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Hydrodynamic conditions, Blankenberge area

Sub report 1
Drifter measurements June 2013

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Hydrodynamic conditions Blankenberge area

Sub report 1 – Drifter measurements June 2013

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Abstract

Between 19th of June and 4th of July 2013 a field campaign was carried out by Flanders Hydraulics Research at Blankenberge harbour. The main objective of this campaign was to investigate the hydrodynamics around Blankenberge harbour. Six instruments were deploy in the immediate vicinity of the harbour: two of them (AWAC and Aquadopp) for 16 days and another four (drifters) for few hours.

The present report contains a description of the experiment and the campaign, instruments' characteristics, settings and calibration, as well as description and interpretation of the collected data. The data collected on the field regards the marine currents speed and direction, wave characteristics (height, period and direction), water pressure variations and water temperature. Data from the Meetnet Vlaamse Banken were also use for interpretation: tide, wave and wind characteristics.

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1 Introduction

1.1 Scope of the study

This campaign was carried out in the framework of the WL R&D project 00_064 " Meetcampagne hydro- en zanddynamica haven van Blankenberge" (Delgado *et al.,* 2012).

The research objective of this project is obtaining meaningful and reliable information about hydrodynamics at the study area and data that can be used for the calibration and validation of high resolution numerical tools both allowing for the investigation of:

-Water and structures interaction. Assessment of local effect of groins and groin fields on water motion patterns.

-General hydrodynamic patterns including cross-shore wave transformation.

-Fluxes of suspended sediment in the area where theoretically, maximal wave driven alongshore transport occurs.

-Currents and wave transformation in and around the access to the harbour.

In order to reach the research objectives stated above the hydrodynamics and sediment fluxes have to be measured through a series of field campaigns.

The campaign described in this report aim to investigate solely the hydrodynamic condition in the study zone and a detailed description of the field campaign design, instruments, deployment and obtained data will be given further on.

The hydrodynamics around the harbour of Blankenberge was measured using one current profilers (Aquadopp) and an underwater buoy (AWAC) deployed for three weeks and drifters repeatedly deployed during one day.

1.2 Team

The field campaign design and execution was made by the following team: Sebastian Dan, Rosalia Delgado, Hans Vereecken, Yaïr Levy, Erwin de Backer and Leonid Verzhbitskiy, all from Flanders Hydraulics Research Antwerp.

Valuable external help was provided by lifeguards teams from Blankenberge led by Tom Cocle for the deployment drifters. An important support was provided by the Zeetijger ship's crew led by captain Karl T'Jaeckx who deployed and recovered the instruments and the navigational buoys.

1.3 Conventions

All the coordinates used in the bellow described field campaigns are UTM, WGS84. The hour was set as Central European Winter Time (CET) which is GMT + 1 hour.

The sound speed is measured in m/s, heading, pitch and roll in degrees (360°, geographical convention), pressure in dbar, temperature in degrees C.

2 Instruments

2.1 General

This section presents a detailed description of the deployed instruments. The settings of each instrument will be also described.

2.2 Aquadopp current profilers

The Aquadopp Profiler measures the current profile in water using acoustic Doppler technology. It is designed for stationary applications and can be deployed on the bottom on a fixed structure. It is a complete instrument and includes all the parts required for a self-contained deployment with data stored to an internal data logger. The dimensions and basic functioning concept of the Aquadopp current profiler are presented in Figures 1 and 2.

The Aquadopp Profiler uses the Doppler effect to measure current velocity by transmitting a short pulse of sound, listening to its echo and measuring the change in pitch or frequency of the echo. This is expressed by the following equation:

$$\boldsymbol{V} = \frac{\boldsymbol{F_{Doppler}}}{\boldsymbol{F_{source}}} \cdot \frac{\boldsymbol{C}}{\boldsymbol{2}}$$

where $F_{Doppler}$ is the change in received frequency, known as the Doppler shift, F_{source} is the frequency of transmitted sound, V is the current velocity, C is the speed of sound.

Sound does not reflect from the water itself, but rather from particles suspended in the water. These particles are typically zoo plankton or suspended sediment. The small particles the Aquadopp Profiler sees move on average at the same speed as the water — the velocity it measures is the velocity of the water. The Aquadopp Profiler measures the current in a set of cells along each beam to obtain the current profiles as shown in Figures 2 and 3. The blanking zone is the area between the instrument transducers and the closest control volume (layer) within which no measurement takes place. Its size (height) is equivalent to the thickness of every measuring layer. Therefore, it can vary depending on instrument settings. The function of the blanking zone is to allow for a Doppler shift of the signal travelling until the closest layer .

Doppler current sensors use large transducers (relative to the wavelength of the sound) to obtain narrow acoustic beams. For the 2 MHz Aquadopp Profiler a beam has a width of 1.7°. Narrow beams are essential for obtaining good data. Each beam measures velocity parallel to the beam and does not sense the velocity perpendicular to the beam at all. The Aquadopp Profiler senses the full 3D velocity with three beams, all pointing in different directions.

The Aquadopp Profiler measures velocity components parallel to its three beams, i.e. in Beam coordinates, but it reports data in East, North and Up or ENU coordinates. To get to ENU components, it first converts the data to XYZ coordinates, an orthogonal coordinate system relative to the Aquadopp Profiler. The instrument then uses its magnetometer and tilt measurements to convert this velocity to components relative to the earth, or ENU coordinates. The coordinate systems used in the field campaign is defined as follows:

- In ENU coordinates, a positive east velocity goes toward east.

Figure 1 – Aquadopp Profiler dimensions (mm)

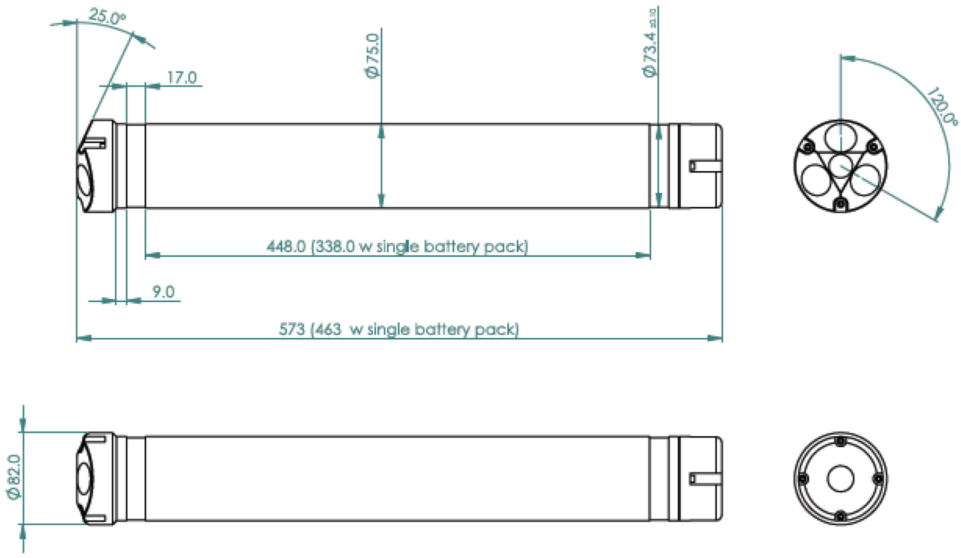
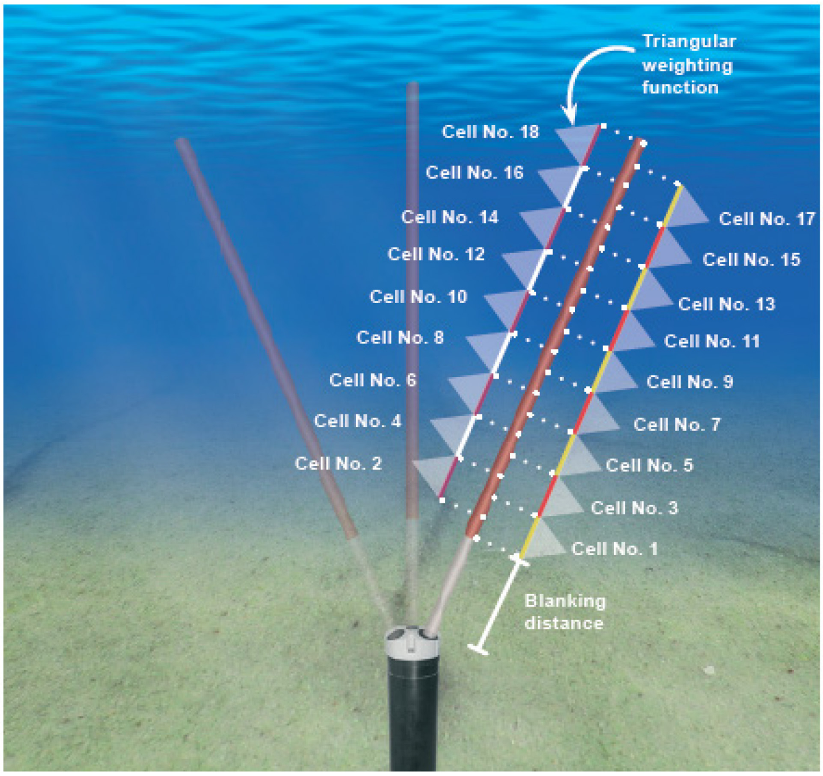


Figure 2 – Aquadopp Profiler basic concept.



2.3 Acoustic wave and current meter – AWAC

The AWAC (Figures 3 and 4) can measure the current speed and direction in 1-meter thick layers from the bottom to the surface. Waves of all varieties are measureable; this includes long waves, storm waves, short wind waves, or transient waves generated by local ship traffic. The sensor is mounted in a frame on the bottom and its wave performance has to do with the optional Acoustic Surface Tracking (AST). The AST is basically echo-ranging to the surface with the vertically oriented transducer. This method circumvents the depth limits imposed by bottom mounted pressure and velocity measurements. Long waves (swell) and storm waves are rarely difficult to measure, but the waves generated by local winds are more accurate measured using AST. The AWAC use the same principle of the Doppler effect presented in the description of the Aquadopp current profilers.

Figure 3 – Acoustic wave and current meter (AWAC) basic concept

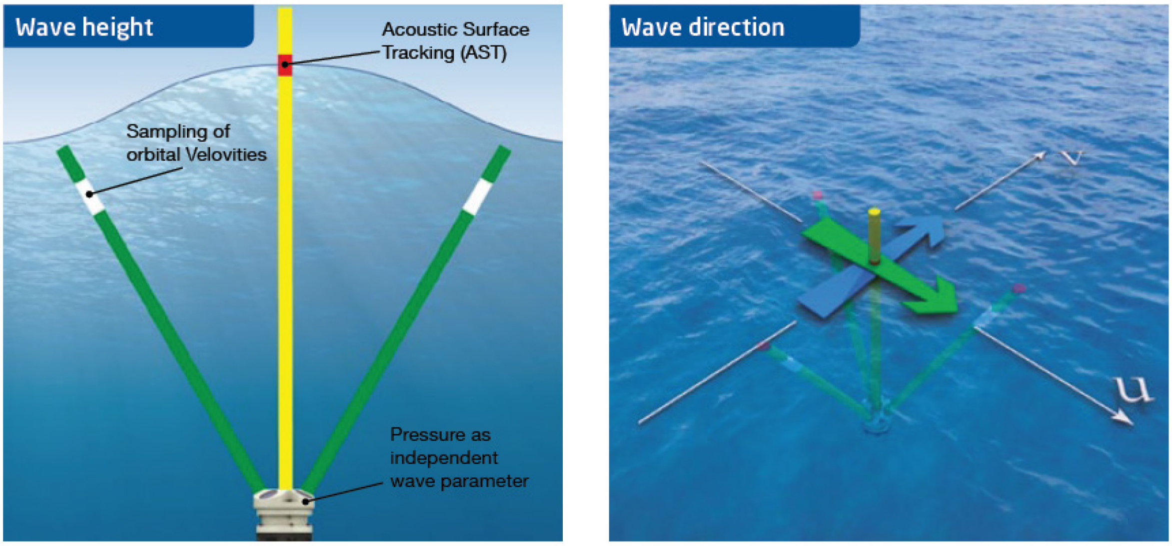
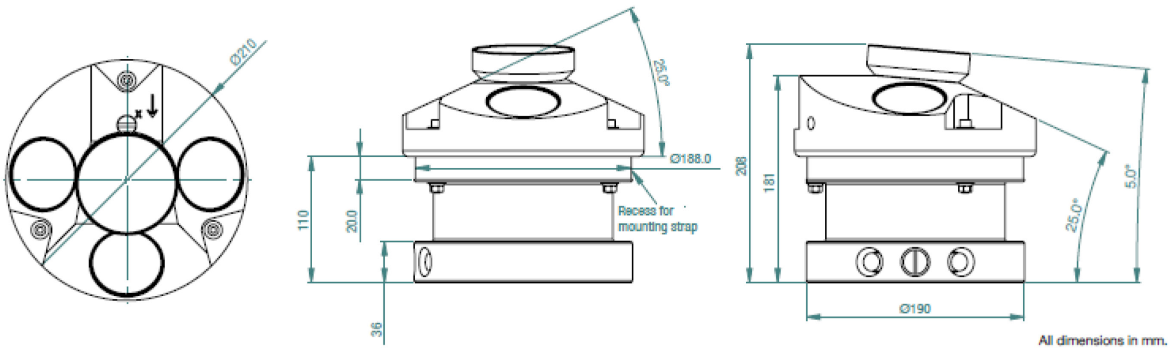


Figure 4 – Acoustic wave and current meter (AWAC) dimensions.



2.4 Drifters

A series of drifters was made at Flanders Hydraulics Research to measure the direction of the marine currents in the surf zone at depth of approximately -1 m (Dan et al., 2012). One prototype was selected and used for measurements northeast of Blankenberge harbour (Figure 5). A Garmin GPS (see the specifications in Table 1) was placed inside the drifter, below the water level. An external antenna was mounted at the top of the thin PVC tube and connected with the GPS trough a cable placed inside of the thin PVC tube.

Figure 5 – The drifter use for measurements of coastal marine currents.

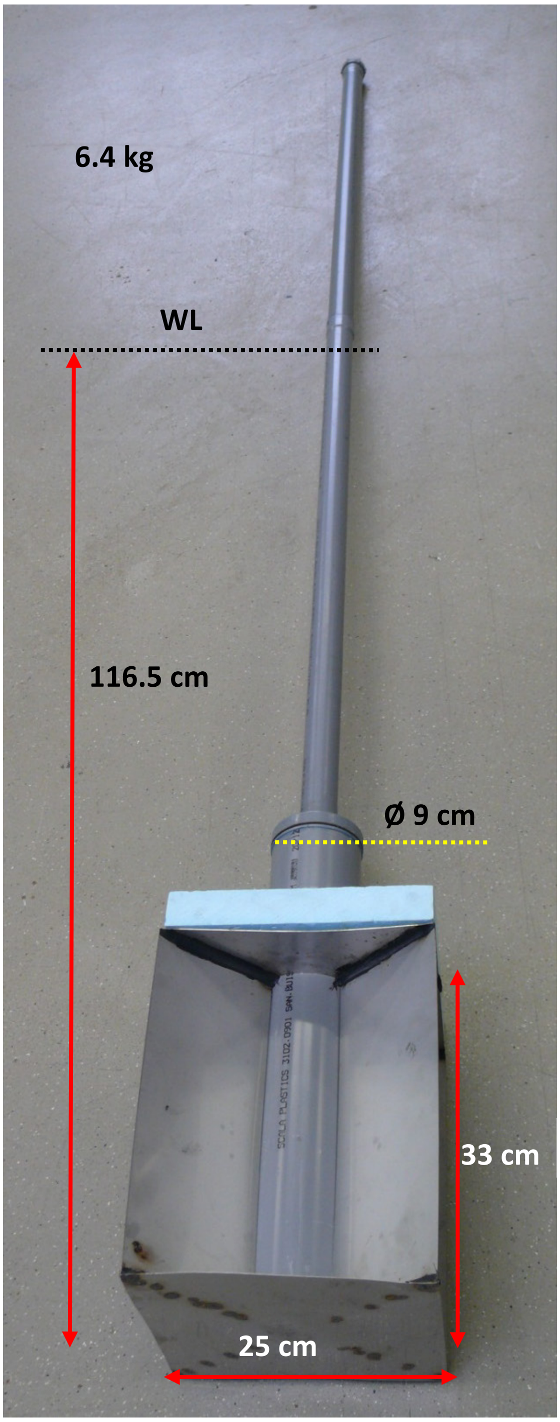


Table 1 – Technical specifications for GPS Garmin 60 Cx.

Dimensions	Height=15.5 cm; Width=6.1 cm; Thickness=3.3 cm
Weight	213 g (including the batteries)
Temperature range	-15 to 70°C
Update rate	1 Hz
Accuracy	GPS < 10 meters in 95% typical (in absence of US degradation) GPS WAAS accuracy in America, is equivalent for EGNOS in Europe = < 3-5 meters in 95% typical (in absence of US degradation)
Velocity	0,05 m/s at steady state
Power source	12 Volt DC Adapter Cable, USB cable, 2x1,5 V AA batteries or up to 36 V DC external power
Battery autonomy	up to 18 hours

3 Field campaign

3.1 Location and time of deployments

In the framework of the field campaign June – July 2013 two instruments were deployed three weeks and six instruments for one day. The area where the instruments were deployed is shown in Figure 6. The exact position of instruments' deployment is detailed in Table 2. The period of deployment is indicated in Table 3.

