Observation and Modeling of High Individual Ocean Waves and Wave Groups caused by a variable Wind Field

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Motivation

To explain Rogue Waves in the Southern North Sea and to find possibilities for warning systems.

Method

Simulate overlay of different statistical ensembles in a numerical sea state model.

Summary

Rogue waves are explained by the overlay of two wave ensembles with different Rayleigh distributions.

Rogue Waves belong to a Rayleigh distribution with an Hs about 1.6 larger than the background waves.

Rayleigh distribution (excceding value)

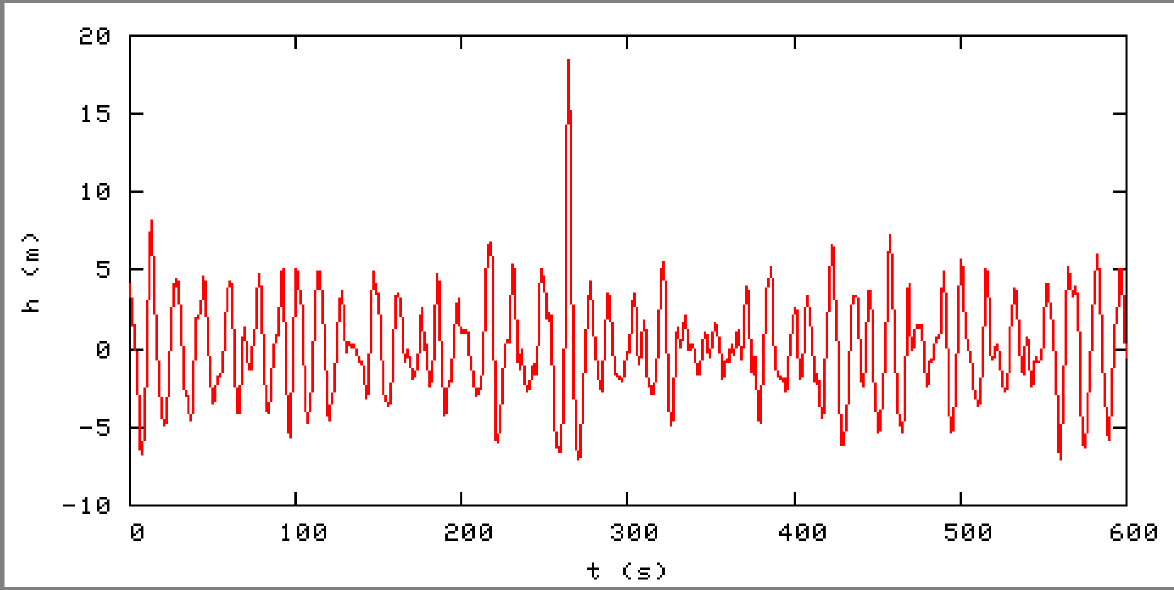
N is the numnber of wavegroups from an ensemble with a given Hs for which on average the wave height H_N is reached or exceeded one time.

$$H_N = H_s (0.5 \ln (N))^{0.5}$$

$$N = \exp (2 (H_N/H_s)^2)$$

N	H_N/H_S
7.4	1
1000	1.86
3000	2.07

Average observed number N of wave groups for a significant wave height H_S until the encounter occurs with a group height H_N or larger.



Time Series Wave Height at Draupner, Jan, 1st 1995 15:20

Significant Waveheight 11.9m

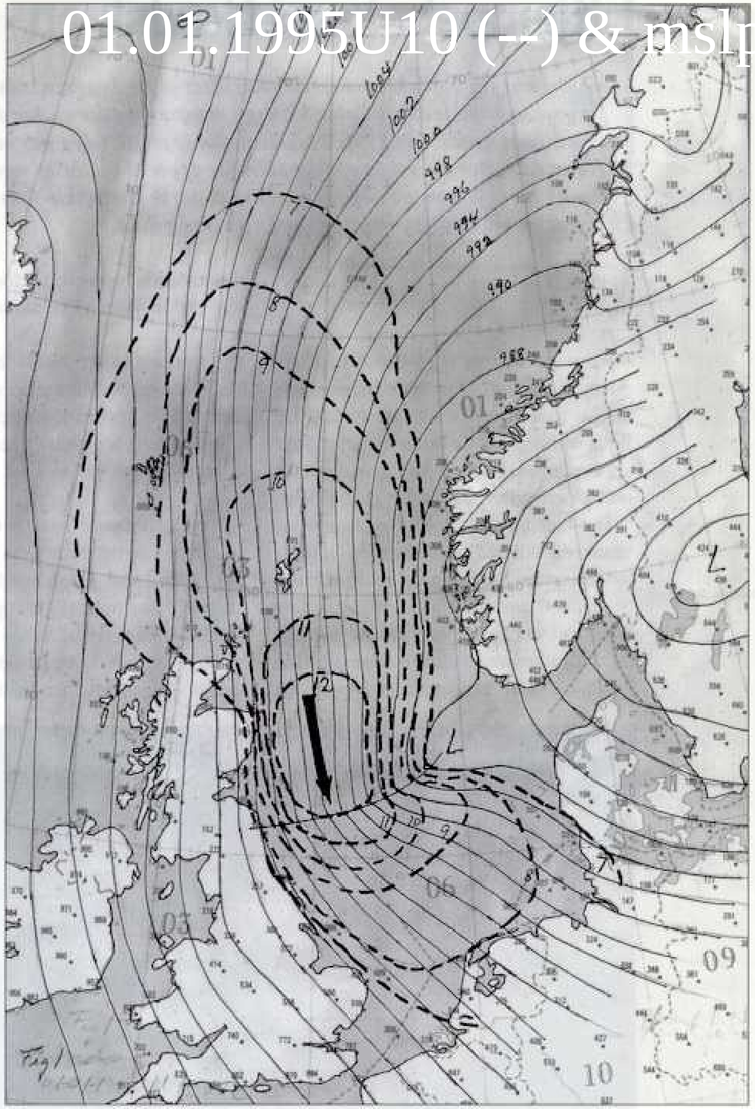
Peak Period 16.7 sec

Maximum crest Height 18.5 m

Adjacent trough -7.1m and –6.5m

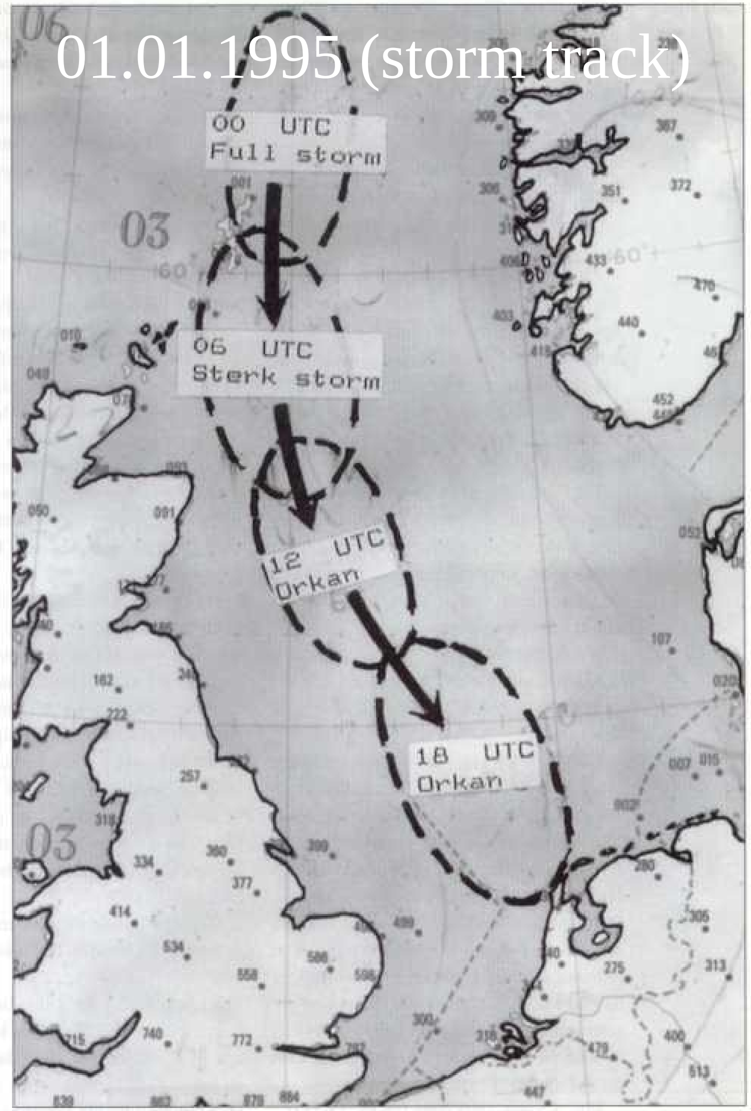
Depth 70m

01.01.1995U10 (--) & mslp



Figur 1. Forenklet værkart for 1. januar 1995 kl. 12 UTC. De tynne linjene er isobarer for hvert 2. hPa. Fra trykkfeltet er beregnet vindfelt. De stiplede kurvene angir vindstyrke i Beaufort. Posisjonen på lavtrykks-virvelen er godt bestemt ut fra satellittbildet fig. 2. Kapteinen på «Color Viking» fortalte om orkan mellom kl. 15 og 18.

01.01.1995 (storm track)



Figur 4. Lavtrykksvirvelen som vi ser vest for Jylland på satellittbildet fig. 2, har vi kunnet følge på tidligere bilder. Virvelen passerte like øst for Shetland tidlig om morgenen, og øket vinden i vestlige Nordsjøen på sin veg sørover, slik som vist på figuren.

