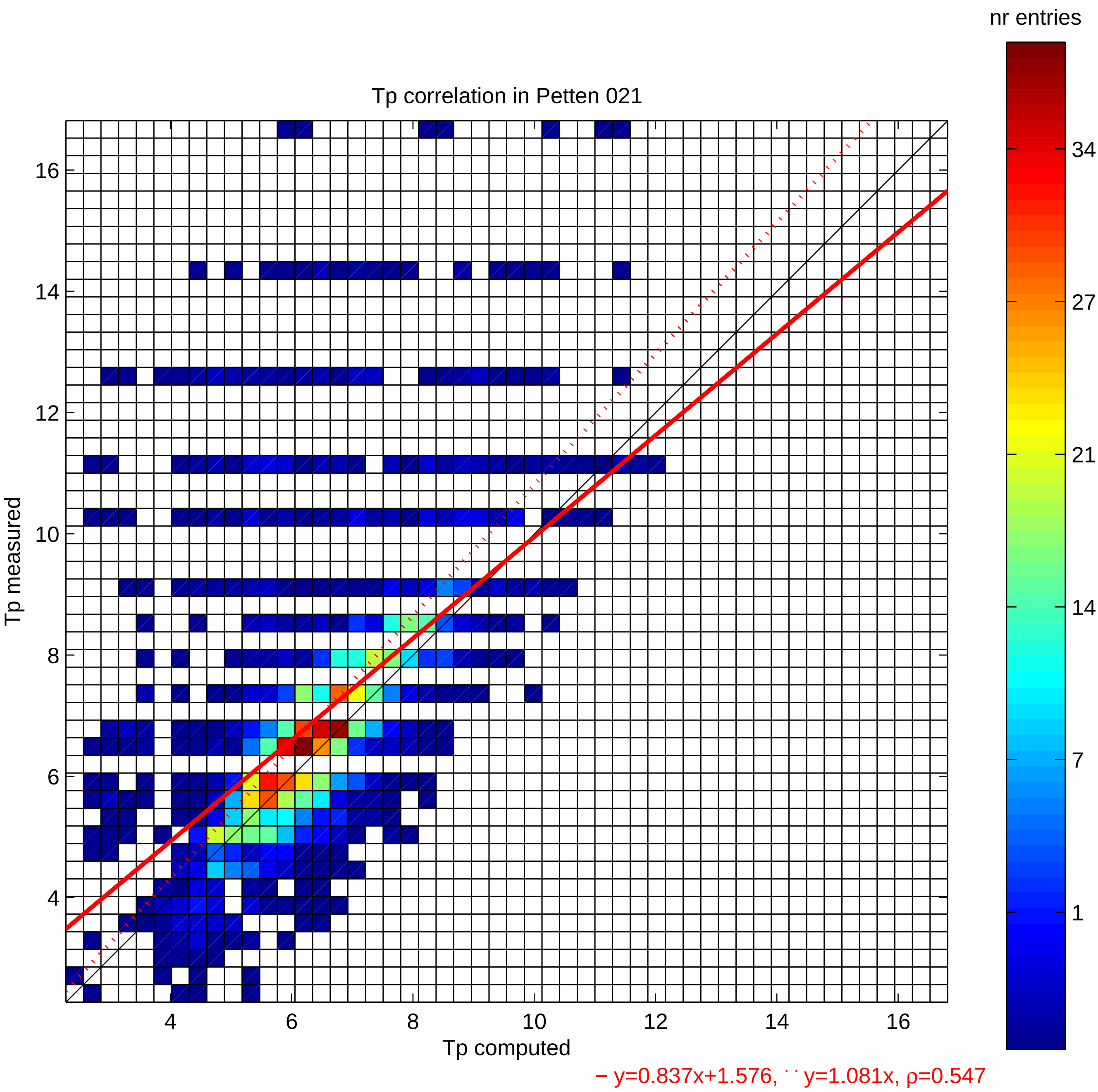
Density scatter mean wave period Tp computed vs Tp measured at Petten 011 number of datapoints = 4486		PET011
	01/01/1995 − 28/12/2001	
Deltares	1002337.002	Fig 8c



Density scatter significant wave heigth Hm0 computed vs Hm0 measured at Petten 021 number of datapoints = 2900		PET021
	01/01/1995 − 28/12/2001	
Deltares	1002337.002	Fig 9a



Density scatter mean wave direction Hdir computed vs Hdir measured at Petten 021 number of datapoints = 2898		PET021
	01/01/1995 − 28/12/2001	
Deltares	1002337.002	Fig 9b



Density scatter mean wave period Tp computed vs Tp measured at Petten 021 number of datapoints = 2900		PET021
	01/01/1995 − 28/12/2001	
Deltares	1002337.002	Fig 9c