Figure 6 – Location of the deployed instruments in the field campaign June – July 2013 at Blankenberge

The yellow rectangle show the area where the drifters were deployed.

Table 2 – The exact location of the deployed instruments for campaign June – July 2013.

Instrument	Geographical coordinates, WGS84 (degree, minute, second - hexadecimal)		Date (dd/mm/yyyy) and hour (hh.mm) (CET)		Depth	
	Longitude	Latitude	Deployment	Retrieval	At the deployment	TAW
Aquadopp WC_E (fixed at 0.3 m above the sea bottom)	3°07'06'' E	51°19'09'' N	19/06/2013 9.45	4/07/2013 11.40	-7.5 m	-3.5 m
AWAC WC_0 (fixed at 0.5 m above the sea bottom)	3°06'11.4' E	51°19'5.4'' N	19/06/2013 10.00	4/07/2013 10.55	-9.1 m	-5.1 m

Distance is considered from the sea bottom to the measuring head of the instrument.

Table 3 – The name, number of instruments, place and duration of the deployed instruments.

Instrument	Amount	Duration
Aquadopp Profiler	1	19/06 – 4/07/2013
AWAC	1	19/06 – 4/07/2013
Drifters	6	27/06/2013

3.2 Instrument setup and deployment

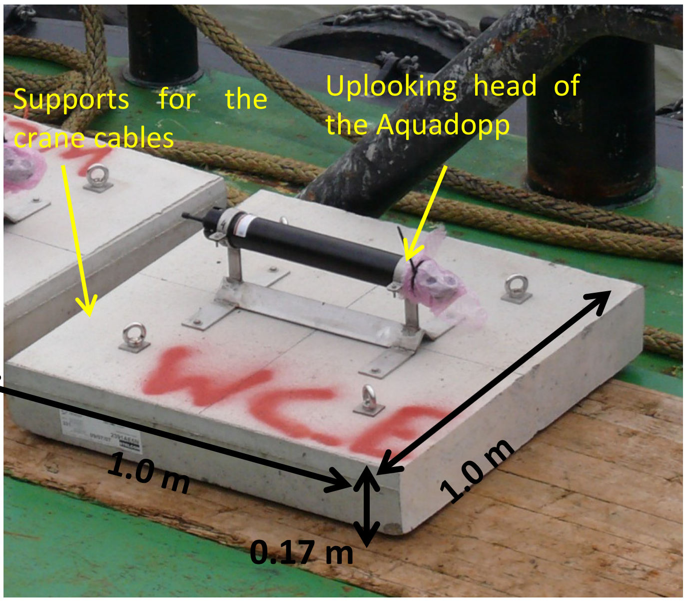
Most of the instruments used in June - July 2013 campaign were acquired by Flanders Hydraulic Research in the first part of 2013. To test and check their proper functioning a series a tests were performed in the laboratory. The instruments function properly according to the technical specifications indicated by the manufacturer.

3.2.1 Aquadopp

Settings

To measure currents one Aquadopp Profiler was used, mounted on a concrete slab (Figure 7). The sensor was placed at approximately 0.4 m from the sea bottom and they measured the entire water column to the surface. The concrete slabs and the fixation systems were design and constructed at Flanders Hydraulics Research. The weight of each slab was estimated at 500 kg.

Figure 7 – The concrete slabs and the current profilers deployed into the North Sea.



The Aquadopp current profiler was used mainly for measuring the marine currents, but can also measure wave height by measuring the pressure variations. For measuring the currents the Aquadopp was set to measure every 5 minutes as an average of 60 seconds. The settings of the Aquadopp are presented in Table 4.

Table 4 – The settings of the current profiler Aquadopp.

Parameter		**Setting**
CURRENTS	Profile interval	300 sec
	Number of cells	20
	Cell size	0.50 m
	Blanking distance	0.20 m
	Average interval	60 sec
WAWES	Number of wave samples	2400
	Wave interval	3600 s
	Wave sampling rate	2 Hz
	Wave cell size	0.50 m
Power level		HIGH
Compass update rate		300 s
Coordinate System		ENU
Speed of sound		MEASURED
Salinity		35 ppt
Analog input 1 and 2		NONE
File wrapping		OFF
Assumed duration		21 days
Battery utilization		47 %
Battery level		11.8 V
Recorder size		185 Mb
Recorder free space		183.799 Mb
Memory required		28.9 Mb

Calibration

The instruments were calibrated before delivery by Nortek. The only calibration necessary to be made was the compass calibration. The compass calibration is designed to adjust for magnetic materials that may be present in the deployment frame or mooring structure. As a consequence, calibration of the compass took place after the Aquadopp Profilers was mounted on the concrete slabs. The calibration procedure started with the mounting of the Aquadopp on the concrete slabs and connection with the computer. On the menu of the AquaPro software under the option On-line>Compass Calibration a window is open (Figure 8). After clicking “start” the entire system was slowly rotated 360° around z-axis of the Aquadopp (Figure 9). After clicking “done” the new values were transferred to Aquadopp to serve as the new compass setting.

Figure 8 – The Compass Calibration dialogue box.

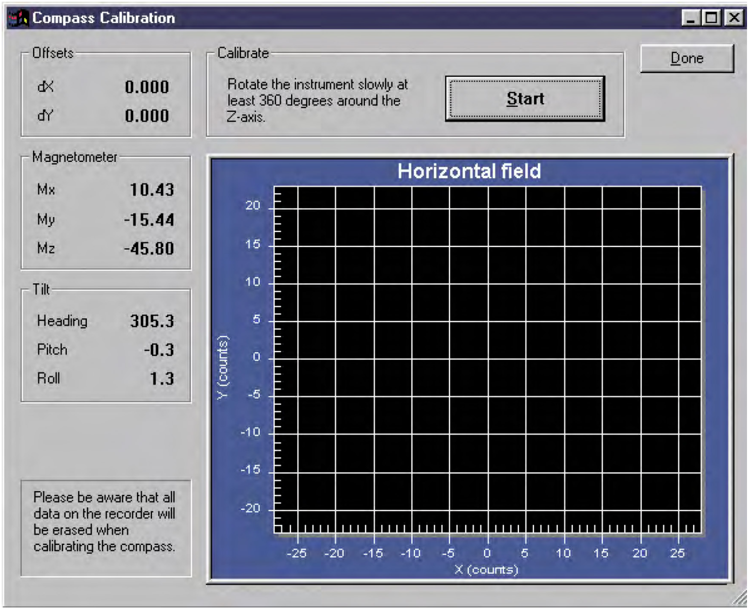
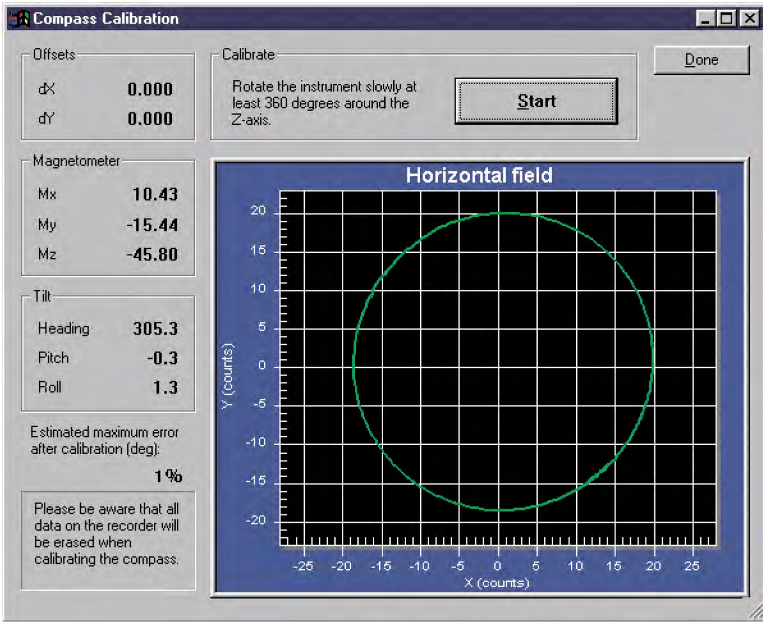


Figure 9 – The Compass Calibration dialogue box after a successful calibration has been made.



Data

The data retrieved from the Aquadopp contain information about marine currents as velocities on the horizontal directions (x, y) and vertical direction (z). The other parameters measured during deployment are: sound speed (m/s) (based on which flow velocities are internally calculated by the AQUADOPP), heading (degrees), pitch (degrees), roll (degrees), pressure (dbar), temperature (degrees C).

3.2.2 AWAC

Settings

To measure the wave characteristics one AWAC was used. The AWAC was mounted on a concrete slab and protected by a plastic barnacle (Figure 10). The sensors placed at approximately 0.5 m from the sea bottom and they measured the entire water column to the surface. The concrete slabs and the fixation systems were design and constructed at Flanders Hydraulics Research. The weight of the slab was estimated at 500 kg. There is gyroscopic mechanism (designed and manufactured at Flanders Hydraulic Research) which ensure that the AWAC stay horizontal when submerged. The list of settings of is detailed in Table 5.

Figure 10 – The concrete slabs and the AWAC in the protecting barnacle deployed into the North Sea.

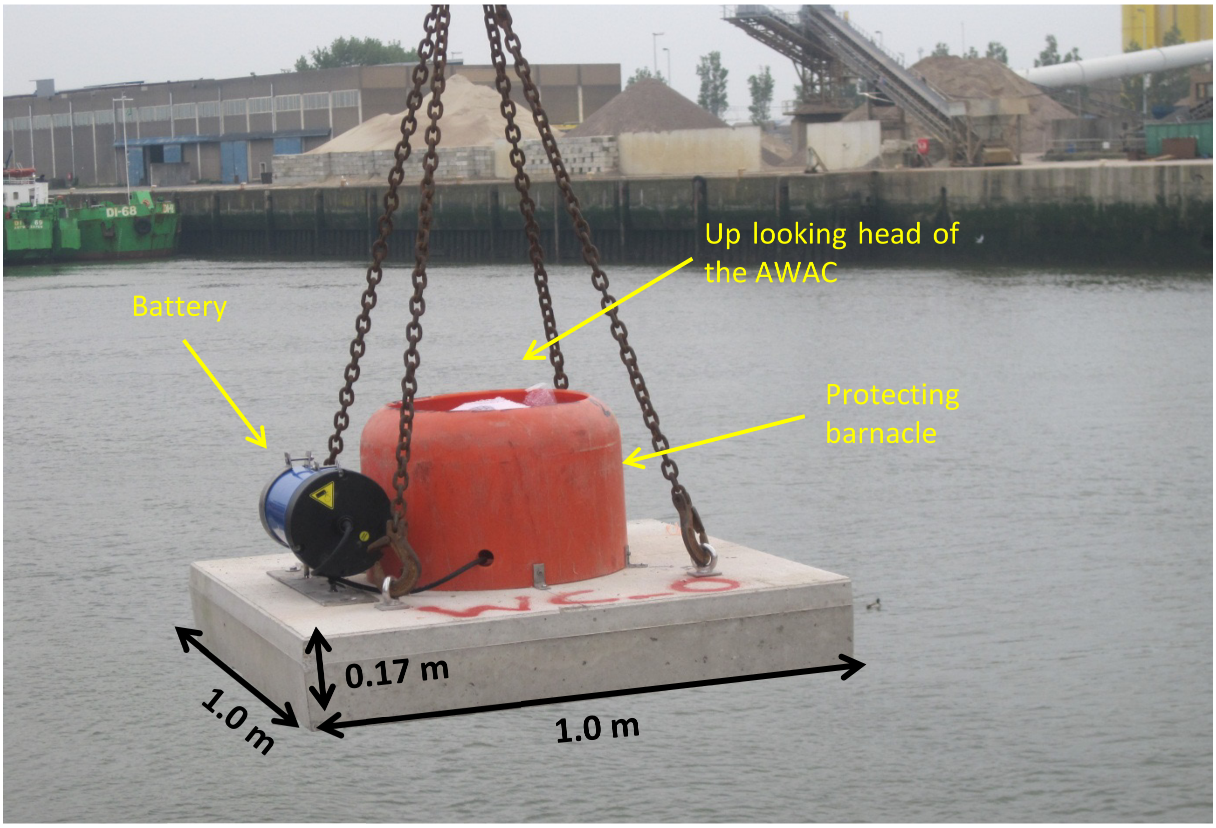


Table 5 – The settings of the submerged wave buoys AWAC.

Parameter		**Setting**
CURRENTS	Profile interval	300 sec
	Number of cells	14/22
	Cell size	0.50 m
	Blanking distance	0.20 m
	Average interval	60 sec
WAVES	Number of wave samples	2400
	Wave interval	3600 s
	Wave sampling rate	2 Hz
	Wave cell size	0.50 m
Power level		HIGH
Measurements load		63 %
Compass update rate		300 s
Coordinate System		ENU
Speed of sound		MEASURED
Salinity		35 ppt
Analog input 1 and 2		NONE
File wrapping		OFF
Assumed duration		21 days
Battery utilization		24/32 %
Battery level		13.8 V
Recorder size		185 Mb
Recorder free space		184.920 Mb
Memory required		29.7 Mb

Calibration

The AWAC was calibrated in the same way as the Aquadopp (for details see section 3.2.1.2).

Data

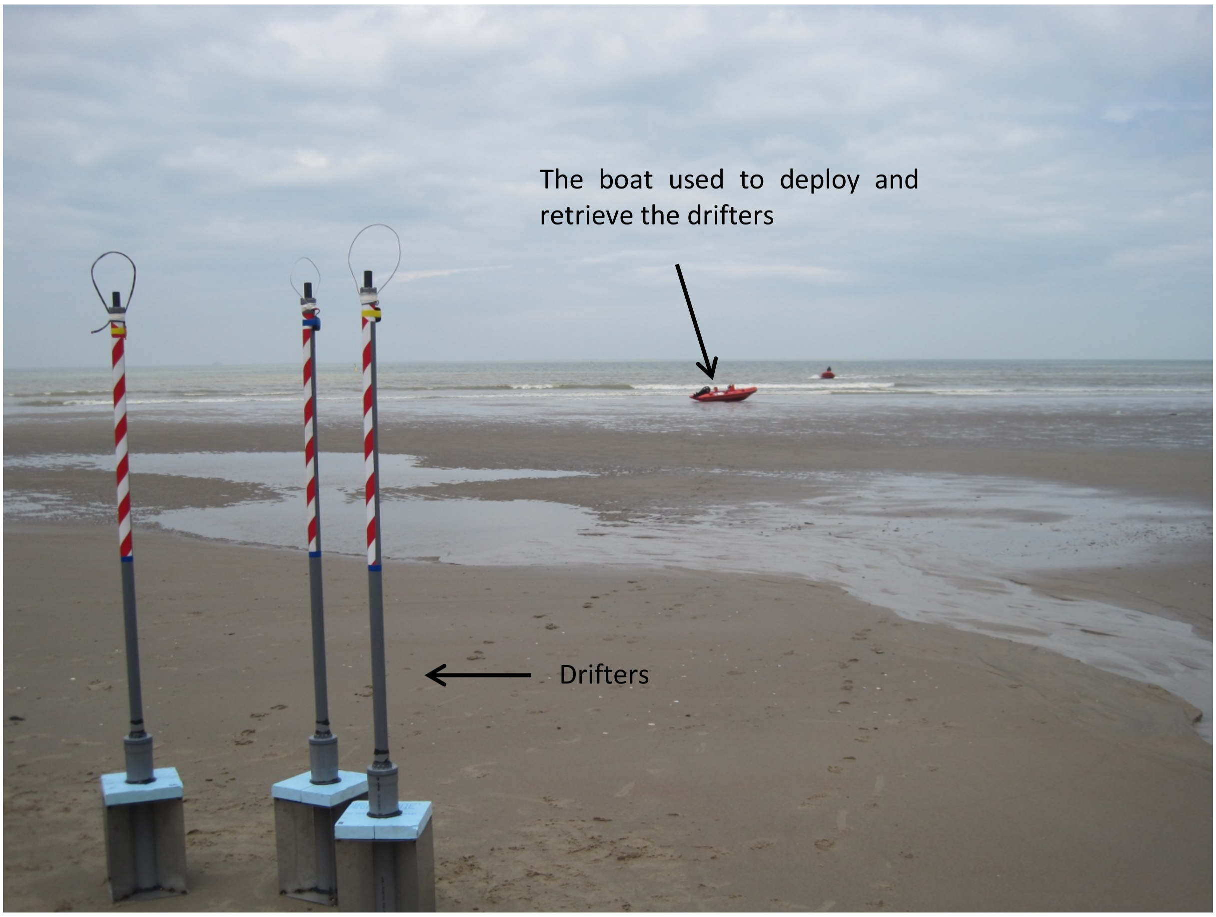
The data collected by the AWAC contain information about waves. The AST (Acoustic Surface Tracking) system measures the water surface elevation. Combined with the other measurements (current velocity) this can result in very accurate estimation of the wave parameters: height, period, direction, spectrum. The marine currents are recorded two as velocities on the horizontal directions (x, y) and vertical direction (z). The other parameters measured during deployment are: sound speed (m/s) (based on which flow velocities are internally calculated by the AWAC), heading (degrees), pitch (degrees), roll (degrees), pressure (dbar), temperature (degrees C). For a complete list of the measured parameters see Appendix II.