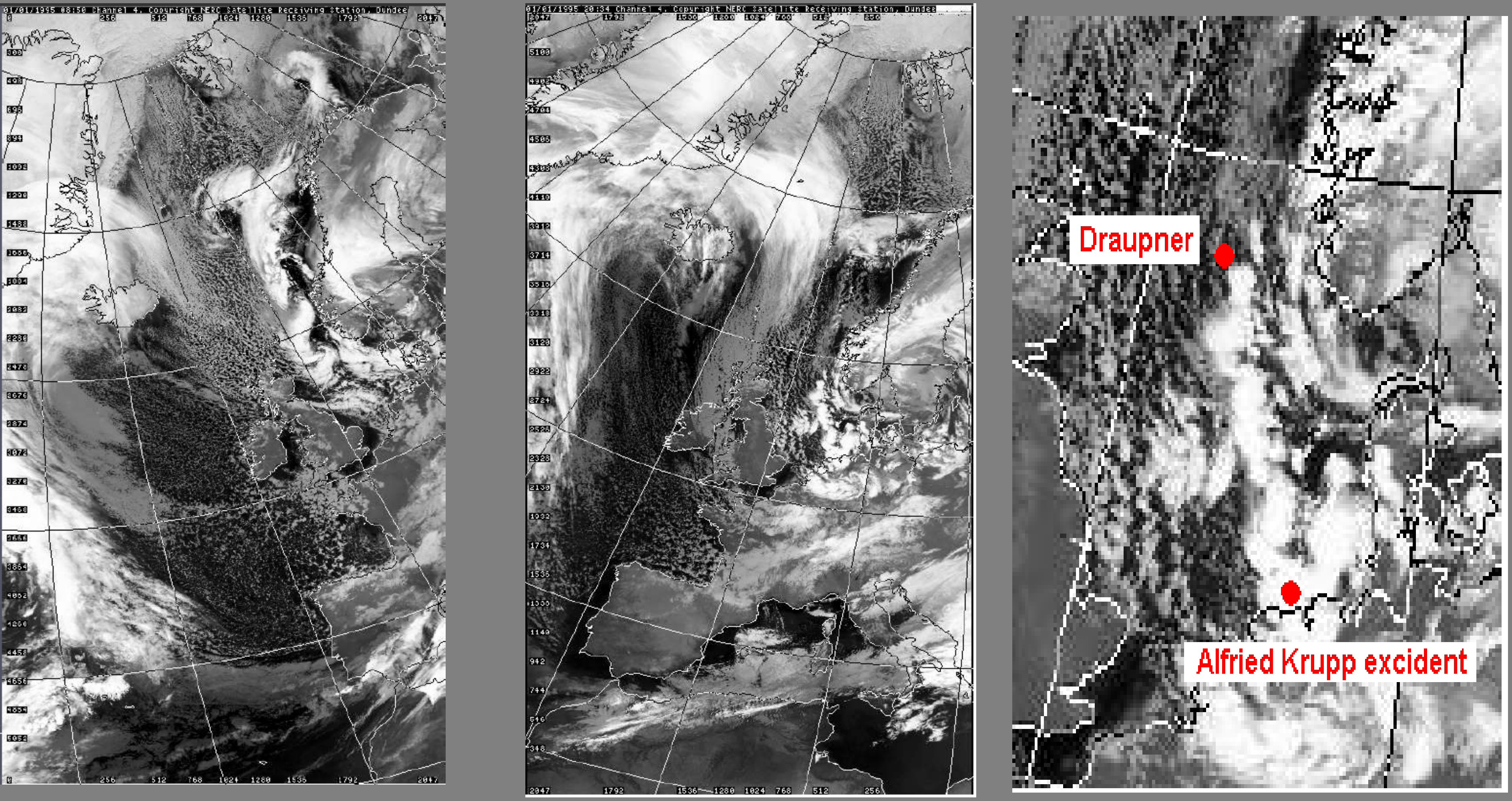
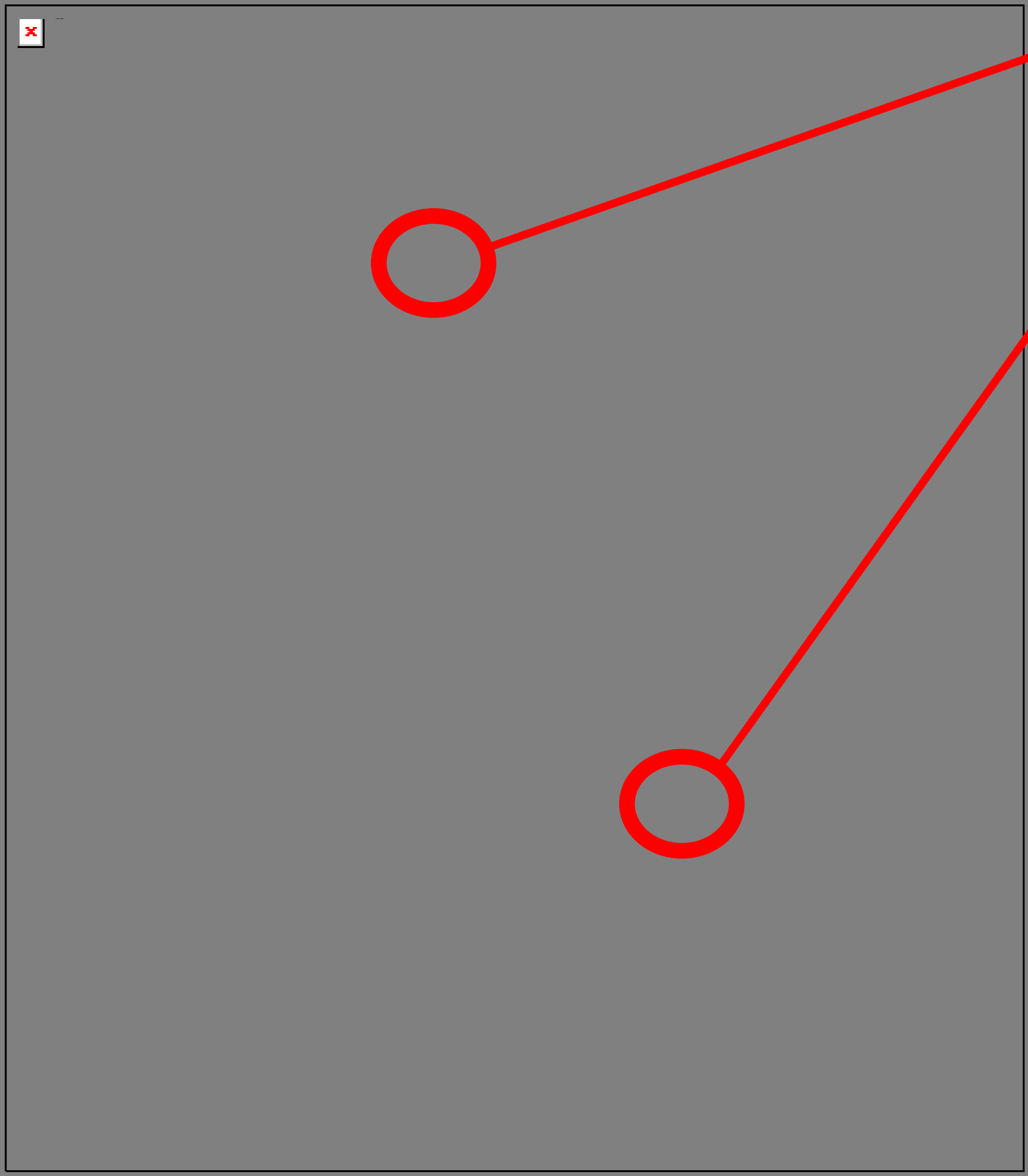