3.2.3 Drifters

Deployment and settings

To measure the current direction and velocity 4 drifters were deployed in the water at one side of the coastal cell (the area between two consecutive groins). The 6 drifters (Figure 11) were deployed perpendicularly to the shore at approximately 50 m between each other. When they reached the extremity of the coastal cell they were recovered by boat and replaced in approximately original position. On the 27th of June 2013, during flood, 6 drifters were deployed 11 times, in total 43 measurements of the surf zone currents. During deployment the GPSs record the position at every 3 seconds.

Figure 11 –Drifters use to measure the marine currents during June – July campaign.



4 Results

The extraction of the measurements from the instruments was successfully performed. The data extracted from the current meters Aquadopp and AWAC were processed using the Nortek software STORM version 1.14. The maps of the drifters' circulation were made using ArcGis and R software (more details in Appendix I).

In order to obtain a complete view of the hydrodynamic conditions around Blankenberge harbour during the entire measurement campaign supplementary data were collected from the Meetnet Vlaamse Banken database:

Tide: measured at Blankenberge, every 5 minutes.

Wind characteristics: average speed, average direction and largest speed during 3 seconds during wind gusts (measured at Meetpaal 4 Scheur Wielingen and located east of Zeebrugge harbour).

4.1 Entire period

The period with valid measurements is comprised between 19/06/2013 12:00:00 and 4/07/2013 2:00:00.

Marine currents:

There is an evident pattern for the speed and direction of the currents (Figure 12) . During flood the average speed is larger than during ebb ranging between 0.5 and 1.4 m/s. The average direction is clearly visible: towards NNE – ENE during flood and towards SSW to WSW during ebb.

The speed is very different on the three directions (Figure 13). The largest is on the north component, with values reaching 1.2 m/s during flood; medium values (up to 0.8 m/s) are recorded for the east component; the vertical component display always very low values (bellow 0.1 m/s).

Tide:

The highest flood from the measuring interval was recorded on the 25/06/2013 2.30 hours when the maximum flood water level reached 4,765 m TAW, while the lowest flood was recorded on the 2/07/2013 20.35 hours when the water level reached 3,648 m TAW.

Based on the tide characteristics three tidal cycles were selected for a detail description:

- The highest tidal cycle between 24/06/2013 20.00.00 to 25/06/2013 8.15.00.
- The lowest tidal cycle between 2/07/2013 14:45:00 and 3/07/2013 4:05:00.
- The drifters tidal cycle between 27/06/2013 10:10:00 and 27/06/2013 23:00:00, the tidal cycle when the drifters were used.

Wind:

The wind speed strongly vary during the measuring interval with some periods when the values were between 10 and 15 m/s average speed (Figure 14). The wind direction was relatively constant, most of the time from the W to N directions, with few episodes when the direction was from S to W directions.

Waves:

The wave height follow the same trend as the wind speed (Figures 16 and 17), while the wave mean direction is more constant than the wind direction, always from W to N direction, dominant being the direction from NW.

Events:

During the measuring interval a storm took place starting with the second half of the 21 until the first half of the 24/06/2013. The significant wave height reached maximum values of 1.5 and the maximum wave height almost 3 m. The storm had an impact on the stability of the instruments (Figure 15). The low values for the wave period clearly show that this event was wind generated storm. Peaks of the wave height in the rest of the interval are due to swell waves. The change in the instrument's heading, pitch and roll did not influence the measurements as there are automatically corrected using the internal compass.

Figure 12 – The average current velocity and direction as measured with Aquadopp for the entire period.

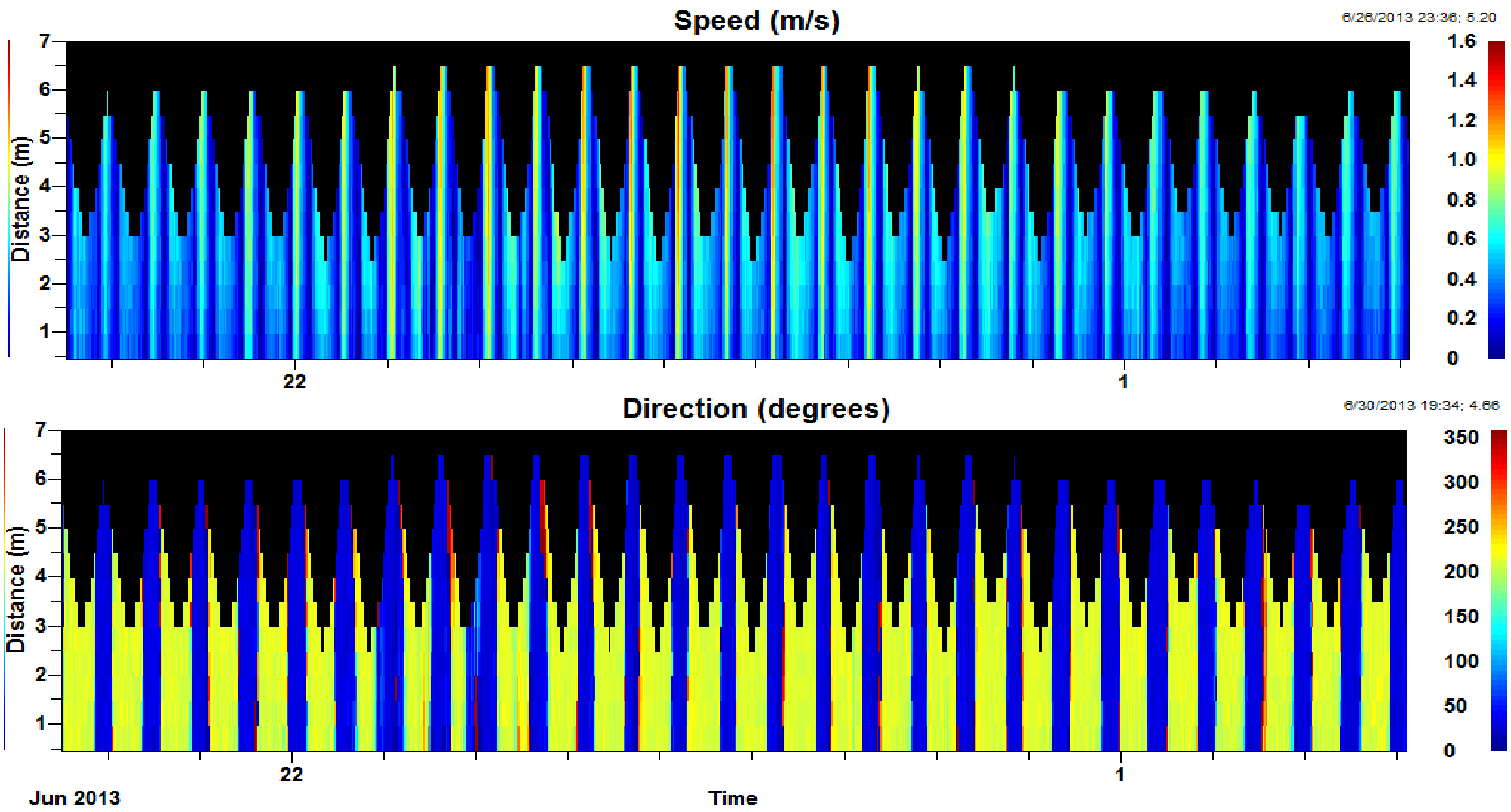


Figure 13 – The current velocity on the three directions as measured with Aquadopp for the entire period.

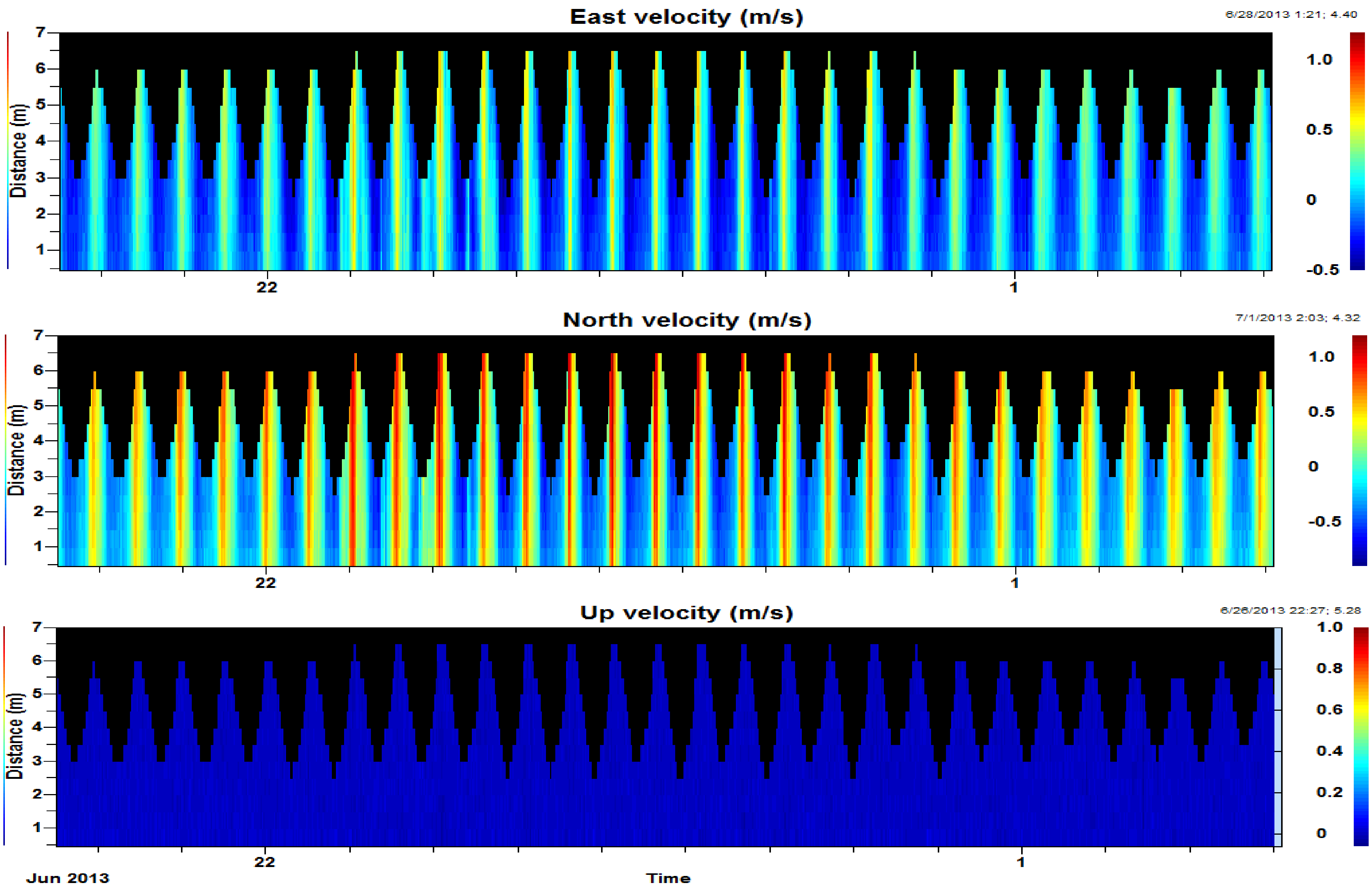


Figure 14 – The tide and the wind characteristics (average direction, average speed and gust speed) for the entire period.

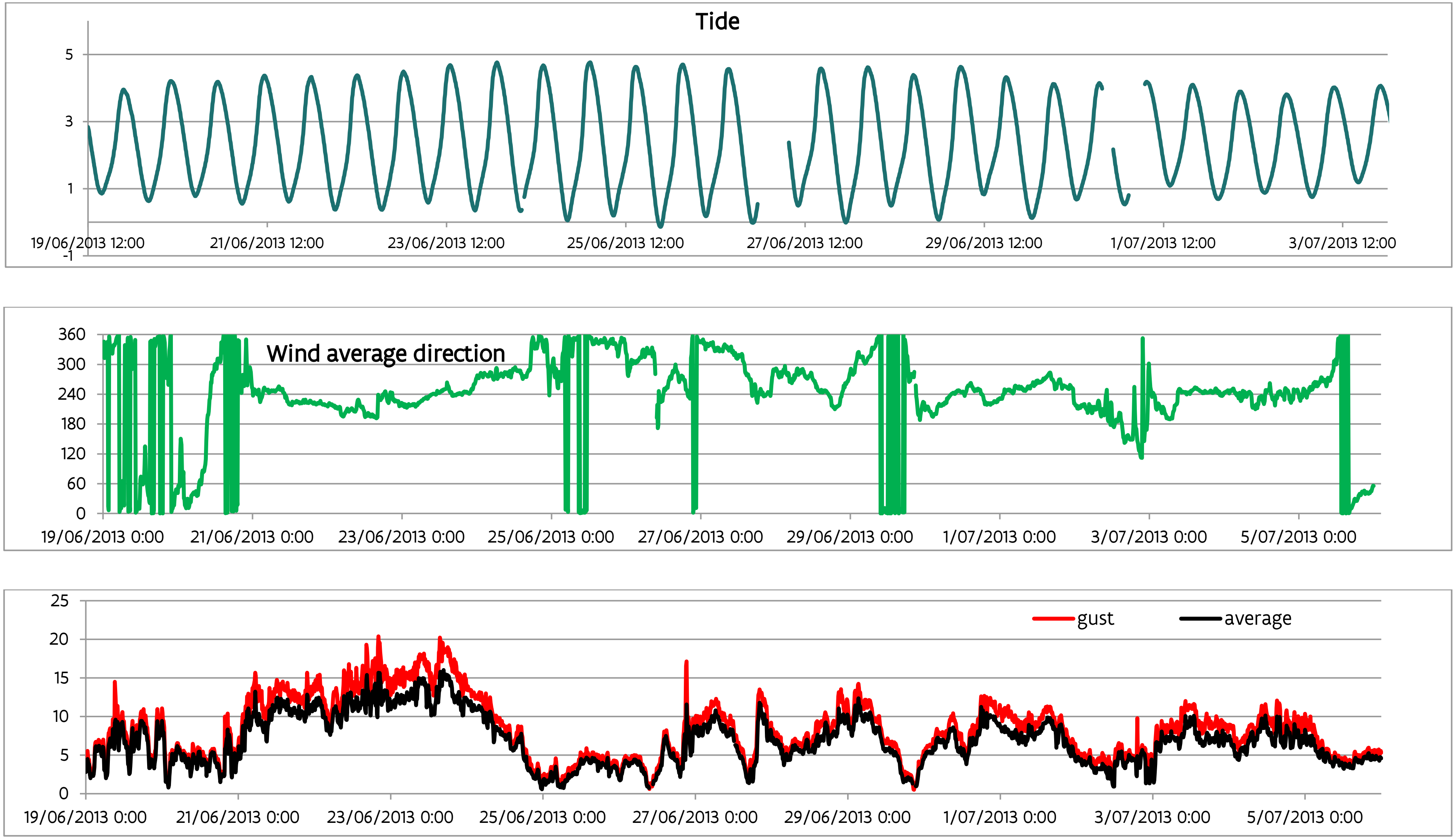


Figure 15 – The temperature and pressure variation as measured by Aquadopp for the entire period. Lower part the orientation of the instrument.

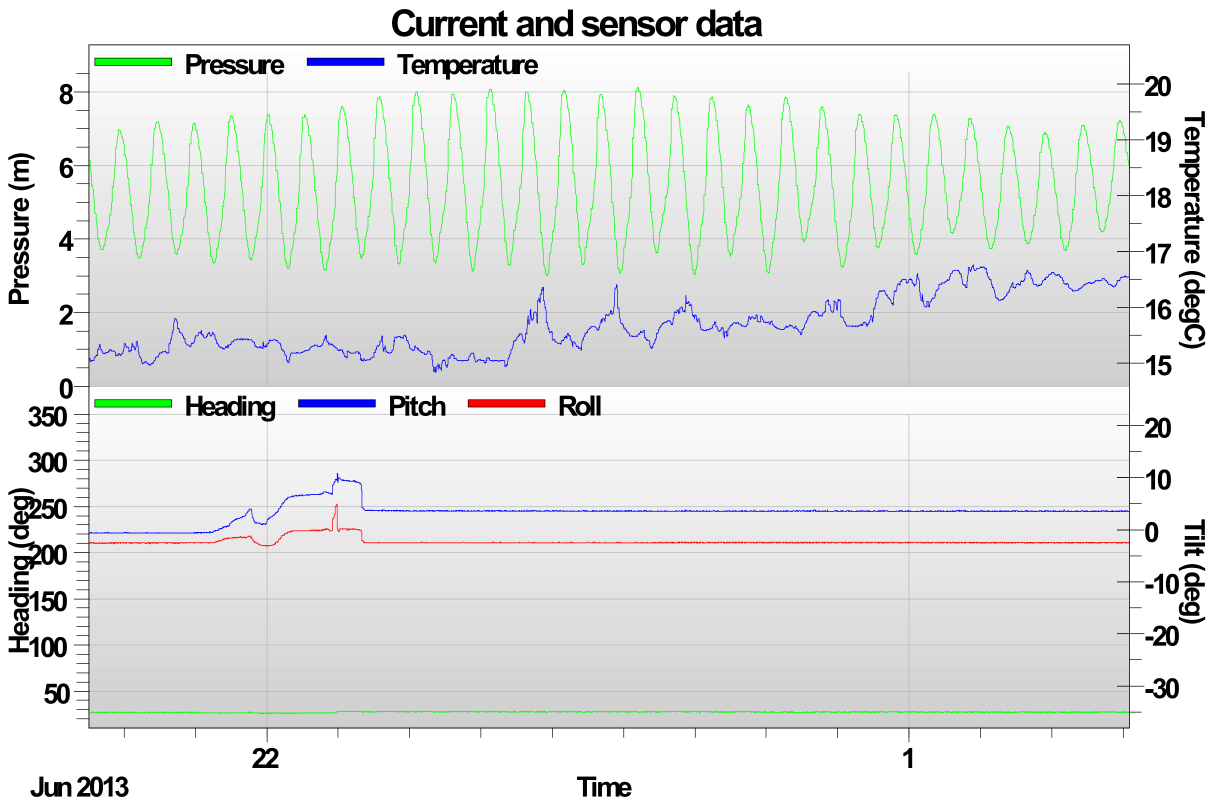


Figure 16 – The wave parameters measured with AWAC for the entire period and processed with STORM software.

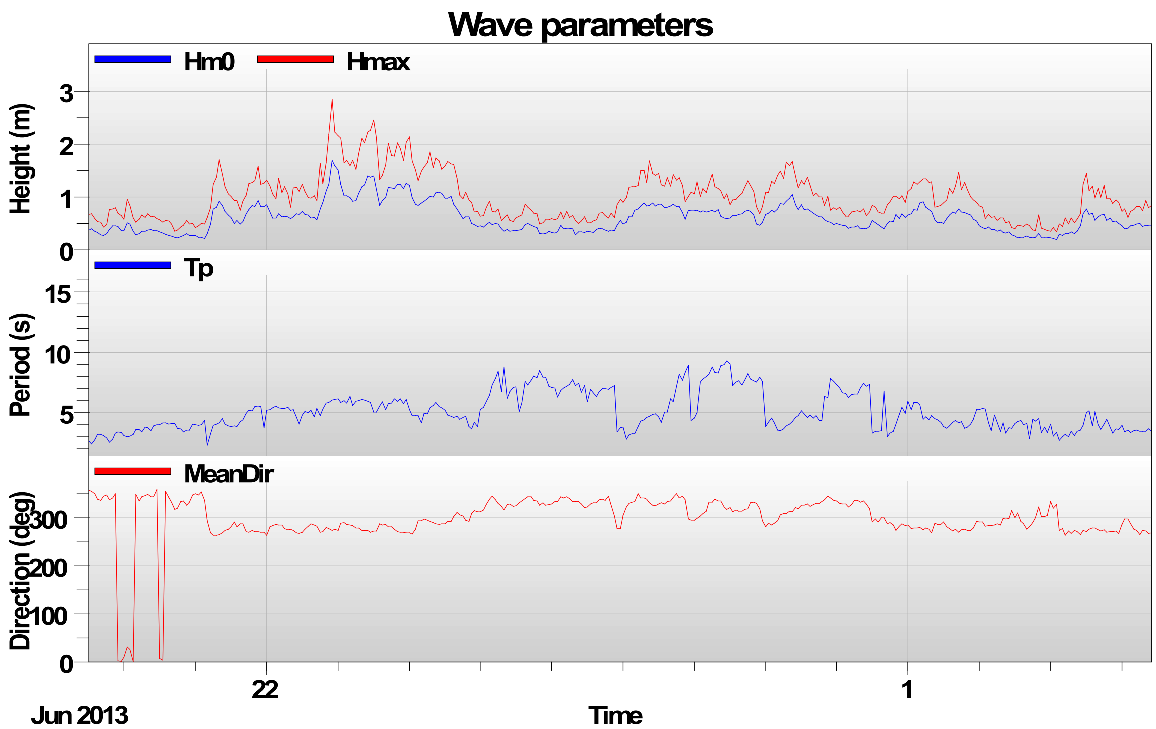
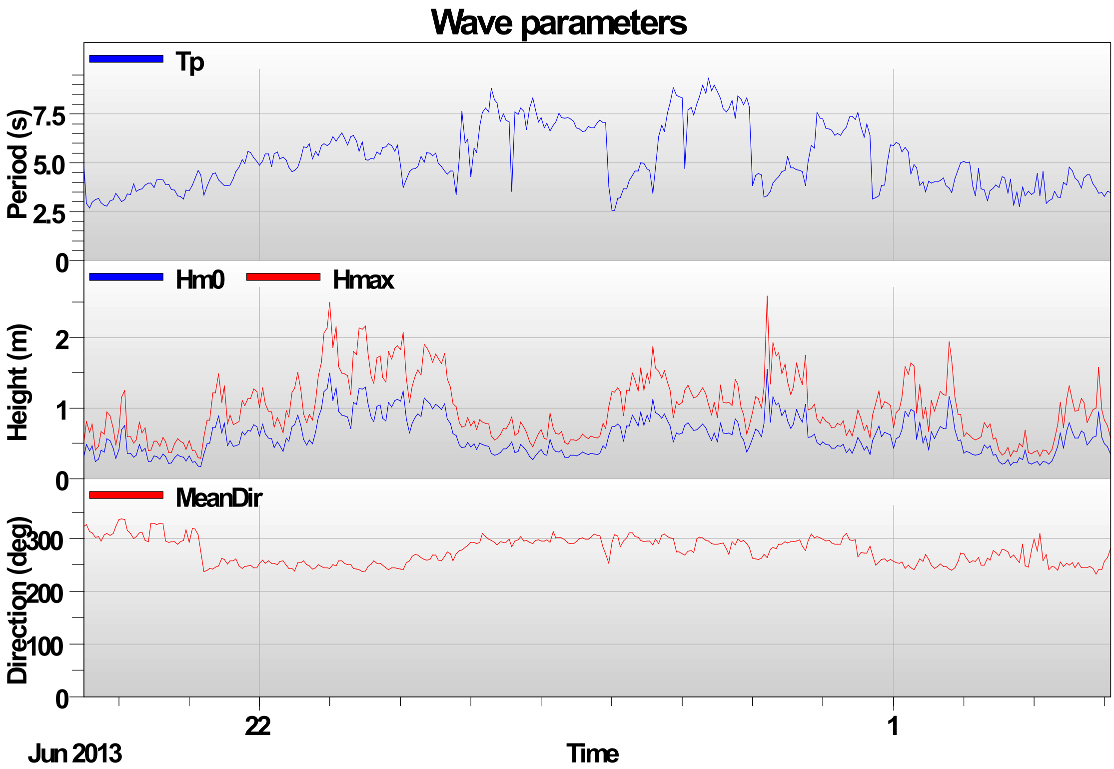


Figure 17 – The wave parameters measured with Aquadopp for the entire period and processed with STORM software.



4.2 Highest tidal cycle

The highest tide level during the measurements was recorded on the 25/06/2013 2.30 hours when the maximum flood water level reached 4,765 m TAW. To cover the entire tidal cycle we considered the interval 24/06/2013 20.00.00 to 25/06/2013 8.15.00.

Marine currents:

The speed and direction of the currents (Figure 18) show the same patterns as the records for the entire period: during flood the average speed is larger than during ebb ranging between 0.5 and 1.2 m/s; the average direction is clearly visible: towards NE during flood and towards SW during ebb.

The speed is very different on the three directions (Figure 19). The largest is on the north component, with values reaching 1.2 m/s during flood; medium values (up to 0.8 m/s) are recorded for the east component; the vertical component display always very low values (bellow 0.1 m/s).

Wind:

The wind speed had low, but constant values, between 1 and 3 m/s (Figure 20). The wind direction was relatively constant, most of the time from the W to N directions.

Waves:

The wave height follow the same trend as the wind speed (Figure 21) with average values of 0.6 m, while the wave mean direction is more constant than the wind direction, always from WNW.

Figure 18 – The current velocity and direction as measured with Aquadopp for the highest tidal cycle.

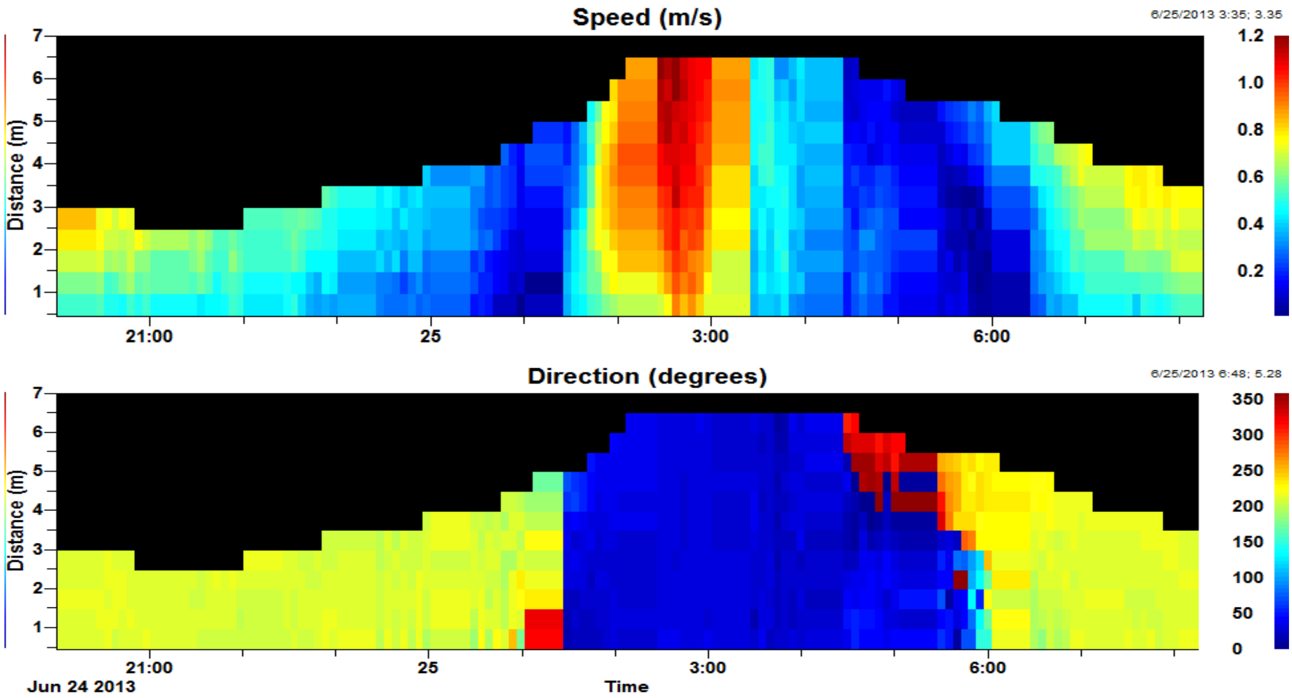


Figure 19 – The current velocity on the three directions as measured with Aquadopp for the highest tidal cycle.

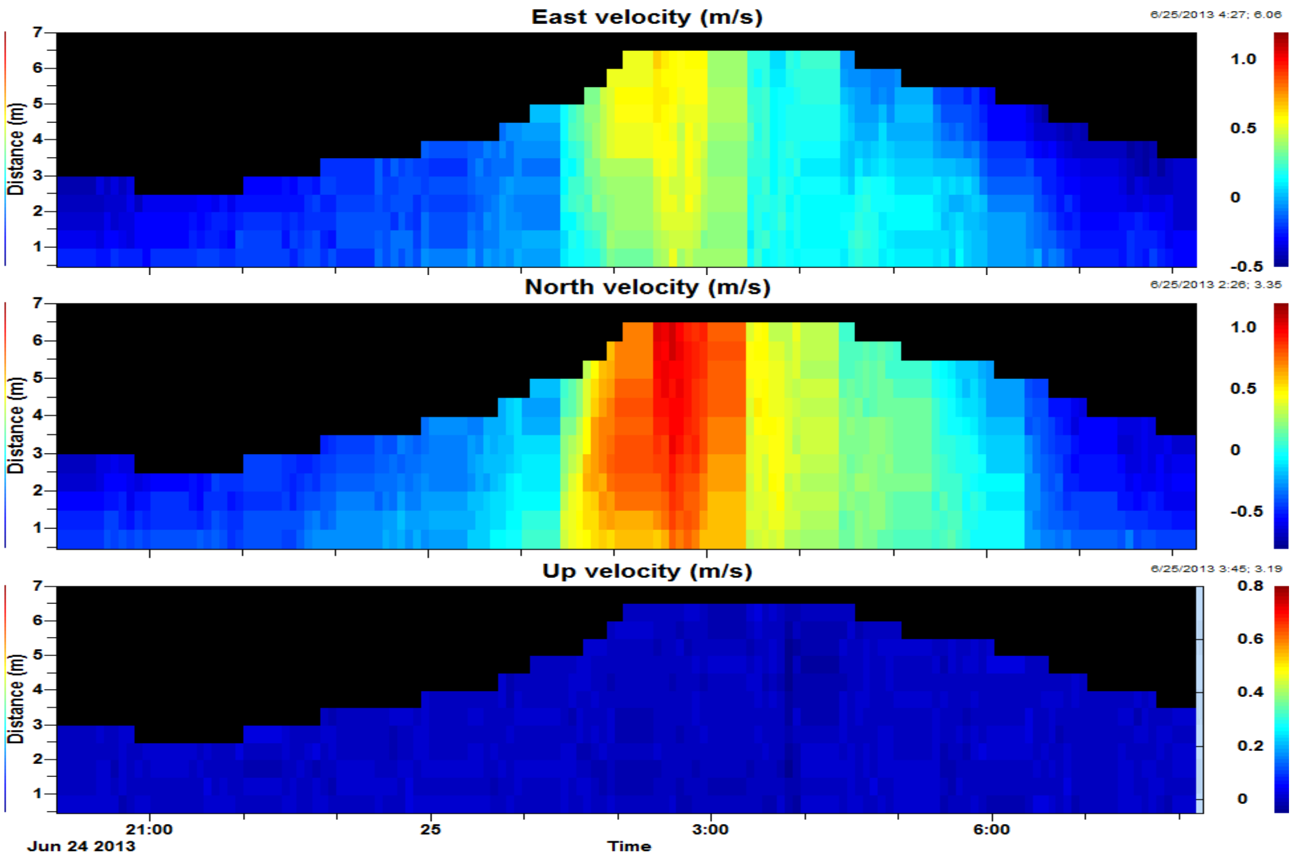


Figure 20 – The tide and the wind characteristics (average direction, average speed and gust speed) for the highest tidal cycle.