Fig.AAA1: AVHRR NOAA Thermal Infrared on 1.1.1995 at 8.50 UTC and at 20.34 UTC



Draupner

58, 11 N / 2,28 E

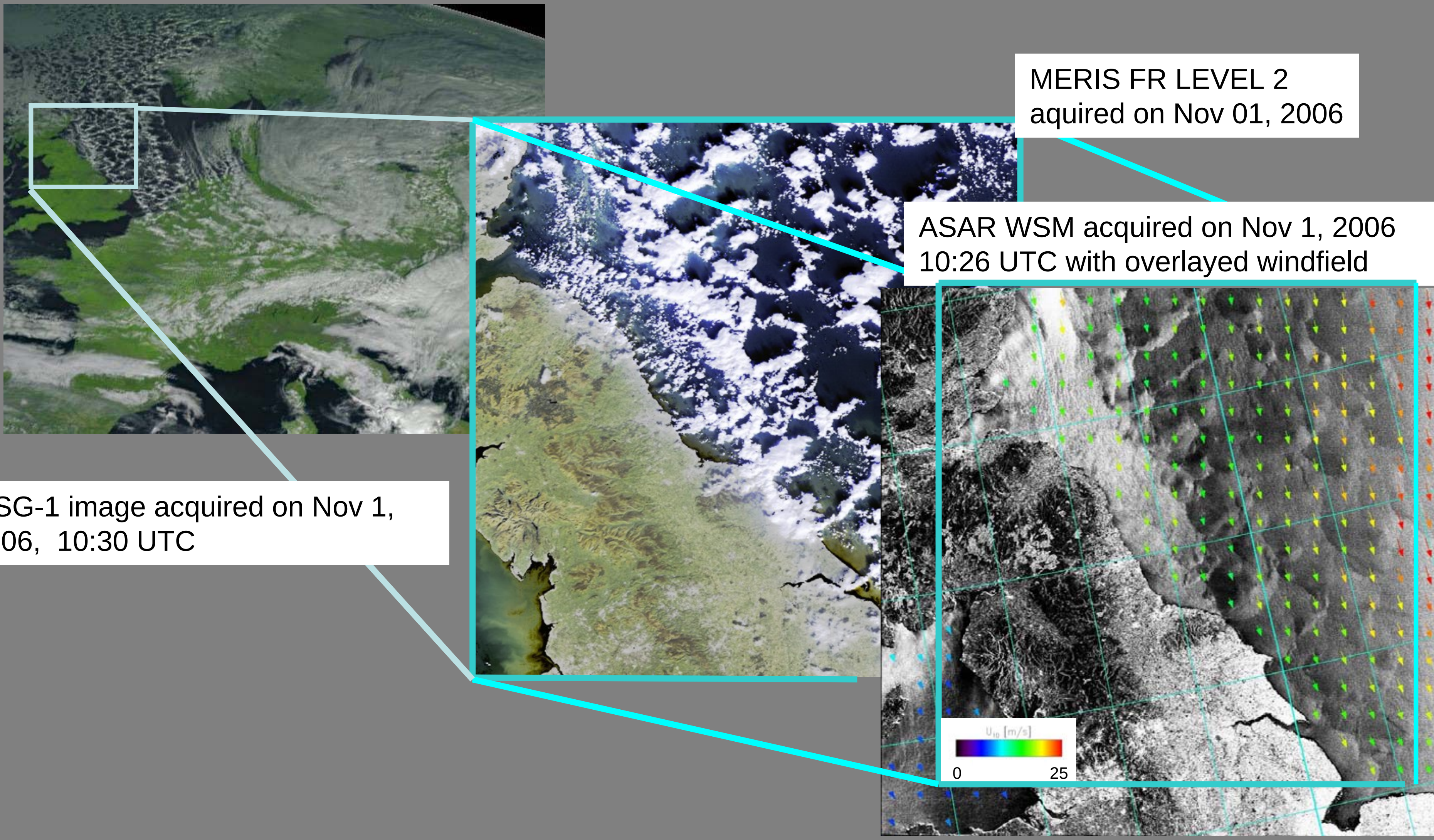
FINO

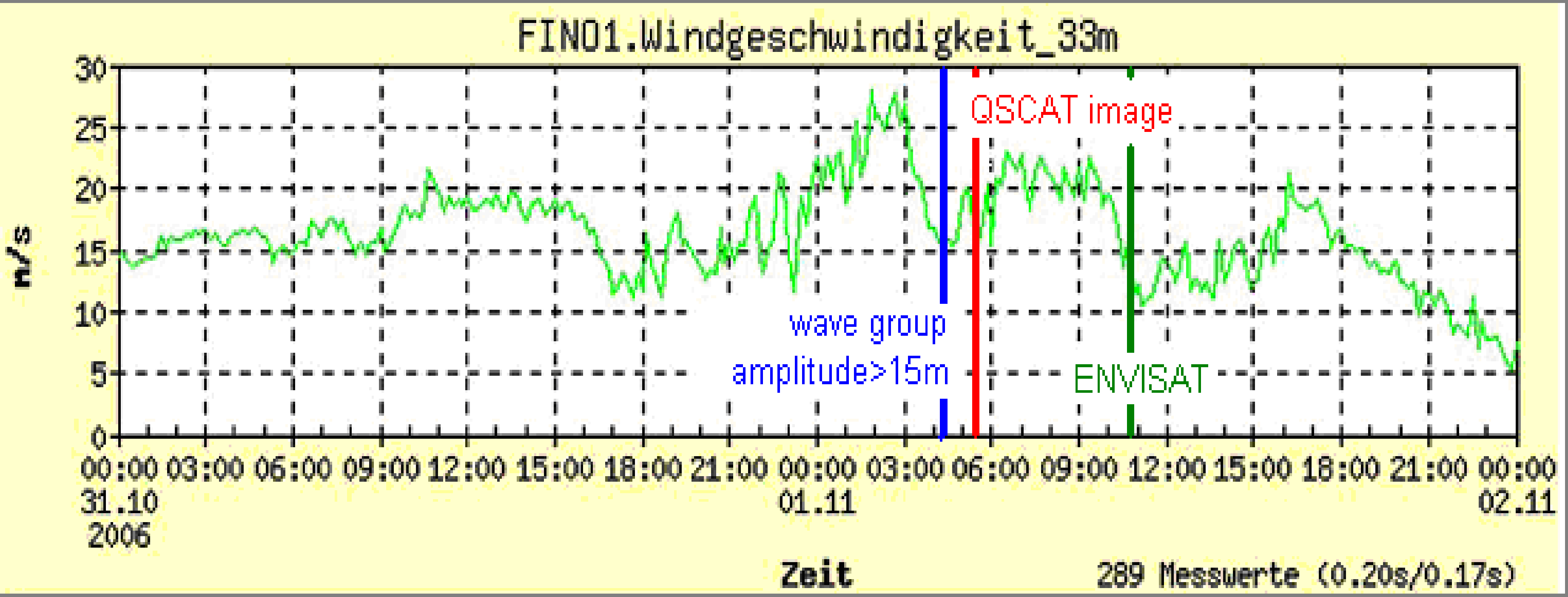
Storm event of the 1st Nov. 2006

BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

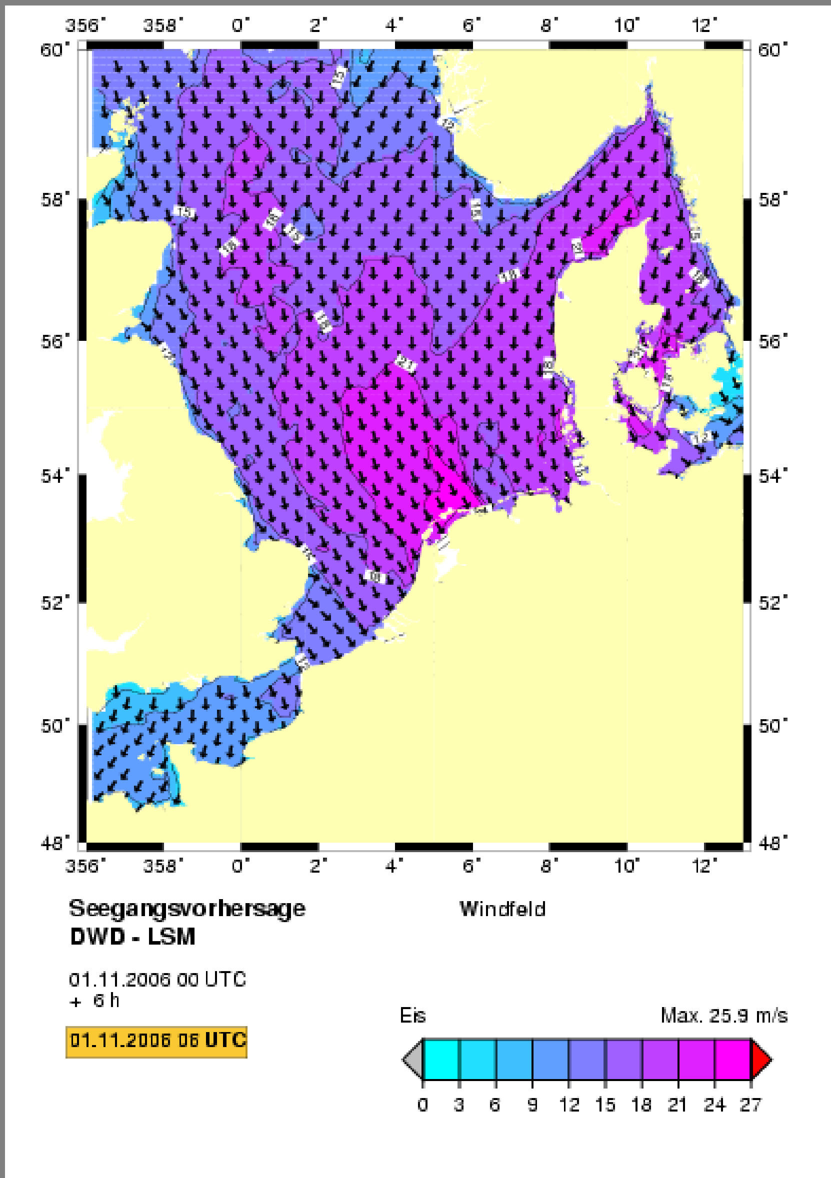
SKN + 15 m
Mean HW + 12,5 m

MSG

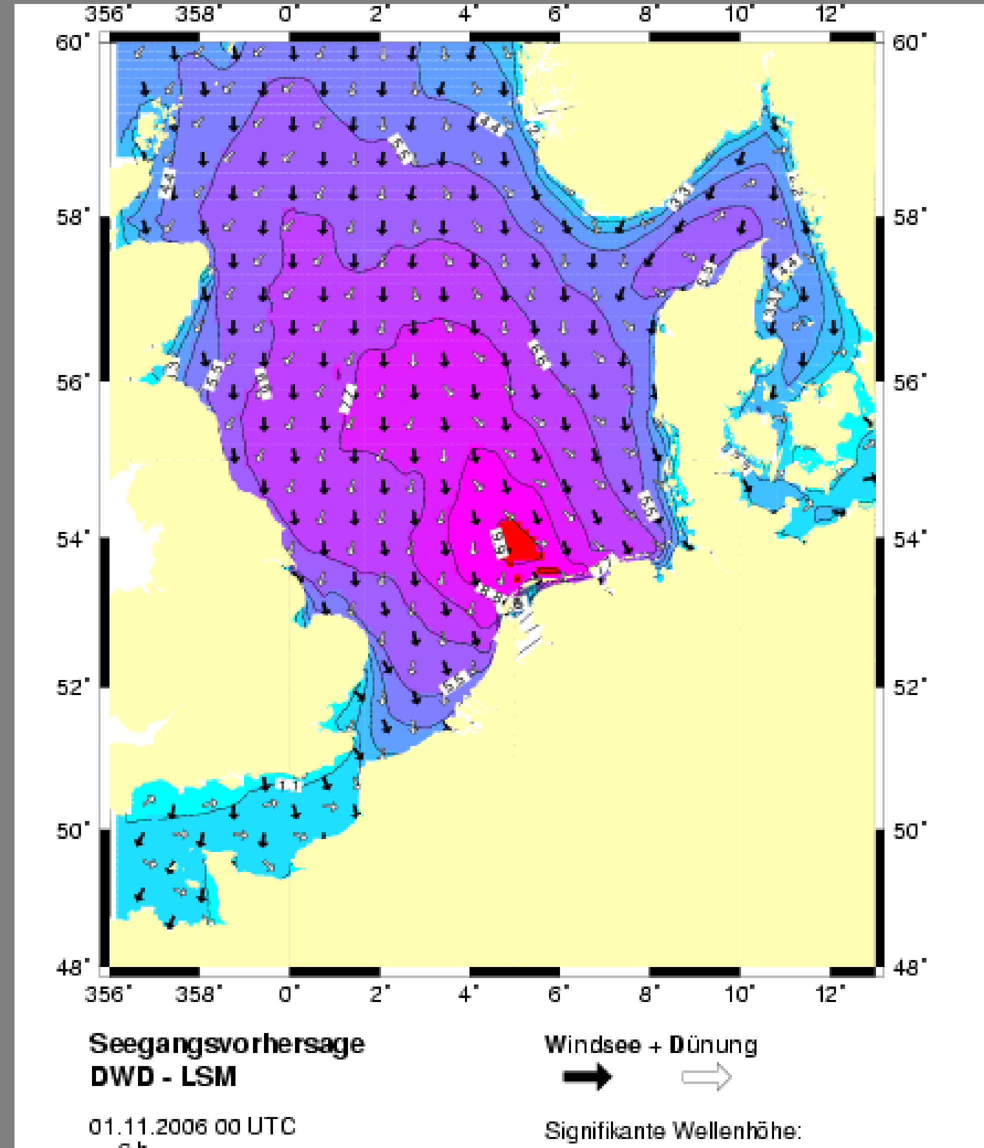

MERIS FR LEVEL 2
aquired on Nov 01, 2006
ASAR WSM acquired on Nov 1, 2006
10:26 UTC with overlayed windfield
MSG-1 image acquired on Nov 1,
2006, 10:30 UTC
0
25