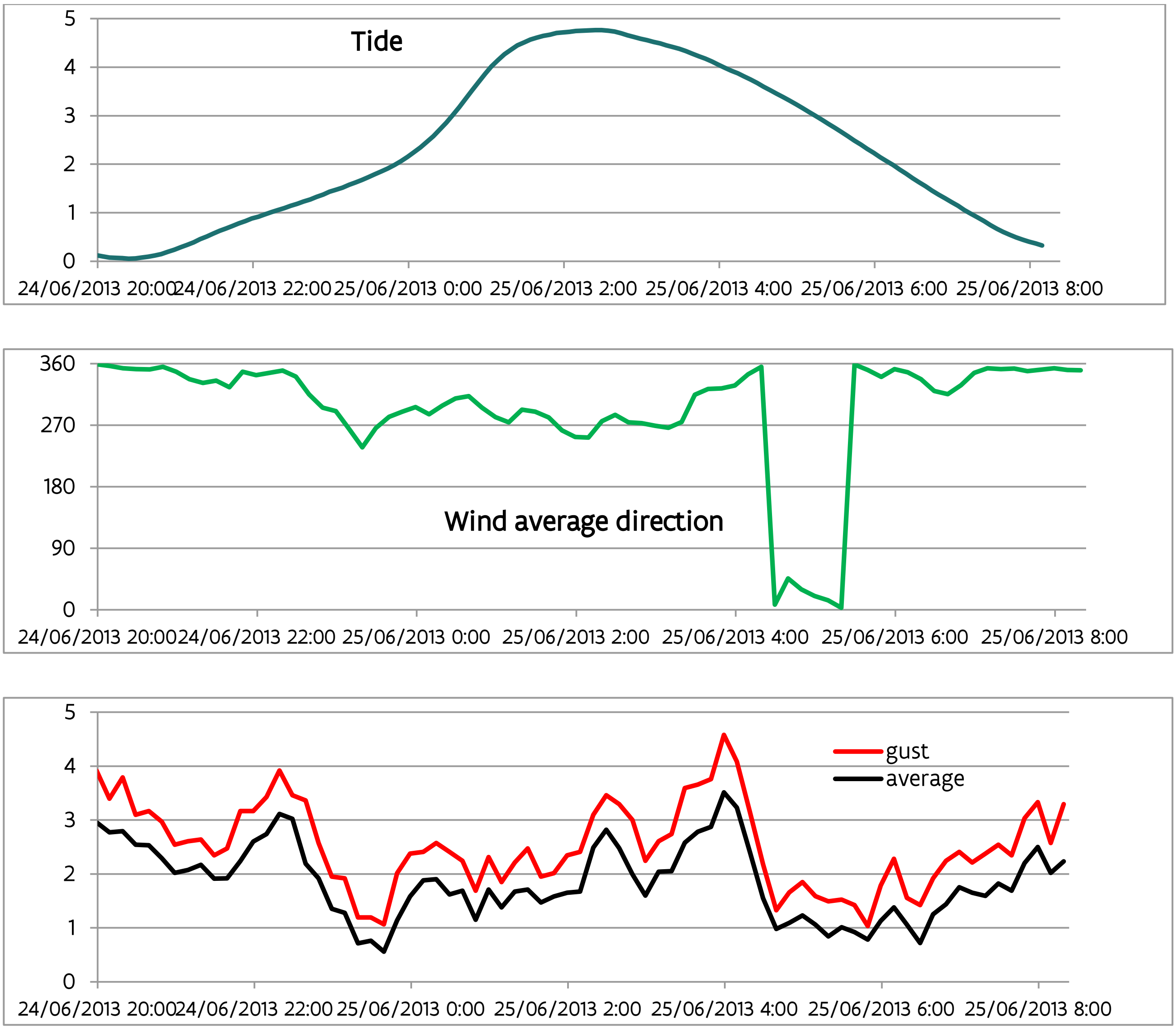
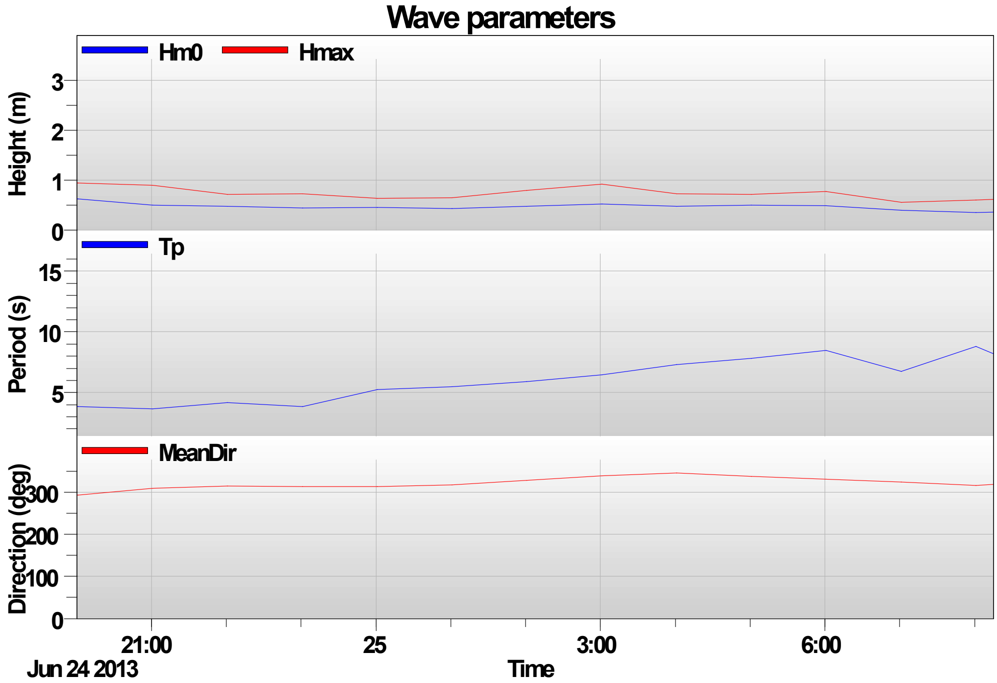


Figure 21 – The wave parameters during the highest tidal cycle measured with AWAC and processed with STORM software



4.3 Lowest tidal cycle

The lowest tide level during the measurements was recorded on the 2/07/2013 20.35 hours when the maximum flood water level reached 3,648 m TAW. To cover the entire tidal cycle we considered the interval 2/07/2013 14:45:00 to 3/07/2013 4:05:00.

Marine currents:

The speed and direction of the currents (Figure 22) show the same pattern as the records for the entire period: during flood the average speed is larger than during ebb ranging between 0.4 and 0.9 m/s; the average direction is clearly visible: towards NE during flood and towards SW during ebb.

The speed is very different on the three directions (Figure 23). The largest is on the north component, with values reaching 1.2 m/s during flood; medium values (up to 0.8 m/s) are recorded for the east component; the vertical component display always very low values (bellow 0.1 m/s).

Wind:

The wind speed had moderate values between 1.5 and 6 m/s (Figure 24). The average wind direction was variable, ranging from SE to N. The peaks for the wind gust speed coinciding with N direction.

Waves:

The wave height had very low values (Figure 25), bellow 0.5 m, while the wave mean direction was very constant comparing to the wind direction, always from WNW.

Figure 22 – The current velocity and direction as measured with Aquadopp for the lowest tidal cycle.

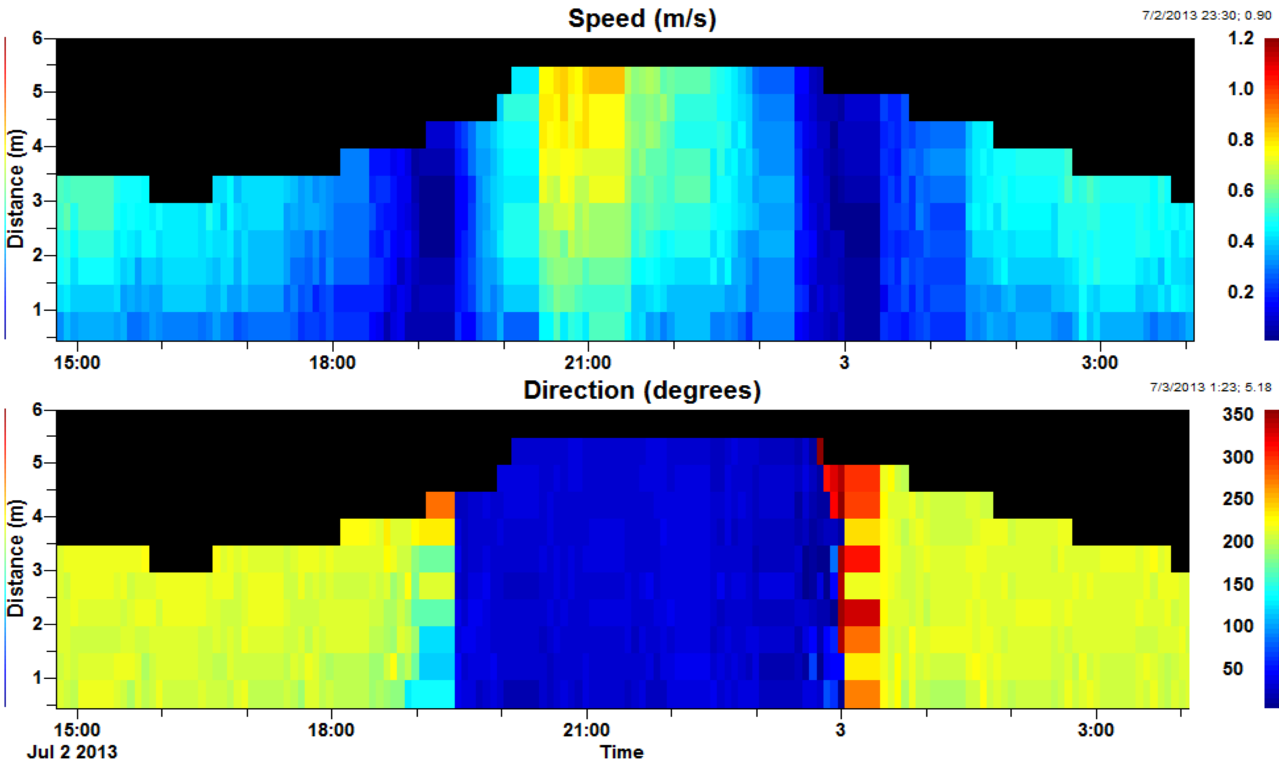


Figure 23 – The current velocity on the three directions as measured with Aquadopp for the highest tidal cycle.

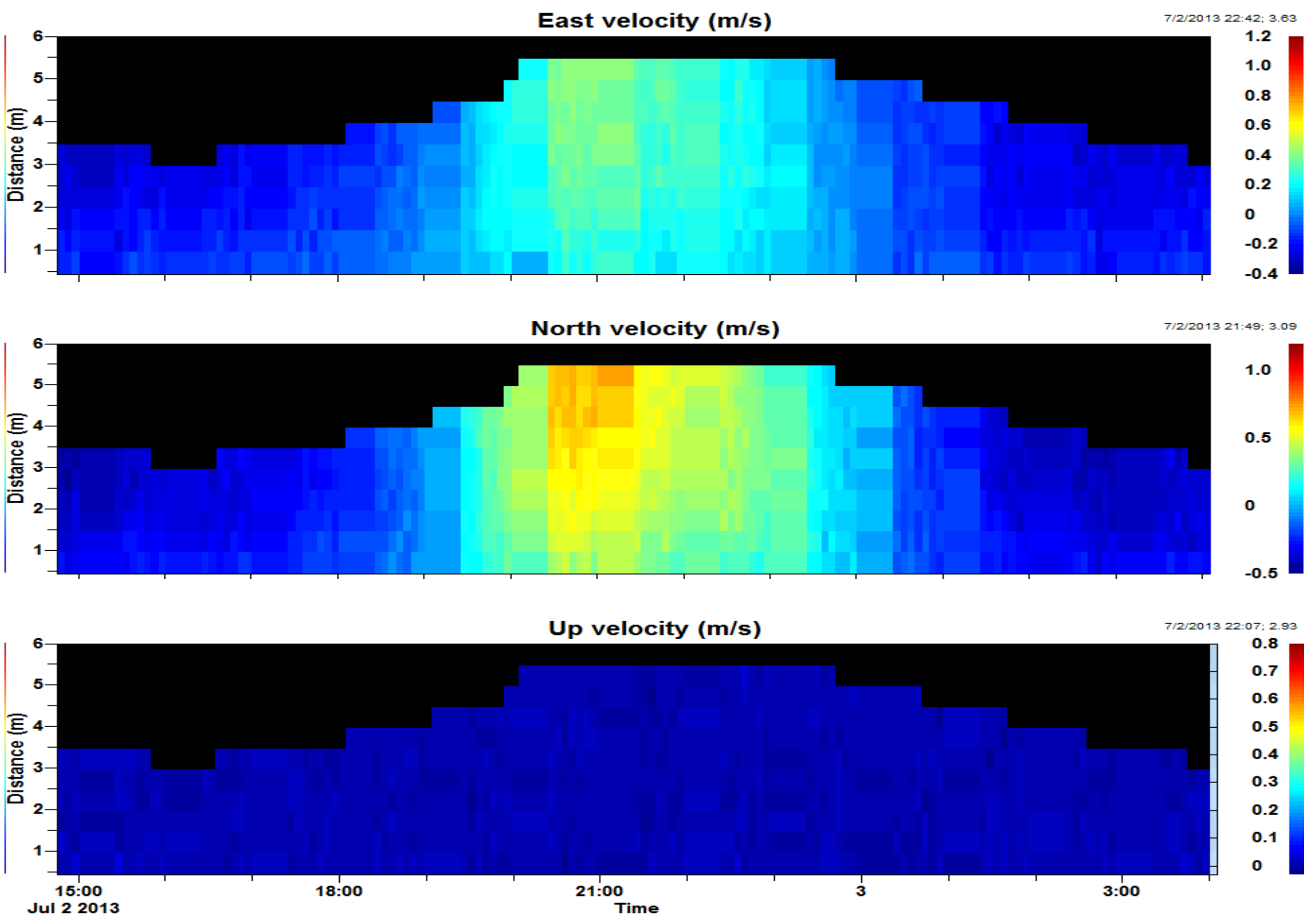


Figure 24 – The tide and the wind characteristics (average direction, average speed and gust speed) for the lowest tidal cycle.

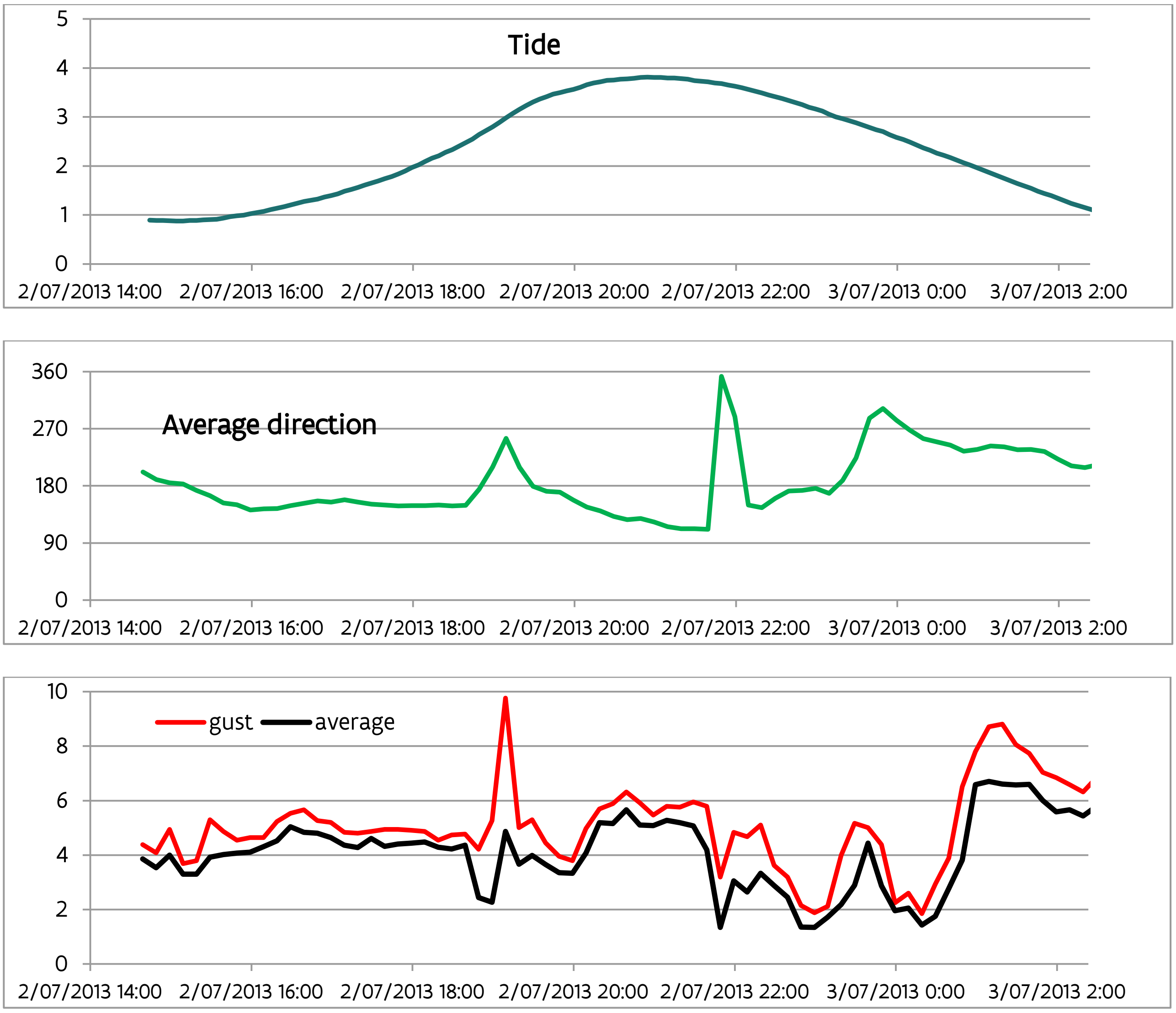
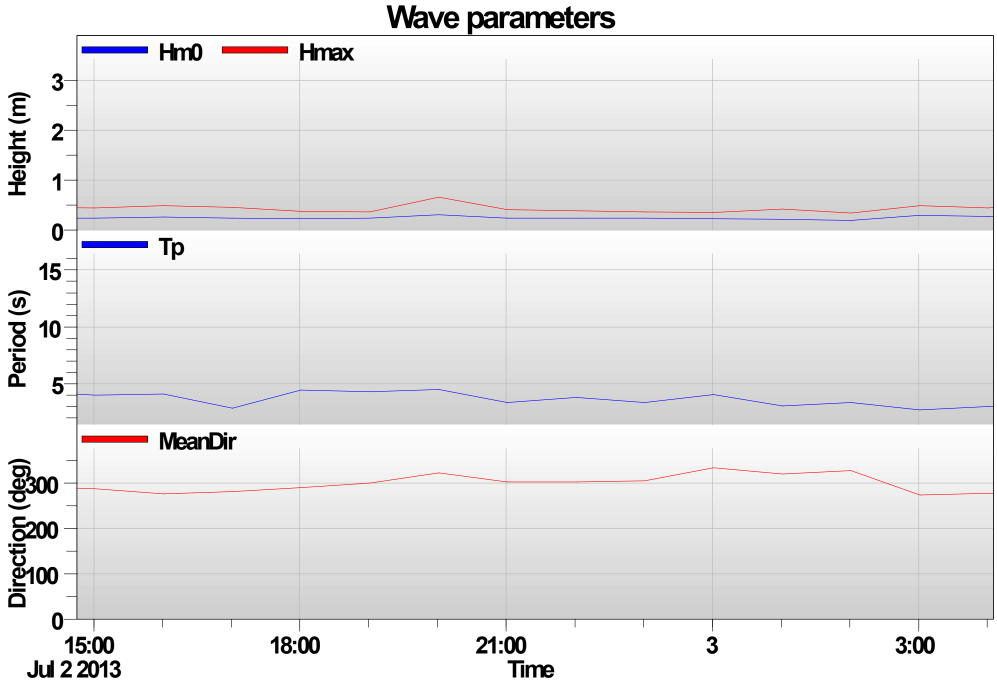


Figure 25 – The wave parameters during the lowest tidal cycle measured with AWAC and processed with STORM software.