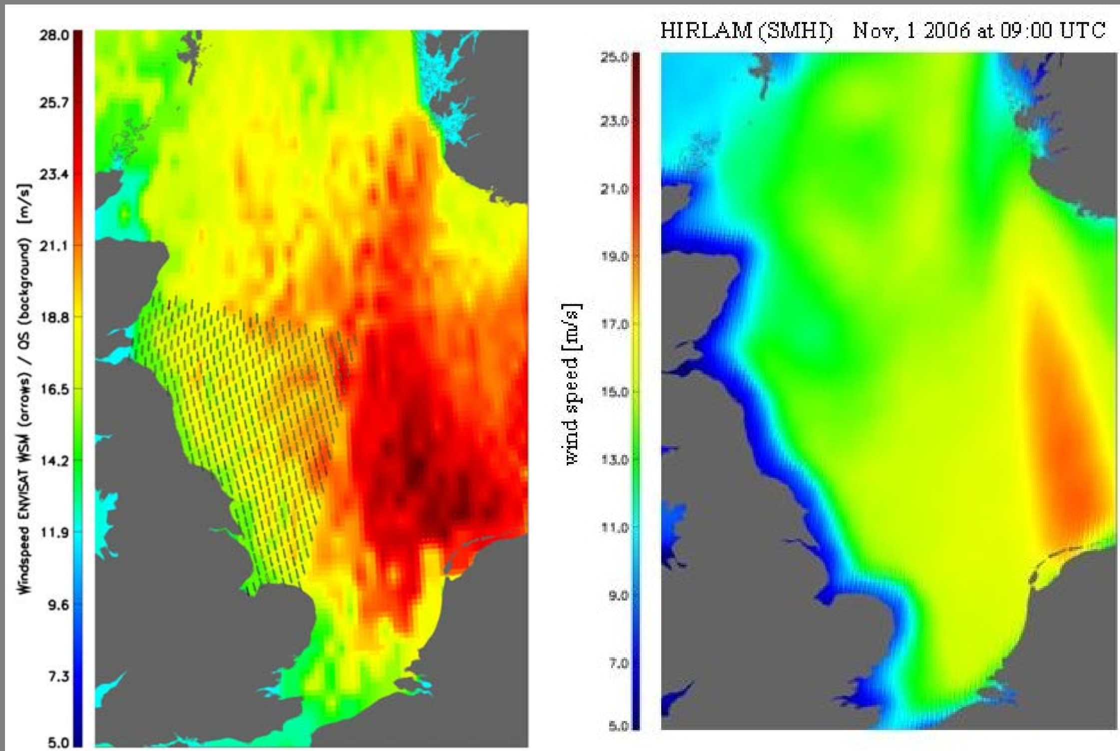
Measurement at FINO-1 Platform. The times of rogue waves entry, Qscat and ENVISAT acquisition are shown.

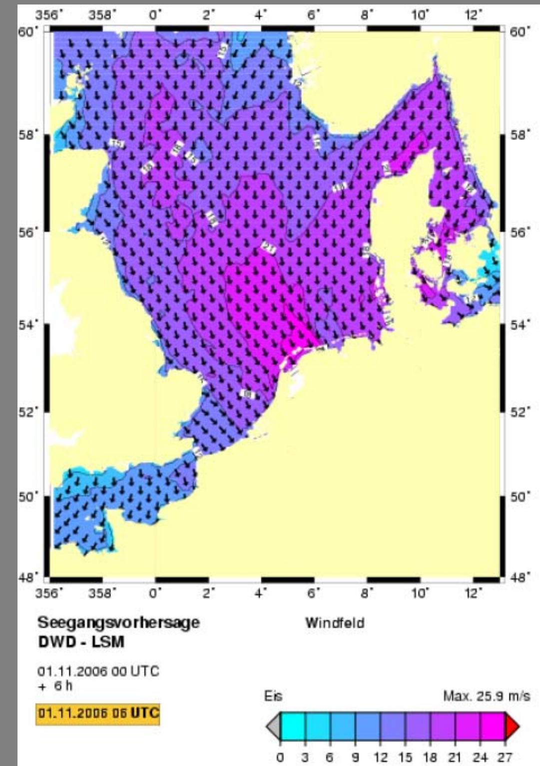


356° 358° 0° 2° 4° 6° 8° 10° 12°
60° 58° 56° 54° 52° 50° 48°
Seegangsvorhersage
DWD - LSM
Windfeld
01.11.2006 00 UTC
+ 6 h
01.11.2006 06 UTC
Eis
Max. 25.9 m/s
0 3 6 9 12 15 18 21 24 27

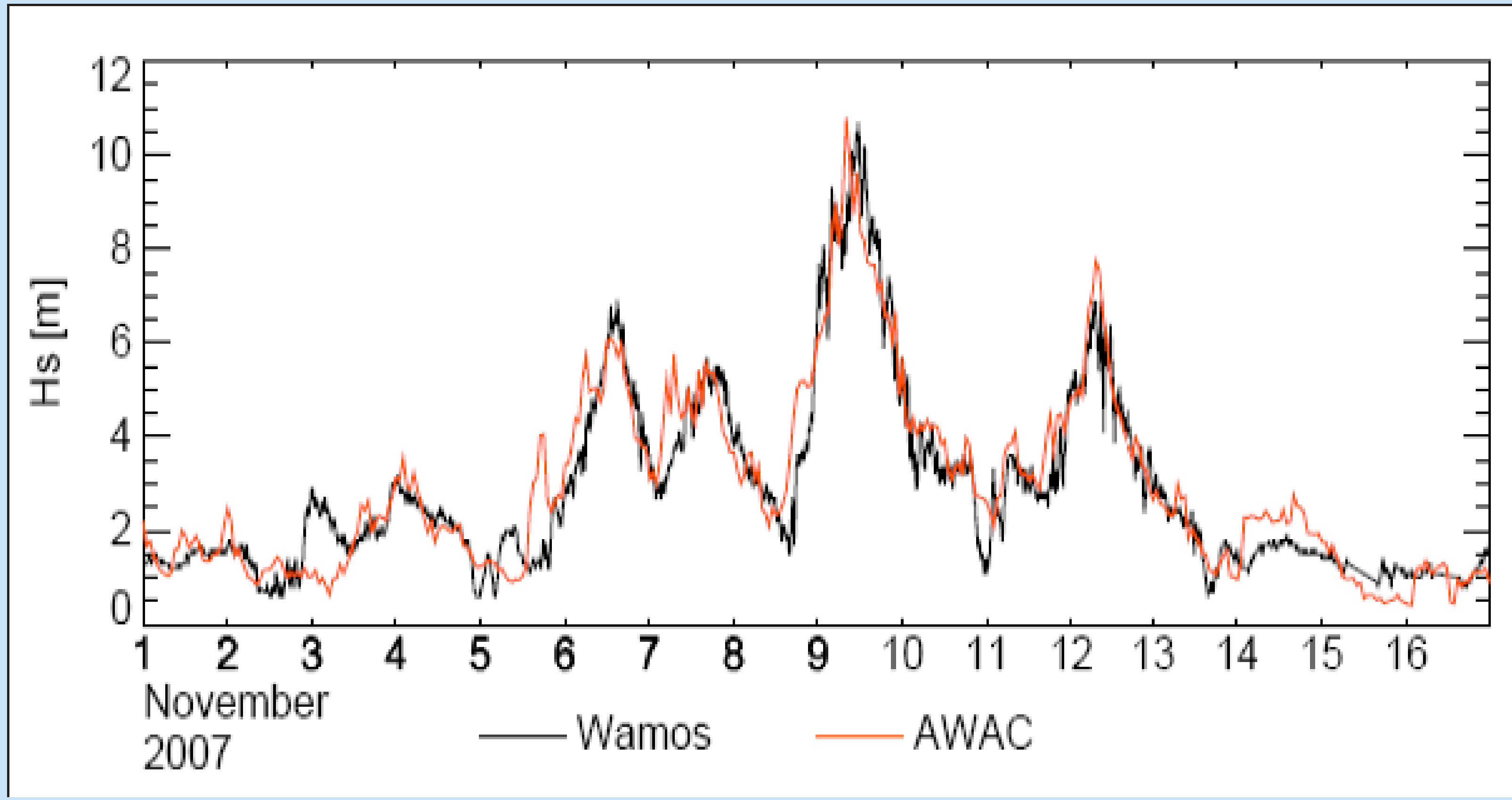


356° 358° 0° 2° 4° 6° 8° 10° 12°
60° 58° 56° 54° 52° 50° 48°
Seegangsvorhersage
DWD - LSM
Windsee + Dünung
01.11.2006 00 UTC
+ 6 h
Signifikante Wellenhöhe:

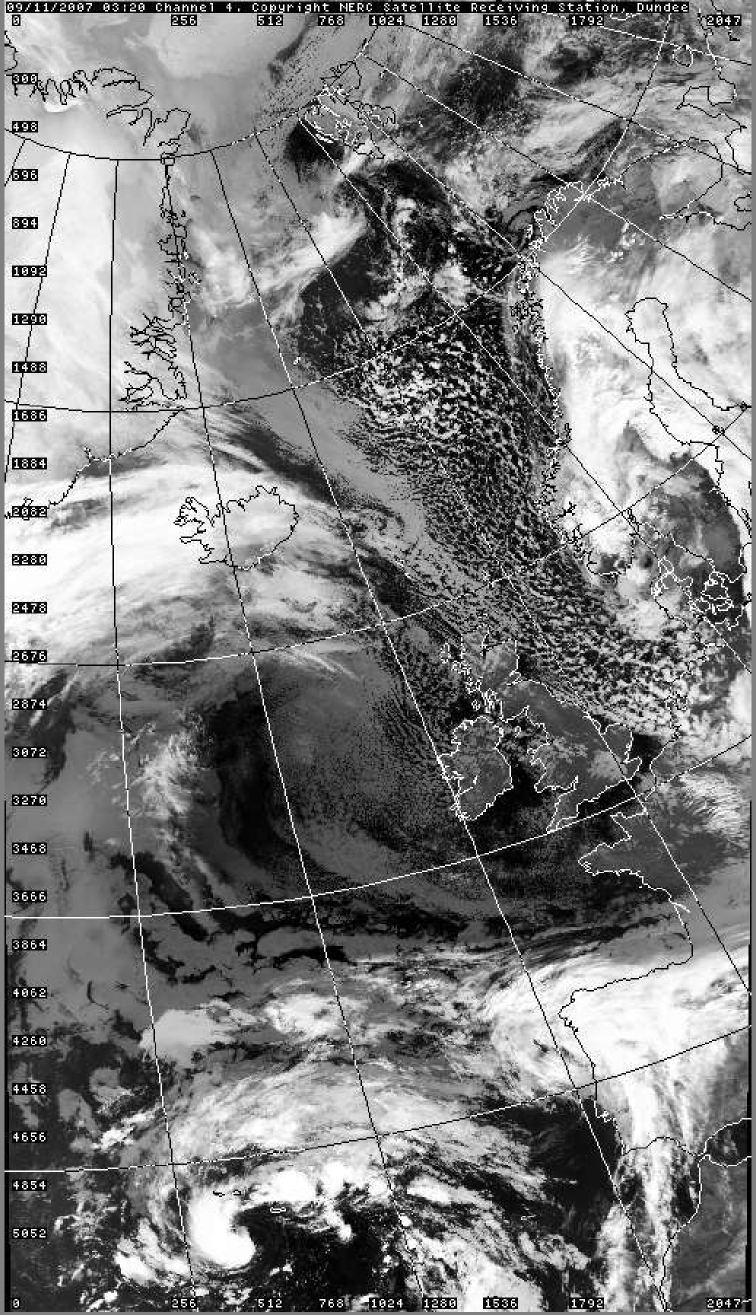




Wind field form A SAR and from QuickSCAT Scatterometer wind field (05:42 UTC, 25x25km) (left), HIRLAM – High Resolution Limited Area Hydrostatic Model, 11x11km Gitter HIRLAM 01.11.2006 09:00 UTC (middle) and wind field from DWD (right). The gustiness are visible in QuickSCAT data. In HILRAM and DWD wind fields the gustiness is not present.

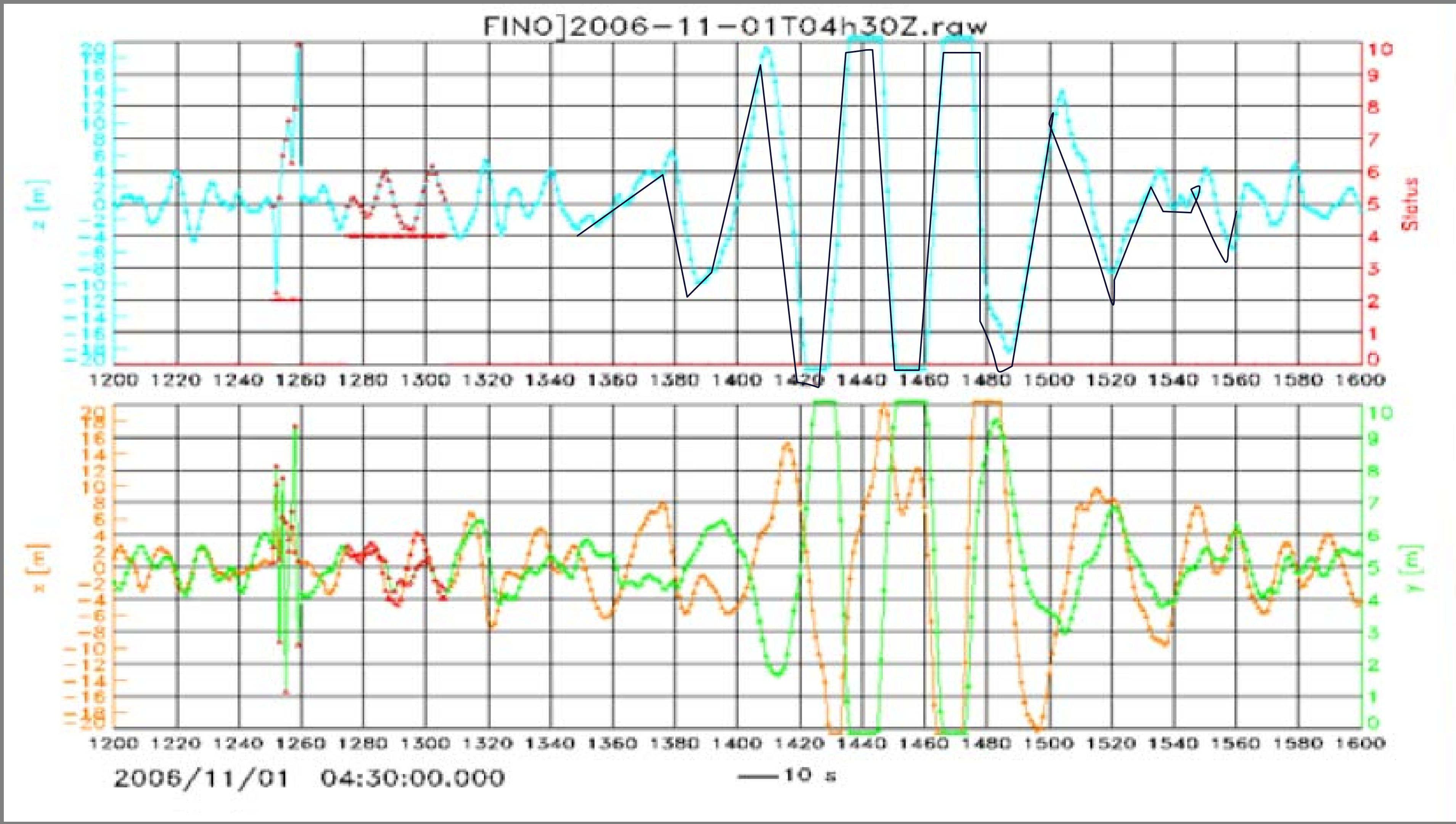


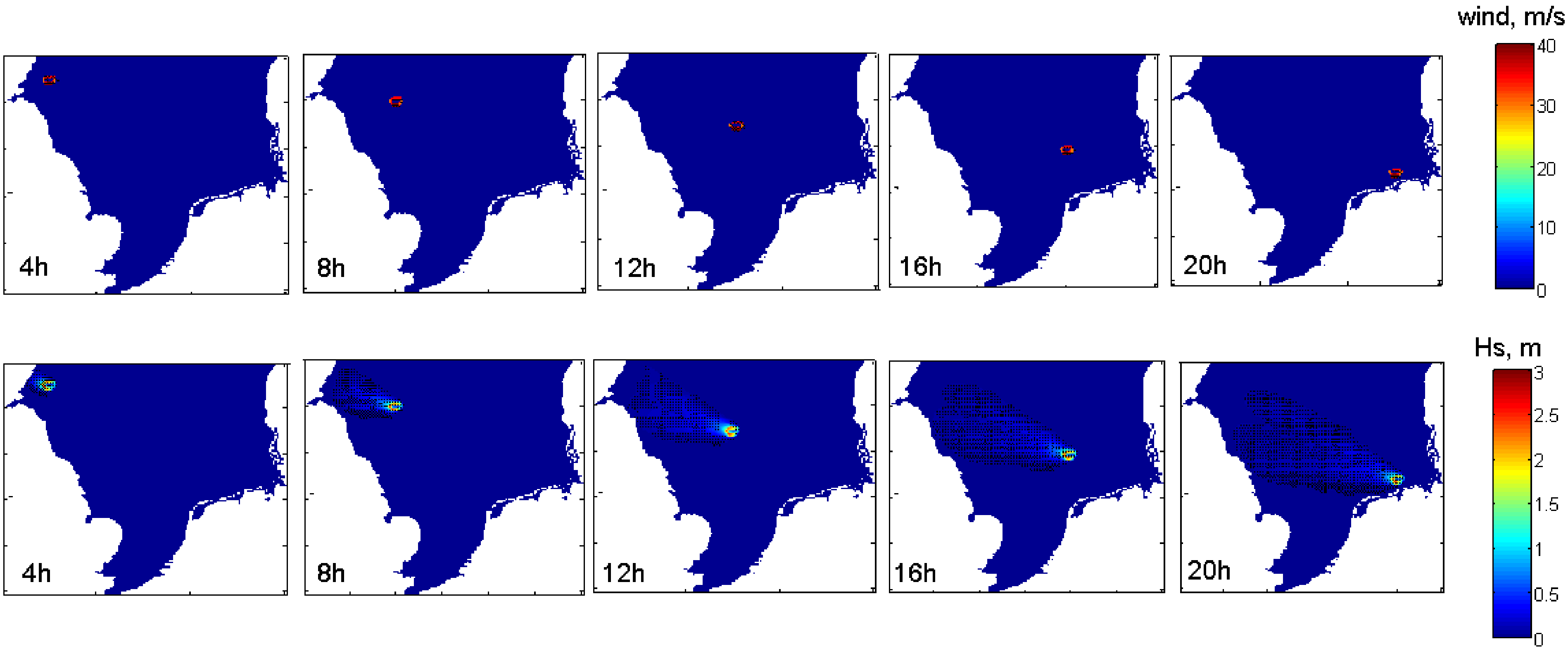
Significant wave heights H_s in November 2007, measured using WAMOS (black) and ADCP (red) on the FINO 1 offshore platform. The averaging period used to determine the statistical wave parameters significant wave height, peak wave direction and peak wave period is 30 min with the wave radar system, and 20 min with the ADCP (AWAC).