4.4 Drifter tidal cycle

On 27/06/2013 between 13:40:00 and 17:00:00 the drifters were used to estimate the velocity and direction of the surface (0 to -1.0 m depth) marine currents. To investigate the hydrodynamic conditions from this interval we consider the entire tidal cycle where the highest water (4.584 m) level was reached on the 27/06/2013 16:15:00. The considered interval is between 27/06/2013 10:10:00 and 27/06/2013 23:00:00.

Marine currents:

The speed and direction of the currents (Figure 26) show the same pattern as the records for the entire period: during flood the average speed is larger than during ebb ranging between 0.4 and 1.2 m/s; the average direction is clearly visible: towards NE during flood and towards SW during ebb.

The speed is very different on the three directions (Figure 27). The largest is on the north component, with values reaching 1.0 m/s during flood; medium values (up to 0.6 m/s) are recorded for the east component; the vertical component display always very low values (bellow 0.1 m/s).

Wind:

The wind speed strongly vary with values between 2.0 and 12 m/s (Figure 28). The average wind direction was variable, ranging from SW to NW.

Waves:

The significant wave height had low values (Figure 29), 0.8 to 0.9 m, while the wave mean direction was very constant comparing to the wind direction, always from NNW.

Main values for the hydrodynamics during the time interval when the drifters were in the water (27/06/2013 between 14:40:00 and 18:00:00)**:**

Currents: average speed between 0.4 and 1.2 m/s and average direction towards SW between 14:40:00 and 15:30:00 and towards NE between 15:30:00 and 18:00:00.

Tide: start - 14:40:00 – 2.94 m, maximum - 16:15:00 – 4.58 m, end - 18:00:00 – 3.89 m.

Wind: decreasing speed from 4.5 m/s at the beginning to 1.5 m/s at the end of the time interval. Direction changing from W at the beginning to SW at the end of the time interval.

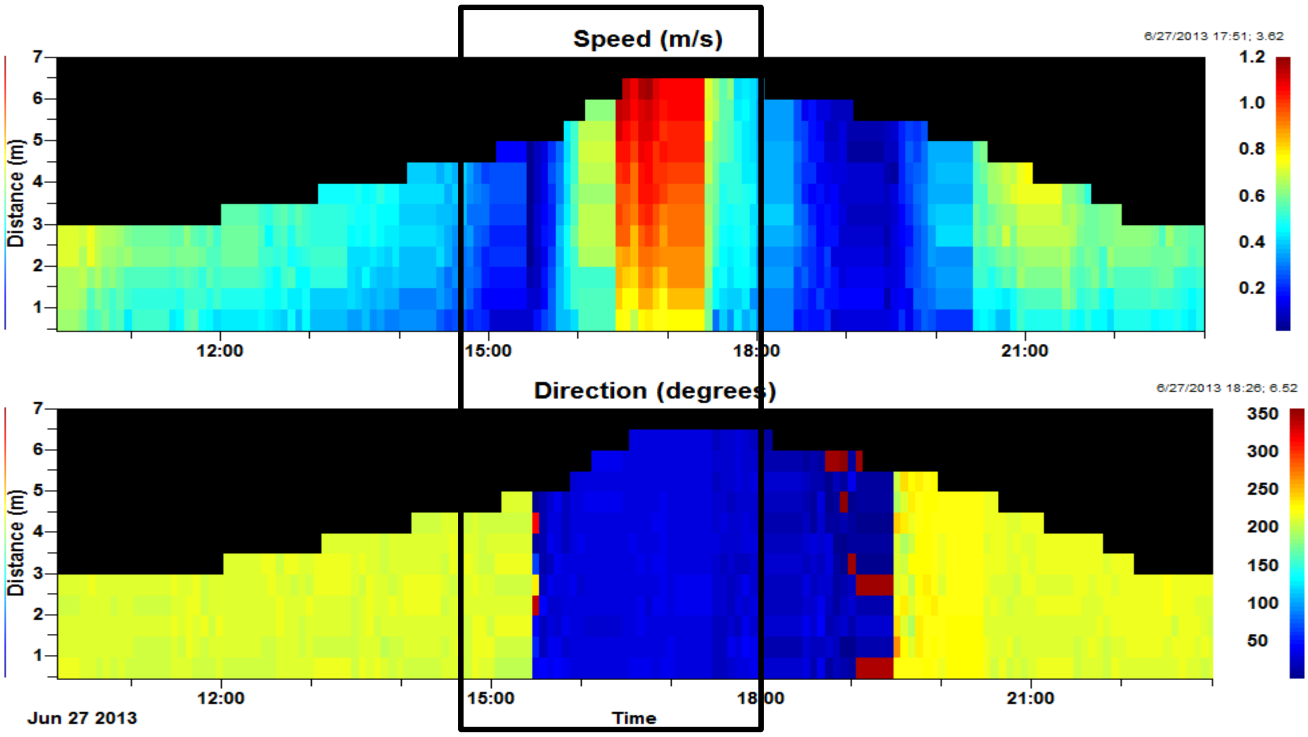
Waves: the significant wave height was constant 0.8 m while the maximum wave height was 1.5 m. The direction was constant from NNW and the peak period increase from 5 to 6 s at the end of the time interval.

Drifters measurements:

The drifters directly measured the average current speed and the velocity of the water layer comprised between 0 and -1.0 m. The currents are measured also with the Aquadopp, but only for the lower part of this water layer, approximately 0.5 m. It was expected some differences for current speed and direction measured by the two type of instruments. This can be due to the distance (100 – 150 m offshore direction) were they have been made and to the fact that the drifters can be influence by the waves and wind. To analyse the measurements we divided the measuring period in 7 time intervals:

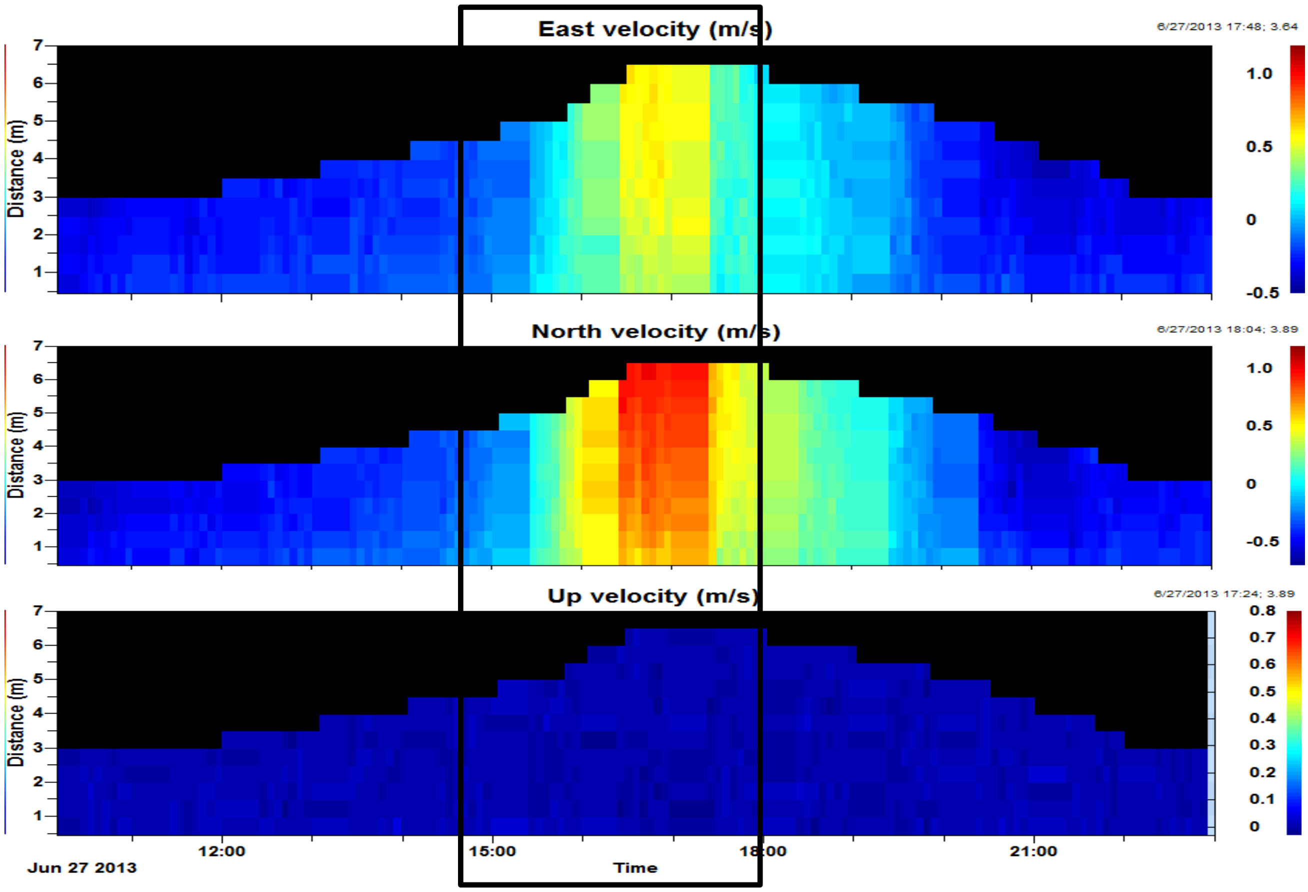
1. Interval between 14:43:04 and 15:13:04 (Figure 30). The speed of the currents has low values, generally 0.1 to 0.2 m/s and the directions are very different. This is due to the fact that the dominant current direction is just about to change. The Aquadopp indicate constant current direction, towards SSW and current speed of 0.3 m/s.
2. Interval between 15:13:04 and 15:43:04 (Figure 31). The speed of the currents is increasing in this time interval from 0.1 to 0.5 m/s and the directions is towards ENE. The Aquadopp show the change in the current direction towards ENE matching with the measurements of the drifters. The match is good also for the current speed, the Aquadopp showing speeds between 0.1 and 0.3 m/s.
3. Interval between 15:43:04 and 16:13:04 (Figure 32). The speed of the currents is ranging between 0.25 to 0.5 m/s and the directions is towards NE - ENE as measured by the drifters. The Aquadopp measurements show similar trends: direction towards NNE – NE and speeds between 0.4 and 0.7 m/s. Interval between 16:13:04 and 16:43:04 (Figure 33). Some of the drifters are situated more offshore and they measure current speed ranging between 0.5 and 1 m/s and the direction is towards ENE. Other drifters are very close to the shore and they start to be influenced by the breaking waves, so the indicate lower speeds and direction towards the shoreline. The Aquadopp measurements indicate constant direction towards NE and speeds between 0.6 and 1.1 m/s.
4. Interval between 16:43:04 and 17:13:04 (Figure 34). The drifters again separate into two groups: one situated onshore with low current speed (0.1 – 0.4 m/s) and variable directions ranging towards N and S; the other group situate more offshore display a rather constant direction towards ENE – NE and speeds between 0.3 and 0.7 m/s. The Aquadopp measurements are similar with those from the offshore group of drifters: direction towards NE and speed 1.1 m/s.
5. Interval between 17:13:04 and 17:43:04 (Figure 35). The speeds of the currents decrease to almost stand still, directions are very different. The Aquadopp measurements indicate constant direction towards NE and a speed decrease from 1.1 to 0.5 m/s.
6. Interval between 17:13:04 and 17:58:04 (Figure 36). The speeds are very low and directions very different showing only local movement of the drifters, probably due to the wave breaking only. The Aquadopp measurements indicate current direction as towards N – NNE and speeds around 0.5 m/s. The drifters again separate into two groups: the onshore one, with a movement dictated by the waves and the offshore one, driven by the currents. The speeds and direction recorded by the offshore group are similar with those measured by the Aquadopp.

Figure 26 – The current velocity on the three directions as measured with Aquadopp for the drifters' tidal cycle.



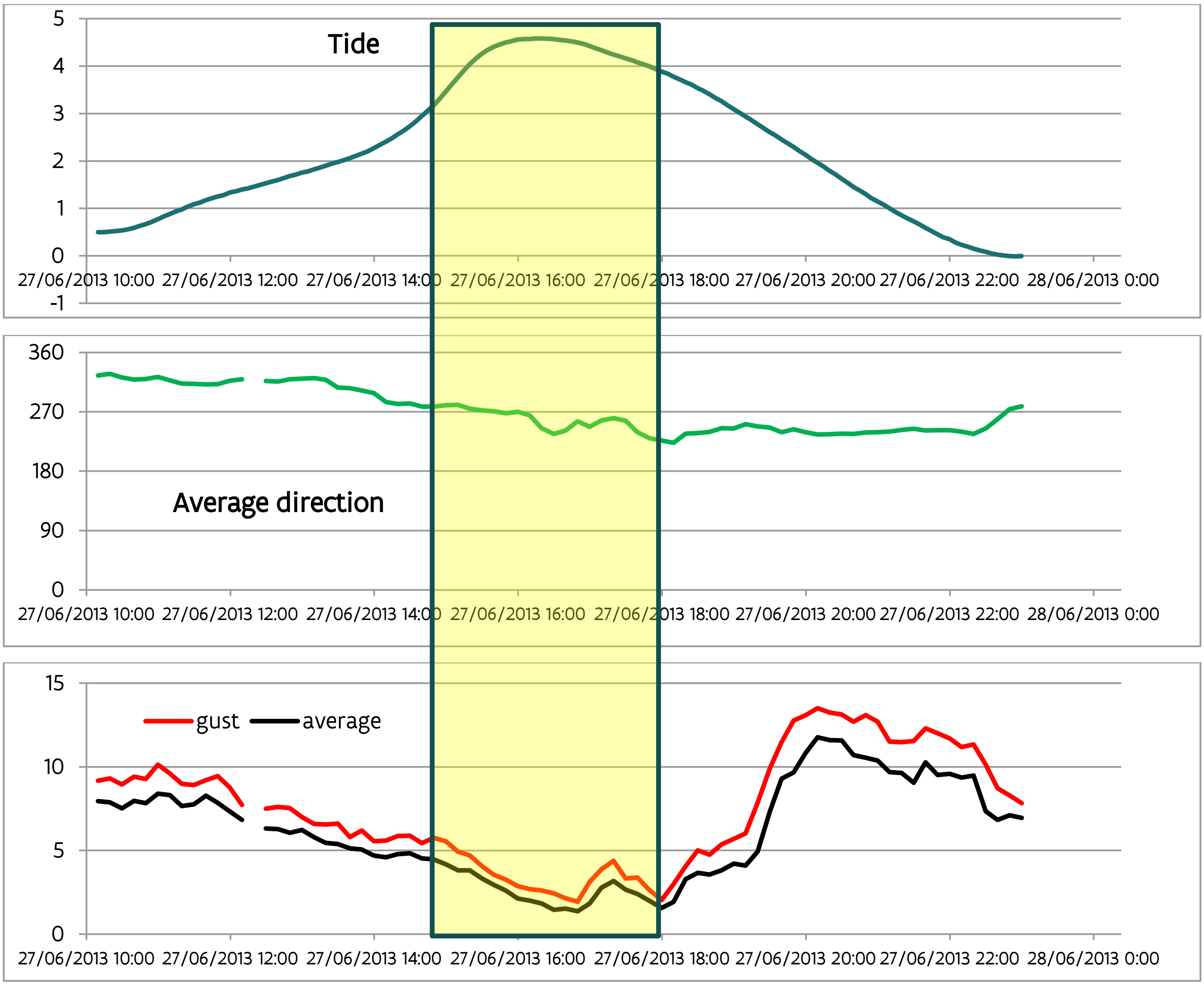
The black rectangle highlights the interval of drifters' measurements.

Figure 27 – The current velocity on the three directions as measured with Aquadopp for the drifters' tidal cycle



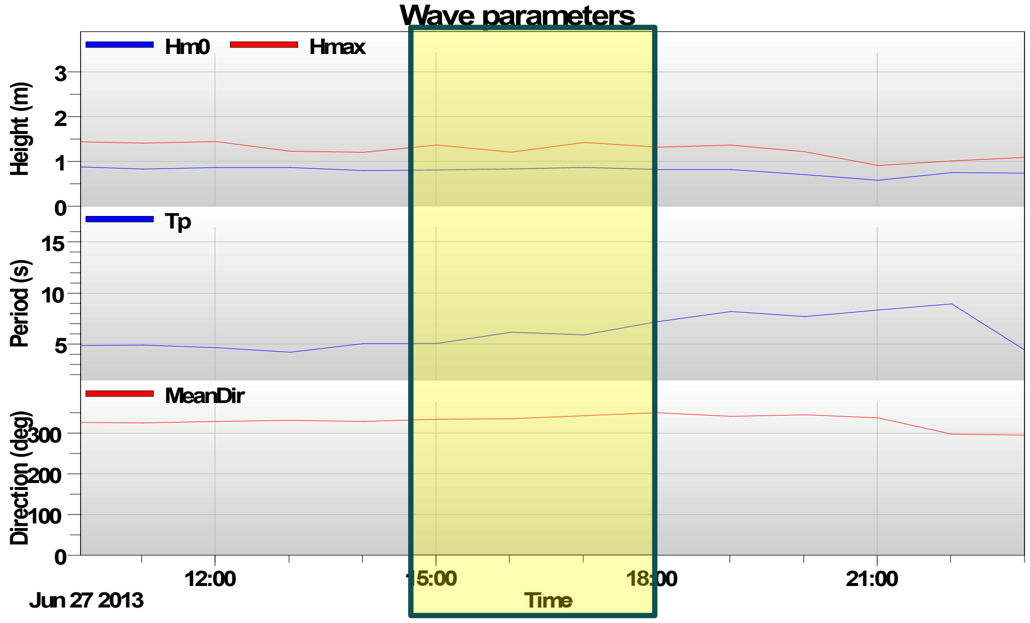
The black rectangle highlights the interval of drifters' measurements .

Figure 28 – The tide and the wind characteristics (average direction, average speed and gust speed) for the drifters' tidal cycle.



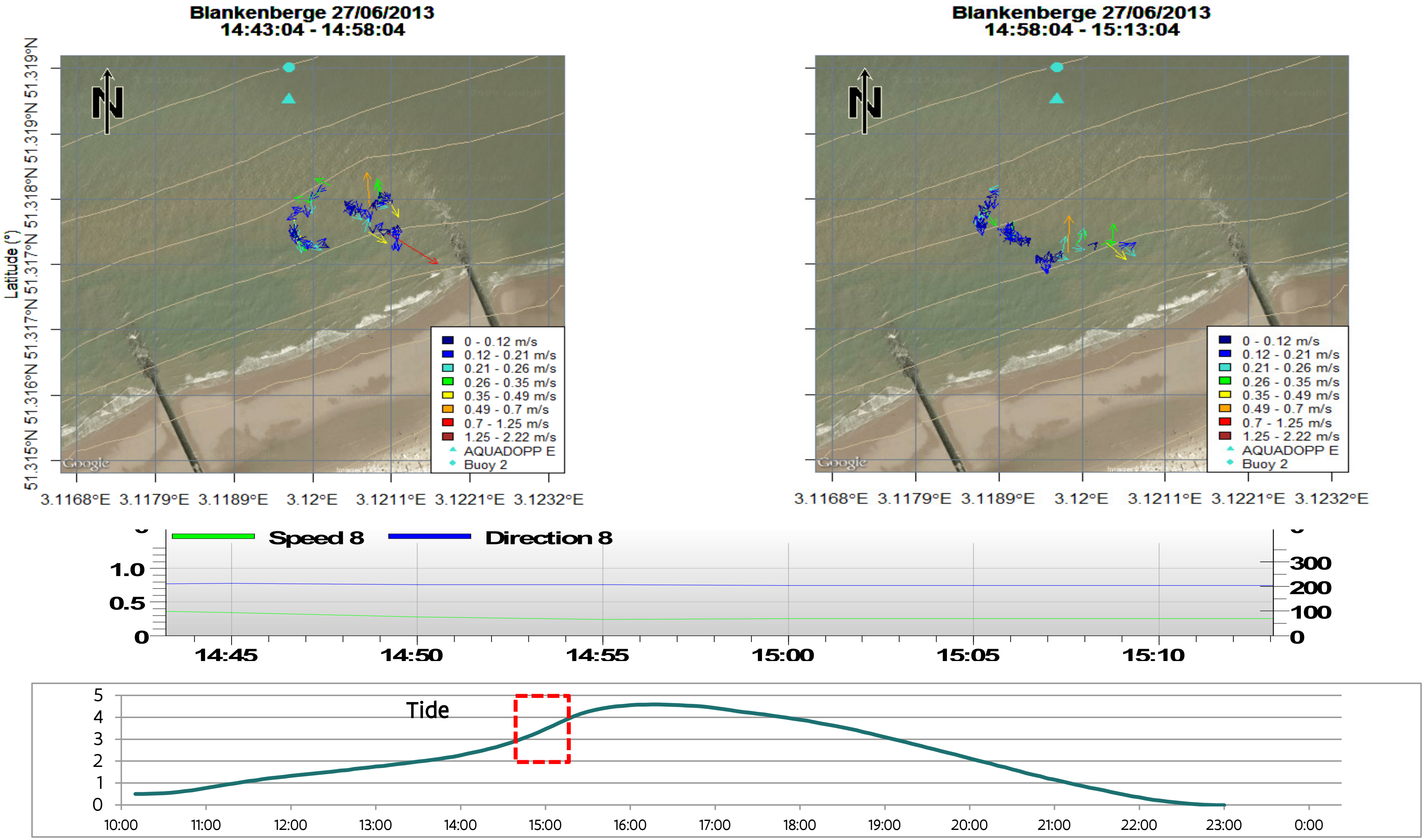
The yellow rectangle highlights the interval of drifters' measurements.

Figure 29 – The wave parameters during the drifters' tidal cycle measured with AWAC and processed with STORM software.



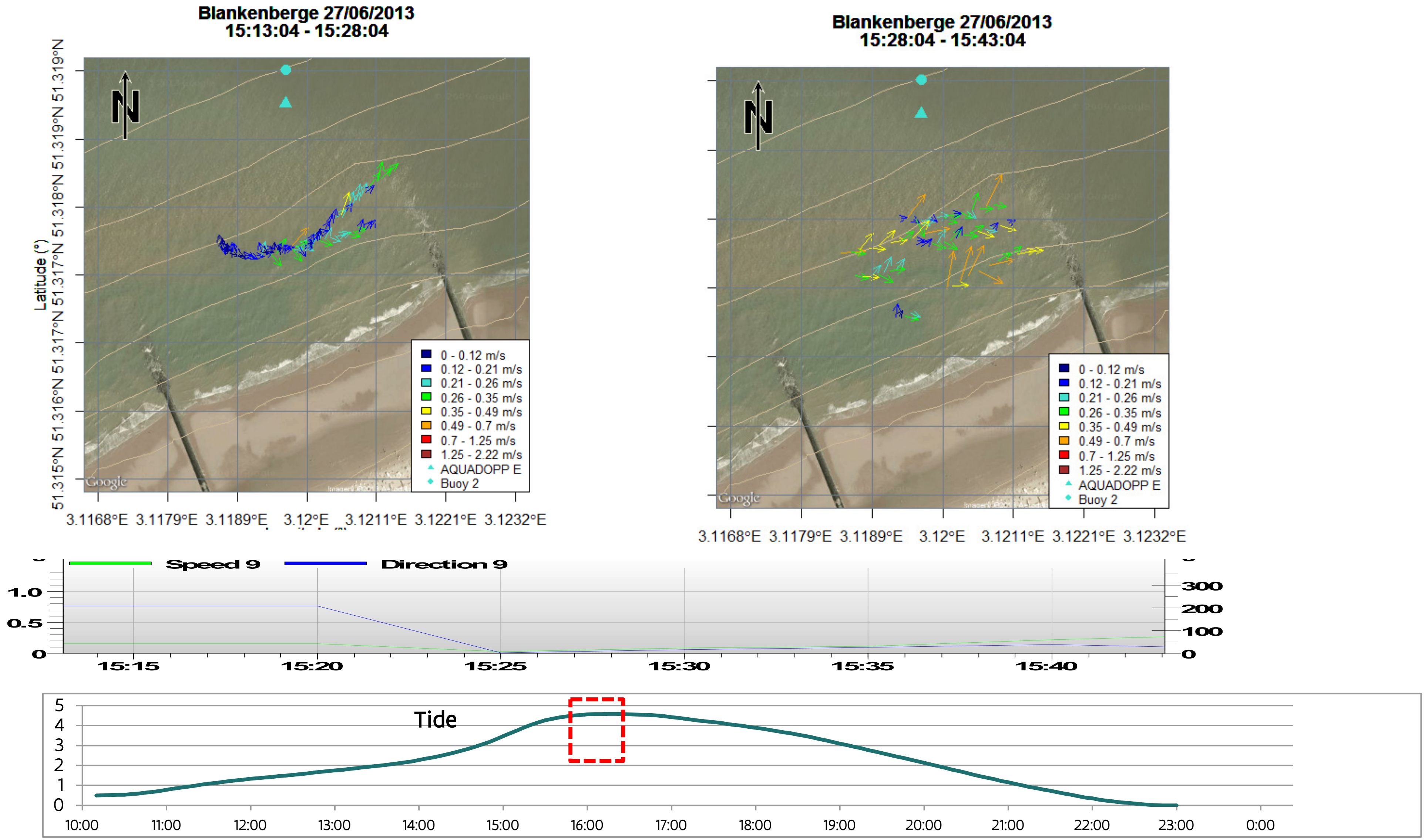
The yellow rectangle highlights the interval of drifters' measurements.

Figure 30 – The speed and direction of the currents measured with the Aquadopp for the highest cell (middle).



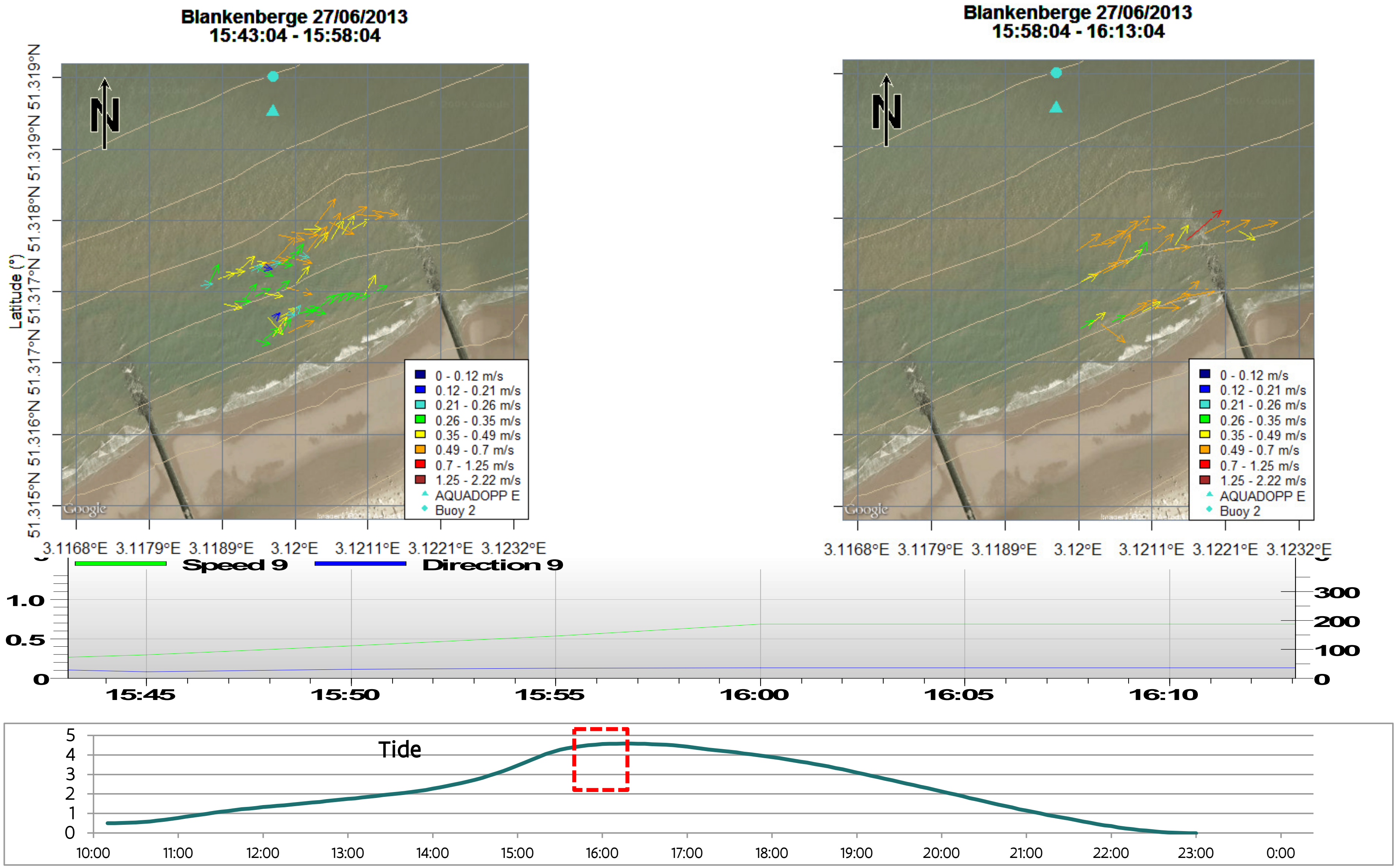
the tide at the moment - red dashed rectangle (down), legend: left - speed m/s, right – degrees.

Figure 31 – The superficial marine currents speed and directions as measured with drifters on the 27/06/2013 between 15:13:04 and 15:43:04 (up).



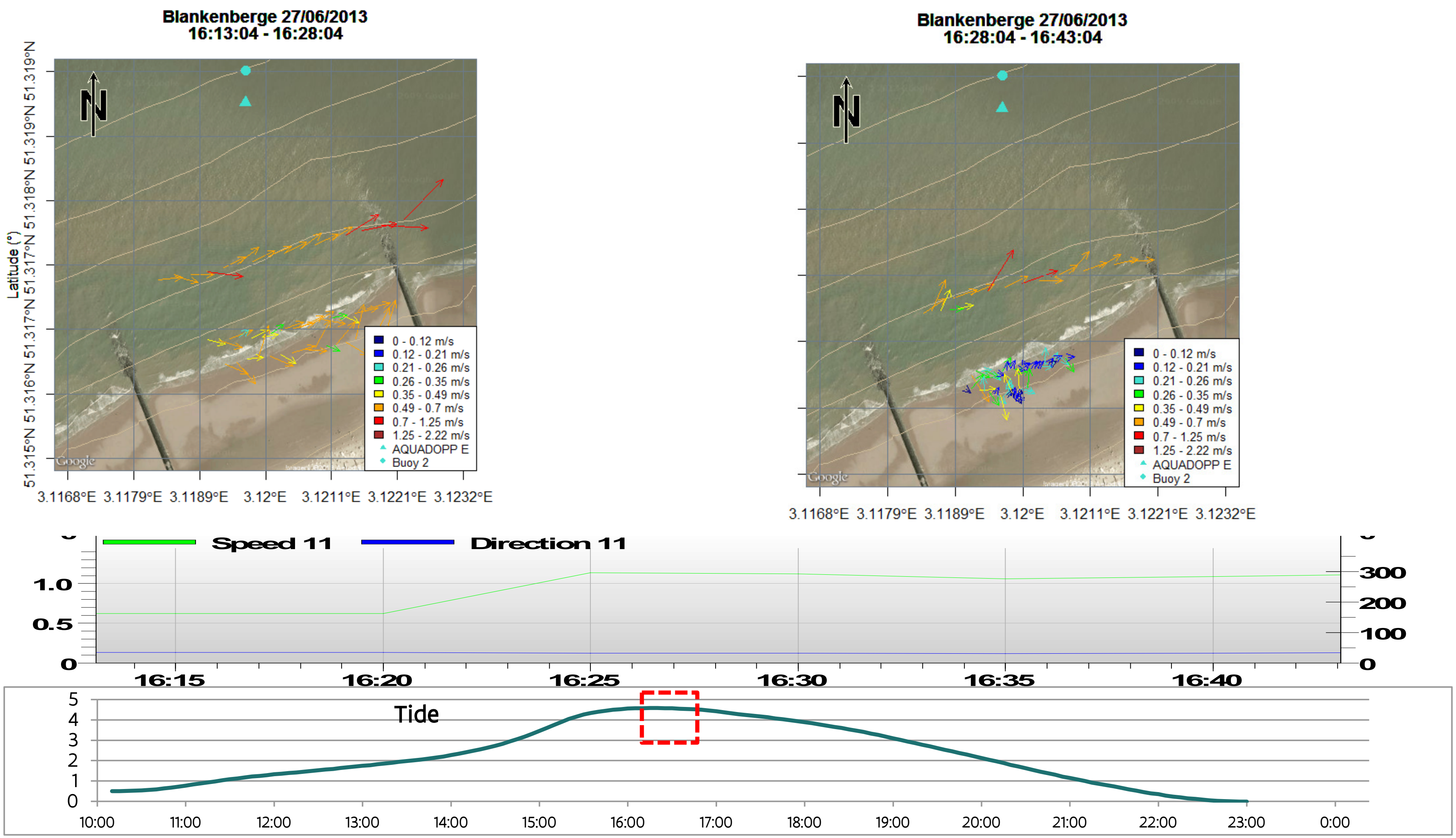
The speed and direction of the currents measured with the Aquadopp for the highest cell (middle); the tide at the moment - red dashed rectangle (down), legend: left - speed m/s, right – degrees.

Figure 32 – The superficial marine currents speed and directions as measured with drifters on the 27/06/2013 between 15:43:04 and 16:13:04 (up).