NOAA,

9.11.2007,
03.20 UTC


FINO]2006-11-01T04h30Z.raw
z [m]
Status
x [m]
y [m]
2006/11/01 04:30:00.000
—10 s



Numerical simulation of a single idealized cell passing across the North Sea. Wind field is updated each 5min, the results are presented in 4h time steps. The cell enters the sea at time t=2h and need about 15h to make land fall again. Local wave height reaches 3m within the footprint of the cell.

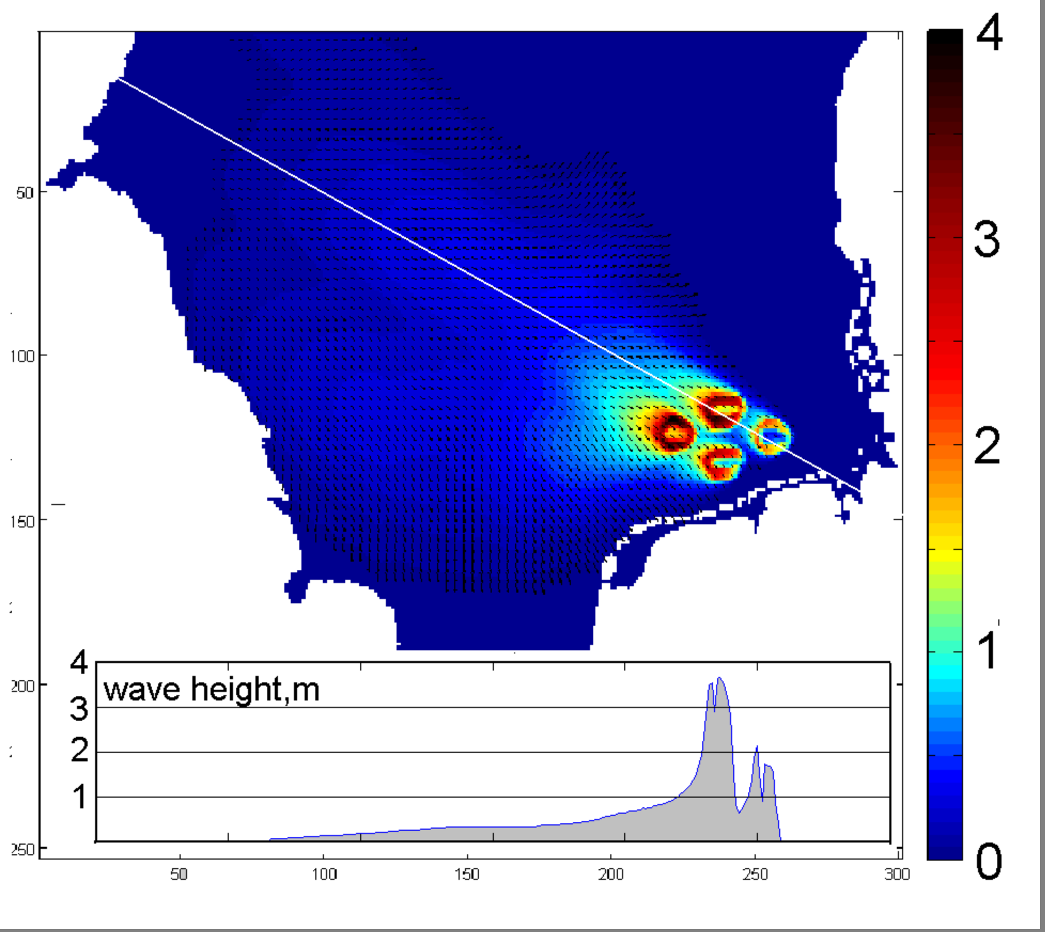


Fig.X3. Simulation of a group of idealized cells moving with a speed of 15m/s across the North Sea (no wind and waves in the background). Significant wave height reaches a value of 2.5m under the first cell and 3.5m under the second cell within an area of about 5x5 kilometers. The wave height time series from location N54°0.86' E6°35.26' (FINO-1) is shown for every 10min. The cell's strongest influence lasts for a time of 10min.

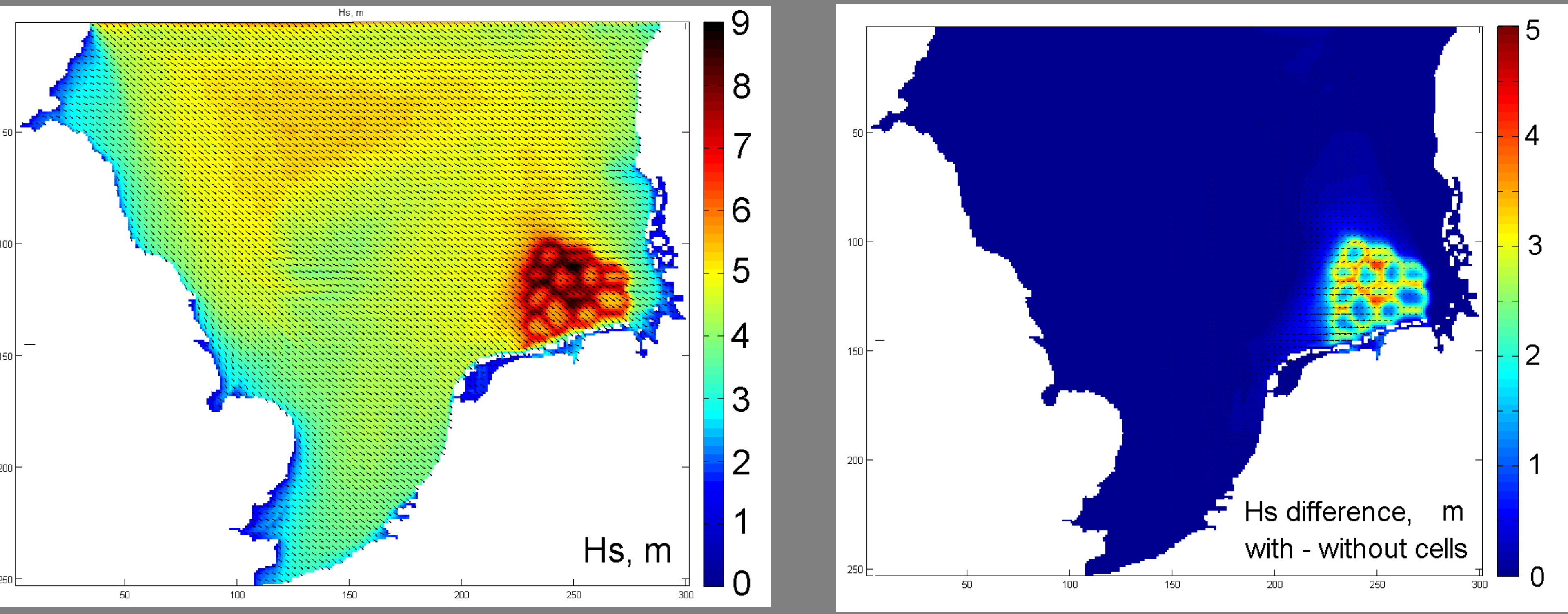
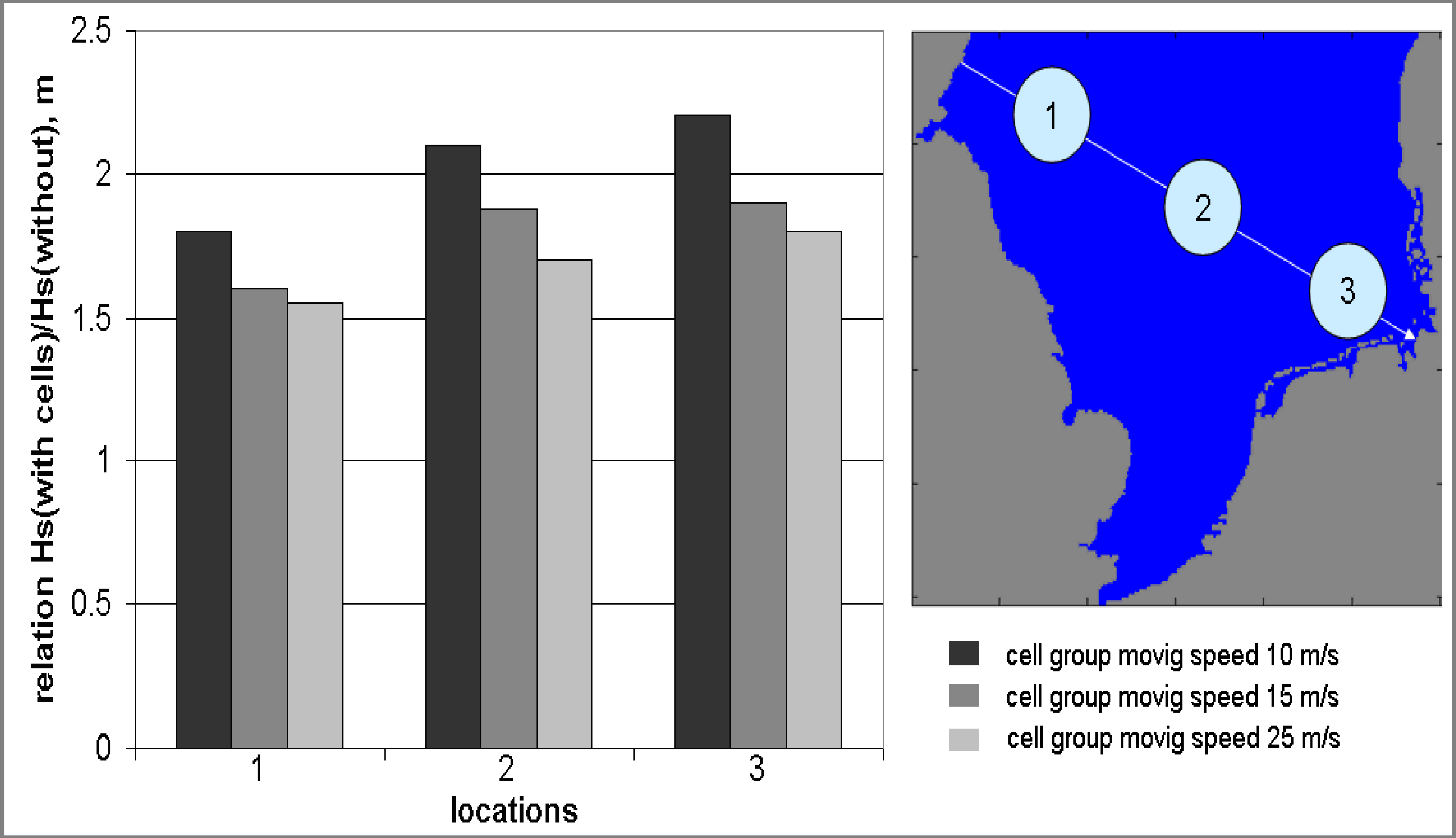