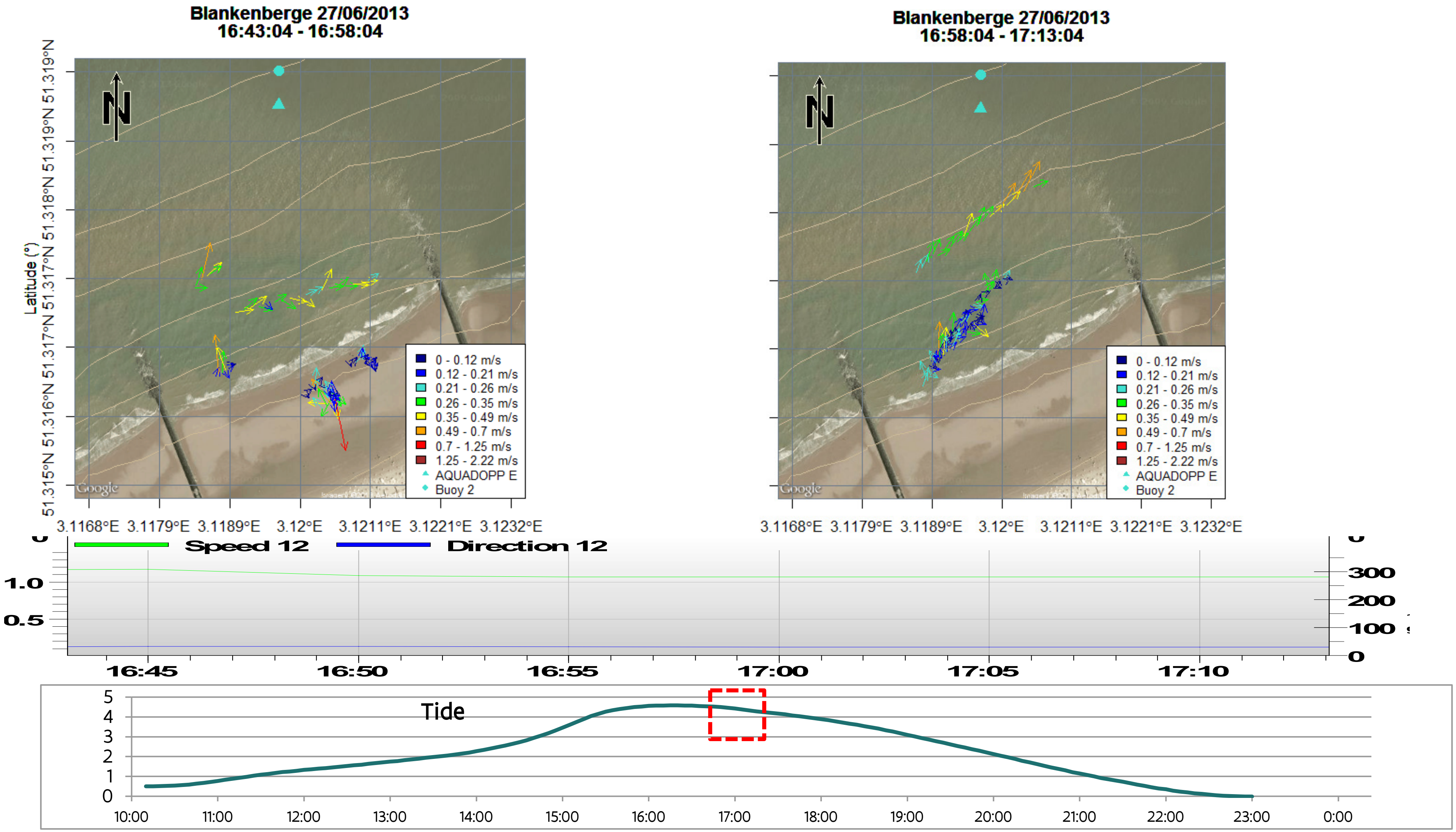
The speed and direction of the currents measured with the Aquadopp for the highest cell (middle); the tide at the moment - red dashed rectangle (down), legend: left - speed m/s, right – degrees.

Figure 33 – The superficial marine currents speed and directions as measured with drifters on the 27/06/2013 between 16:13:04 and 16:43:04 (up).



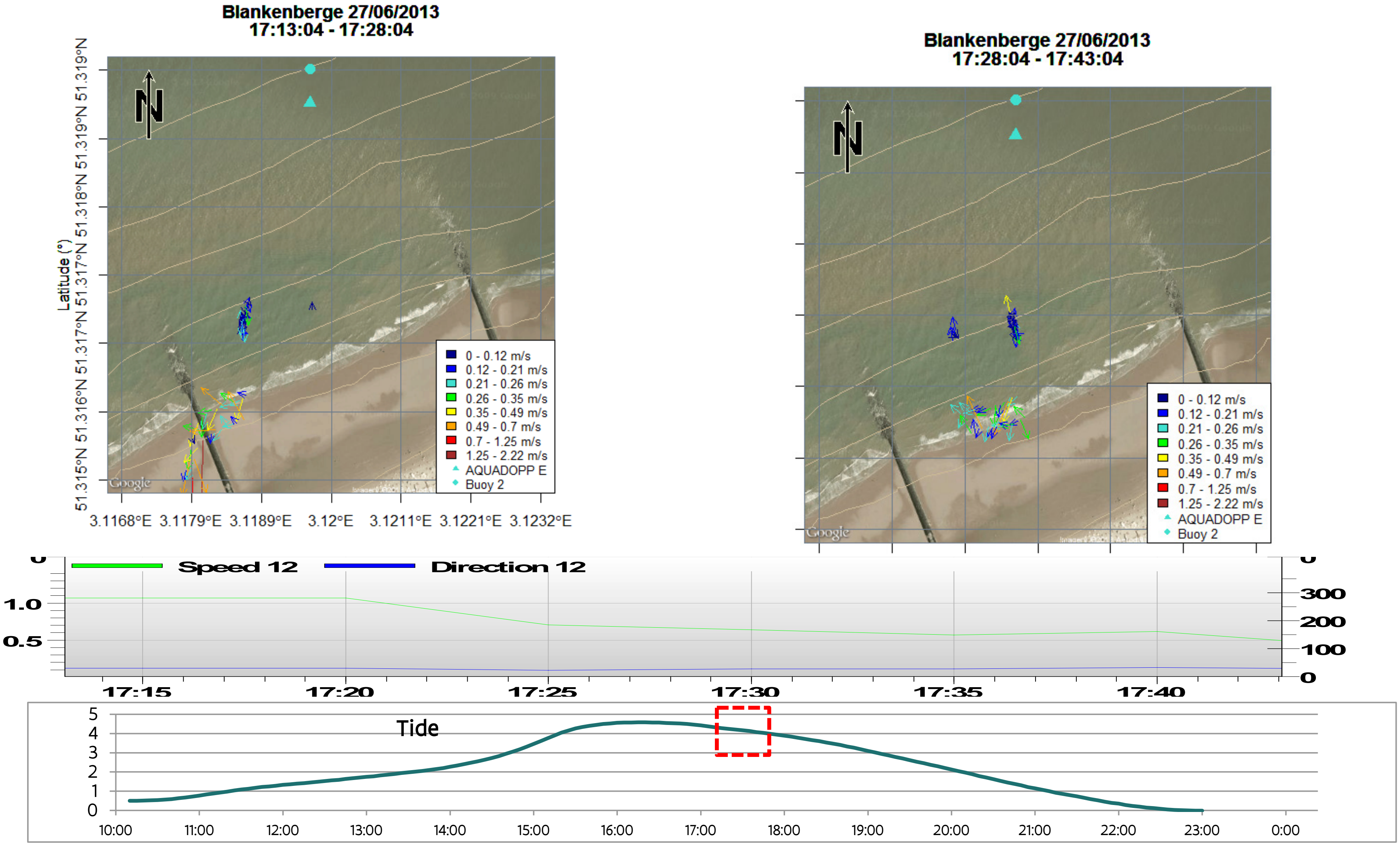
The speed and direction of the currents measured with the Aquadopp for the highest cell (middle); the tide at the moment - red dashed rectangle (down), legend: left - speed m/s, right – degrees.

Figure 34 – The superficial marine currents speed and directions as measured with drifters on the 27/06/2013 between 16:43:04 and 17:13:04 (up).



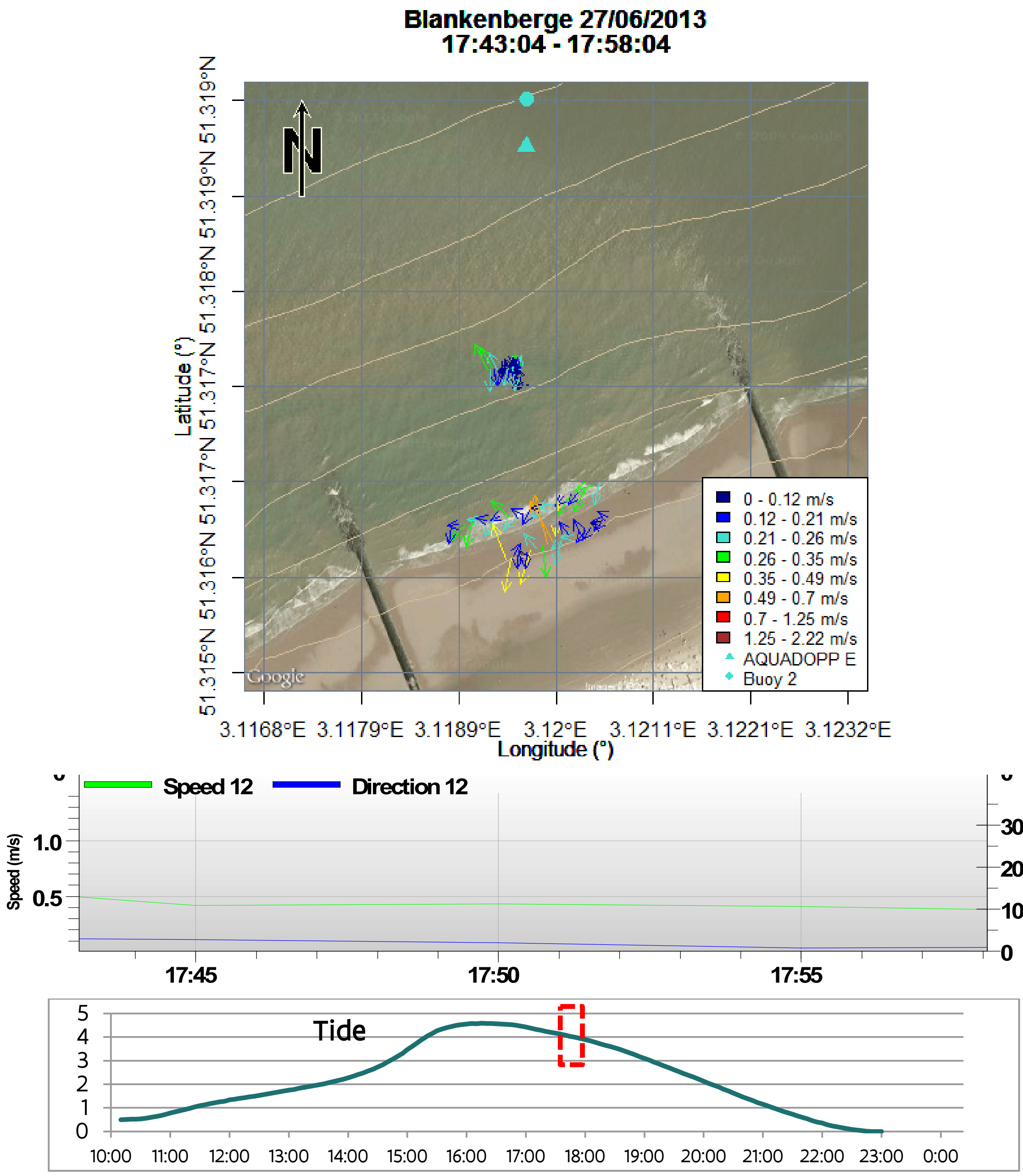
The speed and direction of the currents measured with the Aquadopp for the highest cell (middle); the tide at the moment - red dashed rectangle (down), legend: left - speed m/s, right – degrees.

Figure 35 – The superficial marine currents speed and directions as measured with drifters on the 27/06/2013 between 17:13:04 and 17:43:04 (up).



The speed and direction of the currents measured with the Aquadopp for the highest cell (middle); the tide at the moment - red dashed rectangle (down), legend: left - speed m/s, right – degrees.

Figure 36 – The superficial marine currents speed and directions as measured with drifters on the 27/06/2013 between 17:13:04 and 17:58:04 (up).



The speed and direction of the currents measured with the Aquadopp for the highest cell (middle); the tide at the moment - red dashed rectangle (down), legend: left - speed m/s, right – degrees

5 Conclusions

An field campaign was carried out in the vicinity of the Blankenberge harbour between 19/06 and 4/07/2013 to measure the main hydrodynamic characteristics: marine currents and waves. Additional data were used to analyse the hydrodynamic climate: wind characteristics and tide records.

The marine currents were measured using two different approaches: first, for the entire period acoustic instruments using the Doppler effect; secondly, drifters were used to measure the currents from superficial water layer (1 m depth).

Data analysis led to a series of conclusions for the measuring time interval:

1. Confirm that the nearshore marine currents are strongly influenced by the tide showing two clear trends for directions: towards SW during low tide (ebb) and towards NE during high tide (flood).
2. The speed of the marine currents also reach a maximum during flood, up to 1.4 m/s and a minimum during ebb down to 0.3 m/s.
3. The waves seem to have insignificant influence on the general climate of the marine currents speed and direction during our measuring campaign. At the beginning of the measuring interval a small storm occurred with significant wave heights of approximately 1.5 m. This event had minor impact on the marine currents. However, we anticipate that in the case of a severe storm, the wave induced currents will prevail over the tide induced currents.
4. The measurements of the currents using the two methods show similar speeds. However there are some differences. The speeds measured with the drifters is lower probably due to the influence of the groins and to the lower depths. The breaking of the waves also can exert an influence by creating local turbulence.
5. The measurements of the currents using the two methods show similar directions. The direction of the currents measured with the Aquadopp is more constant than the one measured with the drifters. The Aquadopp does not measure exactly up to the surface of the water, it always leaves the superficial (> 0.5 m) water layer out of the measurements. Yet, this superficial water layer is subject to wind and wave influence, especially when the waves are breaking, the current direction tends to become perpendicular to the shoreline. This explains the differences between the directions measured by the drifters and the Aquadopp. However, these differences are rather small, the trends being the same.

Appendix I

Blankenberge drifters measurements 27 june 2013

The cartographic plots representing the drifters measurements were created using algorithmic programming in the R language. The scripts written here have behaved as genuine Geographic Information System (GIS) to produce colored punctual and linear time series of the measurements.

Some applied spatial data analysis packages were added to the basic R software of the R Foundation for Statistical Computing[1] in order to realize some of the spatial and geographical presentations aspect. Namely coordinate reference systems were defined thanks to packages sp and rgdal. The sp package also allowed to convert the Garmin GPS measured locations in spatial objects. Colors classification using Fisher's method[2] were classified using classint package. Satellite images were loaded from the Google Maps website using package RgoogleMaps.

The vectors were created using own scripts which translated course and location into lines of lengths proportional to their relative speeds (Hence to the measured current speed). The maximum vector length was arbitrary standardized to be equal to a twentieth of the map's image's breadth. The courses represent the drifting orientation measured between two actual locations based upon the GPS's measured azimuth relative to the geographic north. The author is not aware of an existing R package for drifters' measurement reporting. It is an occasion to concretize a user contribution to the R project which can constitute a Flanders' Hydraulics project. The author has indeed as such been scripting hydraulic R tools which he intends to bundle in an upcoming package.

The script[3] takes two data sets as input[4]. On the one hand, ascii text files of the drifters' time, WGS84 longitude & latitude, courses and speeds. On the other hand, ascii text files of the measurements logbooks gathering drifter's identity, respective times of water release and retrievals. The files' names and location paths are to be filled in as parameters. The raw Garmin GPS measurements were saved in ascii text format and corrected by cross checking the campaign logbooks with Mapsource's raw data representations to leave out all ambiguity as to when drifters were released in and retrieved out from the water. Usually on boats speeds were much higher than drifting speeds and the decelerating behavior of a drifter during the first few seconds of its release allow to clearly separate drifting from sailing periods. The script than removes 10 seconds from both ends of each track in order to reduce any possible remnant release and retrieval influences upon the drifters' measured movements.

Fisher's classification was applied. It is a new classification than that of June 2012 because currents were much stronger in the present case.

The bathymetry was constructed using an X, Y, Z text file of the depths along a portion of the coast centered on Blankenberge. This data is the result of measurements realized along punctual depth sensing lines each sailed perpendicular to the shore at more or less constant distances from each other (namely about 100 meter with about 12 meters between each depth measurement).

With ArcGIS, bathymetry can be produced by adding X, Y data (The Z column being included in the tabular data but not used in the first place). This punctual data can be saved as a shapefile. The shapefile can then be used to produce an interpolated continuous depth surface using the Interpolation Spatial Analyst tool. Simplicity will favor using he natural neighbor interpolation method. A contour can then be created.

With R, a contour can be made based on an X, Y, Z data set. Only the X and Y need to be regular as a regular grid and be ascending. This raw data set can hence first be created using ArcGIS with both grid and interpolation methods. Otherwise an ArcGIS contour can be produced in order to be read and plotted in R as a spatial object.

[1] R Development Core Team (2012). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/.

[2] Fisher, W. D. 1958 "On grouping for maximum homogeneity", Journal of the American Statistical Association, 53, pp. 789-798 (<URL: http://lib.stat.cmu.edu/cmlib/src/cluster/fish.f>)

[3] P:\00_064-hydrodynamica\8_Uitvoering\Cartografie_Blankenberge1.0.r

[4] P:\00_064-hydrodynamica\7_Input_Gegevens\Drifters\Drifters_script_Input_Files

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