Fig.X5. Simulation of a group of cells, moving with a speed of 25m/s across the North Sea (constant wind 20m/s with *going to* direction south-east and corresponding sea state pre-simulated with spin-up time of 24h). The wind speed again reaches 40m/s inside the cells. Significant wave height reaches 10m within the cells . The difference between H_s (with cell) and H_s (without cell) reaches the value of 3.9 m-



Ratio between maximal H_s under cell group footprint and H_s simulated without cells (left) for three locations in the North Sea along cell group trajectory (right).

L(Return period in years for the Fino Wave) = 4 years

M(groups per storm at FiNO with Hs=17m) = 6 groups/storm

N (storms like Britta per year) = 2

G = 48 groups with Hs = 17 m in 4 years

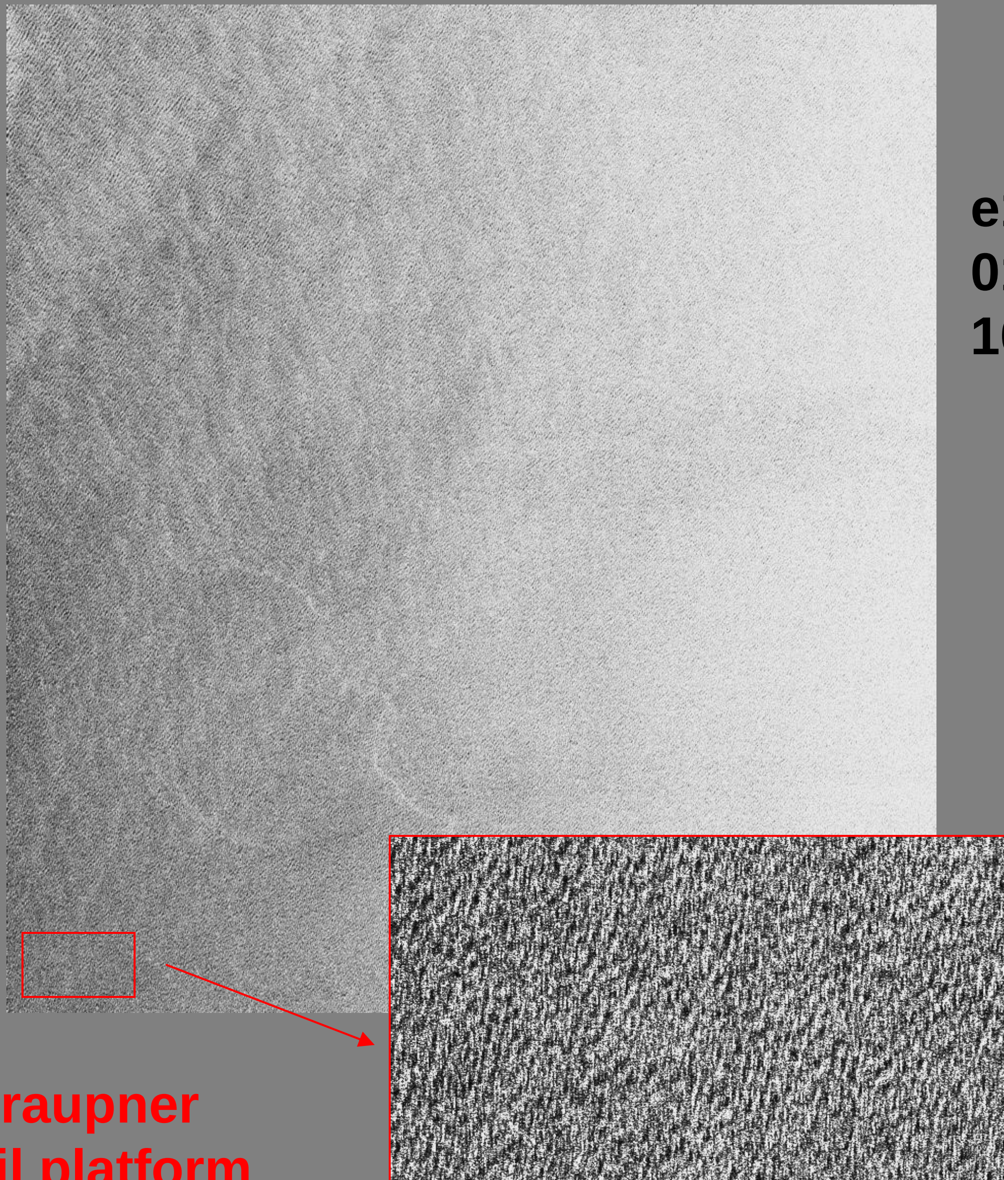
$$H_G = H_S \, (0.5 \ln (G))^{0.5}$$

$$H_{48} = 23{,}7 \text{ m}$$

Conclusions

- To determine the characteristics of extreme individual wave groups and small scale wind variability, satellite data have been used.Since the wind field resolution is too coarse in the present operational numerical wave models, they cannot simulate the ocean surface waves of extreme wind gusts.
- We showed, that fast travelling small scale gusts, embedded in larger depressions, are an effective source for extraordinary high energy wave fields, that travel at the propagation speed of the gusts. They can be described by a Rayleigh distribution with larger Hs than the background wave field.
- With higher resolved wind fields and finer spatial resolution the present wave models shoulde be able to issue warnings for extreme individual waves.

Draupner Plattform

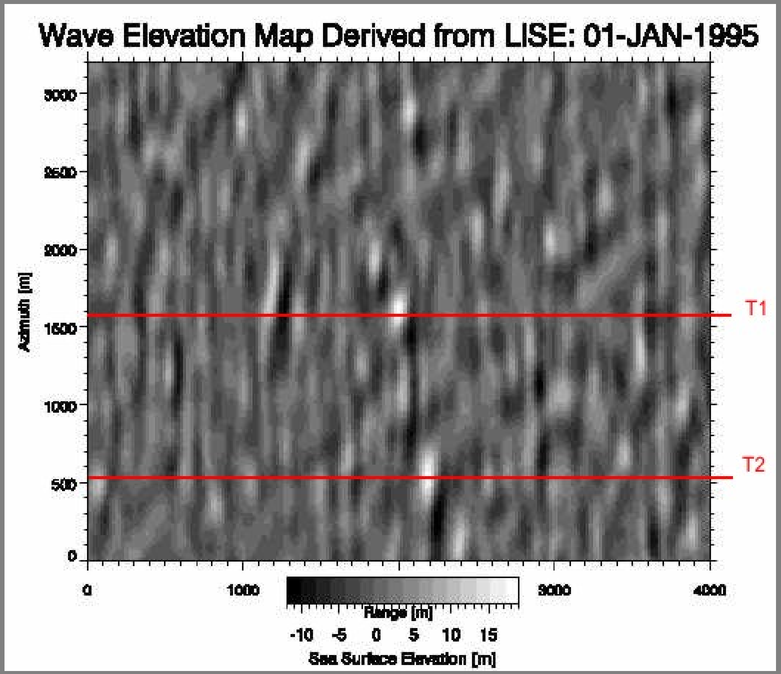


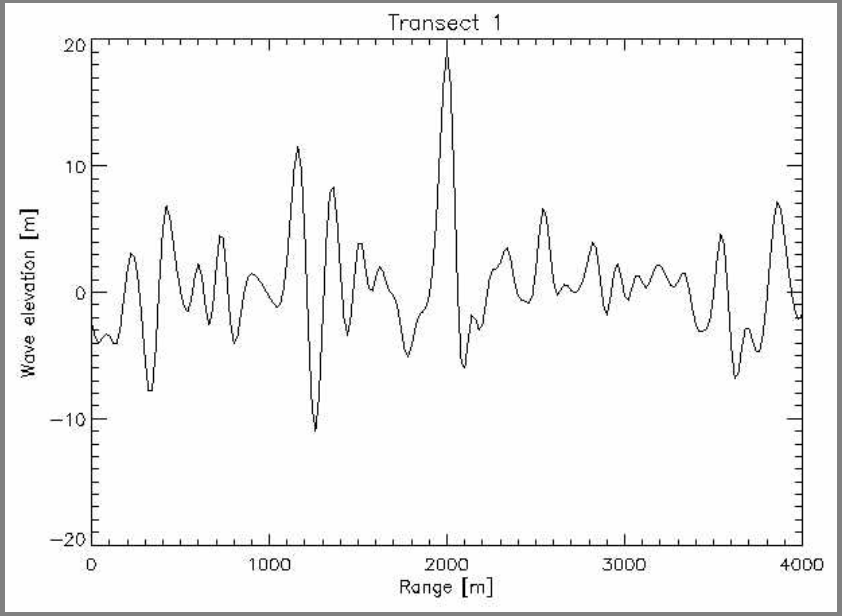
e1_18115_2421_slc
01-01-1995, 10:49 h UTC
100 x 100 km

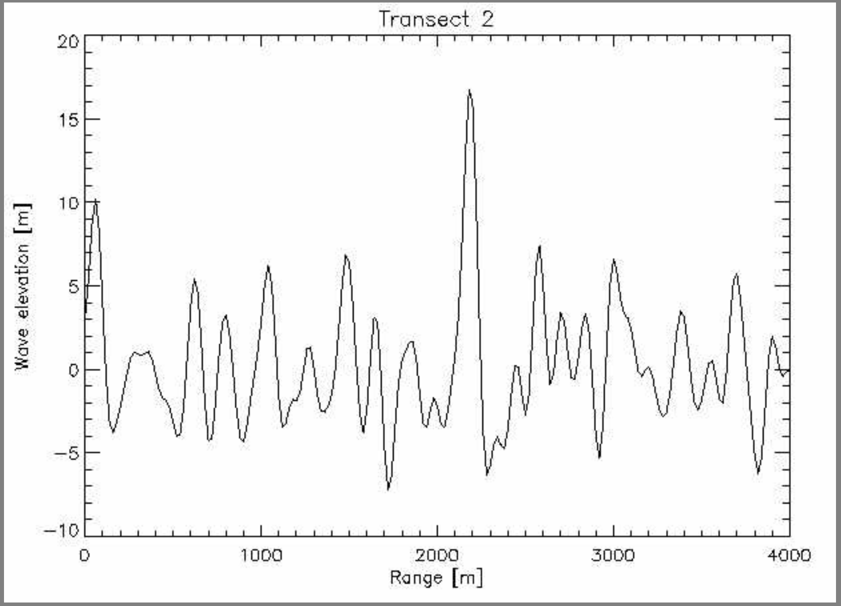
position:
58, 11 N / 2,28 E
70 m water depth

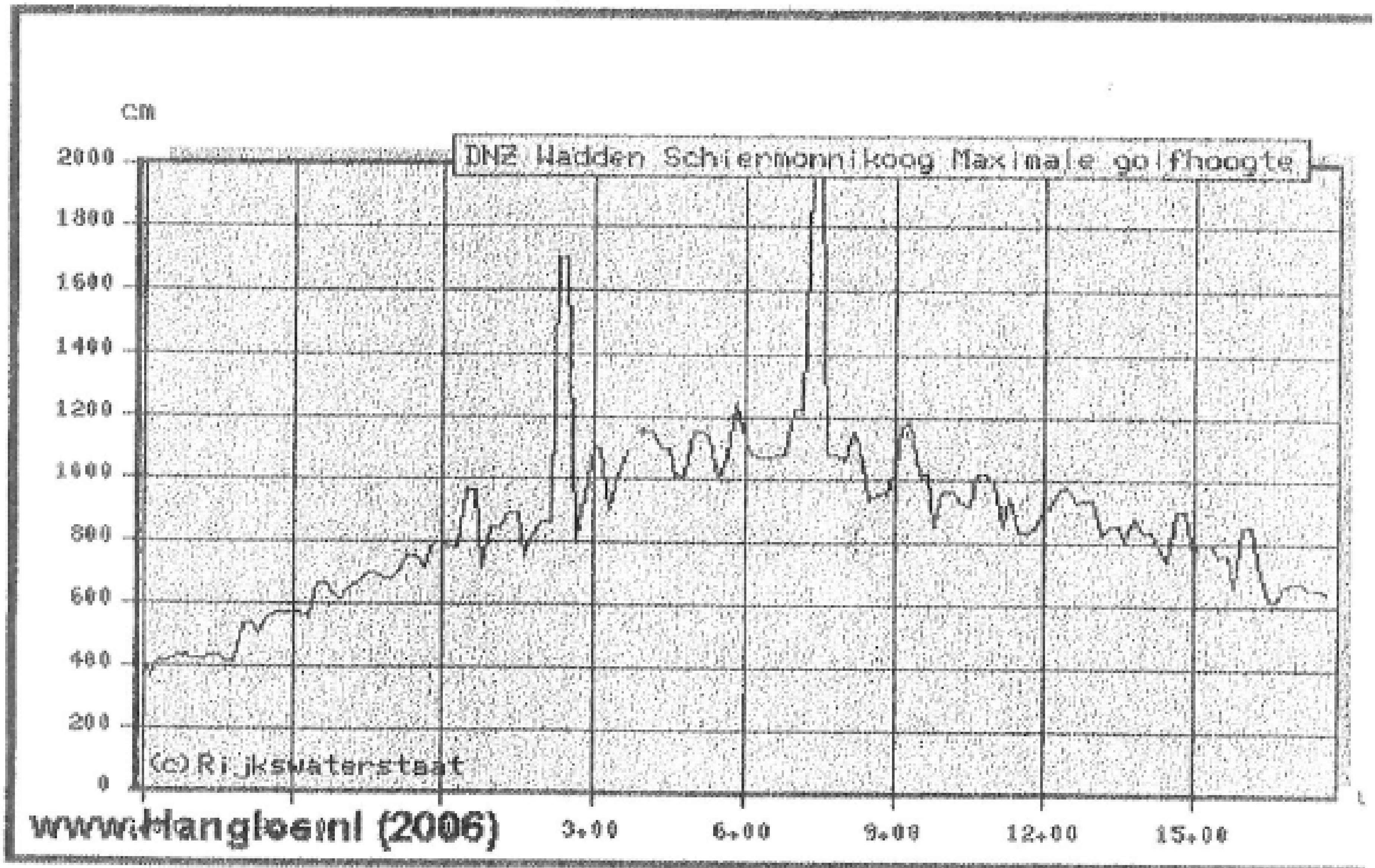
Draupner
oil platform

5 x 10 km


Wave Elevation Map Derived from LISE: 01-JAN-1995
Azimuth [m]
Range [m]
Sea Surface Elevation [m]
T1
T2


Transect 1
Wave elevation [m]
Range [m]


Transect 2
Wave elevation [m]
Range [m]


cm
DNZ Wadden Schiermonnikoog Maximale golfhoogte
2000
1800
1600
1400
1200
1000
800
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400
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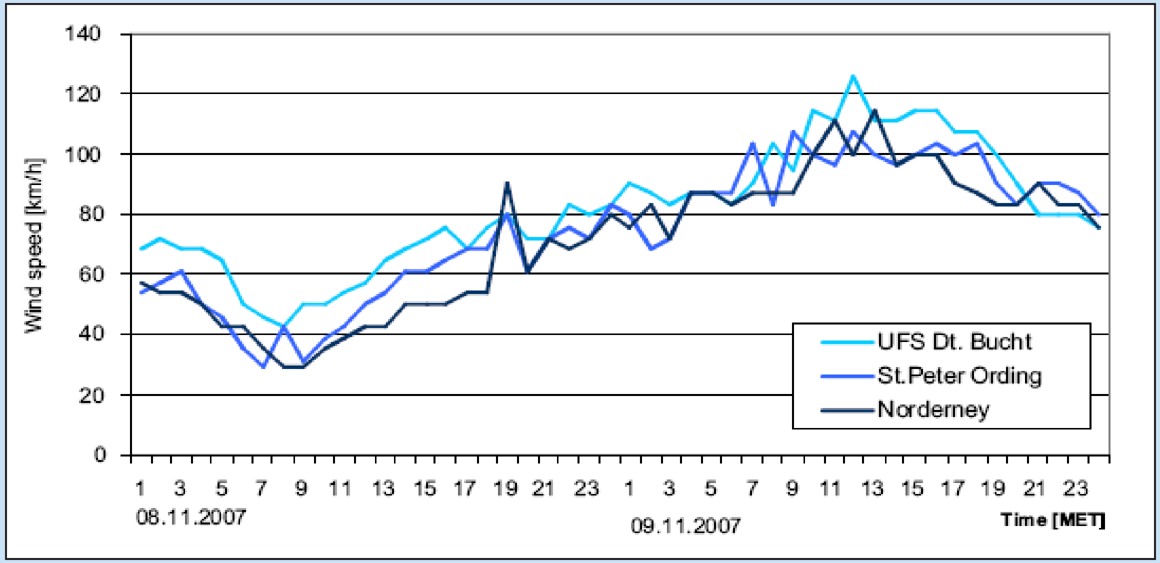
(c) Rijkswaterstaat
3.00
6.00
9.00
12.00
15.00
www.Hangloos.nl (2006)



Station	Max. Gust (km/h)
North Sea	
Spiekeroog	146.5
UFS Deutsche Bucht	127.4
Strucklahnungshörn	124.6
List auf Sylt	120.2
Norderney	115.9
Hallig Hooge	111.6
Helgoland	110.5
Sankt Peter-Ording	108.7
Büsum	108.4
Bremerhaven	100.4
Borkum-Süderstraße	96.8
Brunsbüttel (Schleuse)	95.4
Cuxhaven	94.0
Leck	90.4
Emden	86.4

Wind gusts in the German Bight/ North Sea on 9. Nov. 2007 as a time series (above).

Max. Gusts at different stations (below)

t on 9

.2007