REPORT

Flemish Government - Department of Mobility and Public Works

Maritime Access Division

Evaluation of the external effect on the siltation in Deurganckdok (2012 - 2014)

Report 1.14: Analysis of the boundary conditions in survey years 5 and 6: 01/04/2010 - 31/03/2012

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Table of Contents

Annexes

List of Tables

List of Figures

0. SUMMARY

This report presents the data analysis of long-term stationary measurements in the Lower Sea Scheldt for survey years 4 and 5, or between 01/04/2010 and 31/03/2012. In particular, it aims to provide as much insight as possible into the 2-yearly evolution in discharge, current velocities, temperature, salinity and suspended sediment concentrations in the River Scheldt. Because of their long duration, it will be possible to study the variations of the measured variables in accordance with different times scales (ebb/flood, spring tide/average tide/ neap tide, seasons). Due to the importance of external effects on the siltation in Deurganckdok the report will focus more on sediment transport into the Lower Sea Scheldt.

1. INTRODUCTION

1.1 THE ASSIGNMENT

This report is part of a set of reports concerning the project 'Evaluation of the external effects on the siltation in Deurganckdok (2012 - 2014)'. The terms of reference were prepared by 'Department of Mobility and Public Works of the Flemish Government, Maritime Access Division (16EF/2011/28). Part 1 of the study was awarded to International Marine and Dredging Consultants NV in association with Deltares on February 3rd 2012.

This study is a follow-up study on the study 'Evaluation of the external effects on the siltation in Deurganckdok' (2009 - 2012) and the study 'Siltation Deurganckdok (2006 -2009)'.

The data and information that are used in this project are carried out or collected by Flanders Hydraulics Research, Maritime Access Division and the Agency for Maritime Services and Coast. Flanders Hydraulics Research provided data on discharge, tide, salinity and turbidity along the river Scheldt. Maritime Access Division provided maintenance dredging data. Agency for Maritime Services and Coast – Coast Division provided depth sounding and density profile measurements.

1.2 AIM OF THE STUDY

The purpose of this study entails evaluating the external effects on the siltation in the Deurganckdok (DGD). External effects are those effects caused by recent or near-future human operations in the vicinity of Deurganckdok:

- The deepening and widening of the navigational channel in the Lower Sea Scheldt between the entrance of the Deurganckdok and the access channels to the locks of Zandvliet-Berendrecht (2008–2010);
- The deepening of the entrance to the Deurganckdok by removing the sill at the entrance (2009–2010);
- The construction of the Current Deflecting Wall downstream of the entrance of the Deurganckdok (2010–2011);
- The change in maintenance depth or strategy;
- Construction of the second Waaslandlock at the landward end of DGD (started in 2011)

1.3 OVERVIEW OF THE STUDY

This study is composed of 2 parts:

- Reporting and analysis of existing documents and delivered measurement data.
- Execution of specific measurement campaign to determine the siltation and salinity rates at the entrance of DGD.

Reports of the project "Evaluation of the external effects on the siltation in the Deurganckdok (2009–2012)" are summarized in Table 1-1 (IMDC, 2010a – IMDC, 2013a). The numbering of the reports follows the previous project that ran between 2009 and 2012 (Annex A). This report is a sequel to the set of analysis reports: IMDC (2007) and IMDC (2008).

Table 1-1: Overview of the project "Evaluation of external effects on the siltation in Deurganckdok (2012–2014)".

Report	Description
I.	**Analysis and Reporting**
I.1 Annual Sediment Balance: Bathymetry surveys, Density measurements, Maintenance and construction dredging activities	
1.09	Annual Sediment Balance in survey year 7: 01/04/2012-31/03/2013 (I/RA/11406/13.143/JCA)
1.10	Annual Sediment Balance in survey year 8: 01/04/2013-31/03/2014 (I/RA/11406/13.144/JCA)
I.2 Boundary Conditions: Upriver Discharge, Salt concentration Scheldt, Bathymetric evolution in access channels, dredging activities in Lower Sea Scheldt and access channels	
1.11	Boundary Conditions in survey year 7: 01/04/2012 – 31/03/2013 (I/RA/11406/13.145/JCA)
1.12	Boundary Conditions in survey year 8: 01/04/2013 – 31/03/2014 (I/RA/11406/13.146/JCA)
I.3 Analysis of the boundary conditions	
1.13	Analysis of the boundary conditions in survey years 3 and 4: 01/04/2008 – 31/03/201 (I/RA/11406/13.054/MGO)
1.14	***Analysis of the boundary conditions in survey years 5 and 6: 01/04/2010 - 31/03/2012 (I/RA/11406/13.062/MGO)***
1.15	Analysis of the boundary conditions in survey years 7 and 8: 01/04/2012 – 31/03/2014 (I/RA/11406/13.147/JCA)
I.4 Analysis: evaluation of external effects on siltation in Deurganckdok	
1.16	Analysis of external effects on siltation processes and factors (I/RA/11406/13.147/JCA)
II.	**Longterm salinity and turbidity measurement campaign at the entrance Deurganckdok**
II.1 Salinity Siltation Distribution at the entrance of Deurganckdok	
2.14	Salinity-Siltation distribution Deurganckdok in survey year 7: 01/04/2012 - 31/03/2013
2.15	Salinity-Siltation distribution Deurganckdok in survey year 8: 01/04/2013 – 31/03/2014
II.5 Quality Control instruments	
2.16	Calibration stationary equipment 2012
2.17	Calibration stationary equipment 2013

1.4 STRUCTURE OF THIS REPORT

Chapter 2 will provide a general summarizing description of the project. Chapter 3 describes the processing method and the boundary conditions (tide, discharge) for the analysis.

In the following chapters an analysis will be given of the variable variations that influence the sediment transport or that might explain the variations thereof. The variations of the influencing variables will be processed according to different time scales (tide, months, neap tide – spring tide cycle, semester, seasons). Chapter 4 will deal with the velocity measurements, Chapter 5 will treat the salinity and Chapter 6 will treat temperature.

A similar analysis will be carried out in Chapter 7 regarding the variations shown on different time scales in relation to the sediment transport. Additionally, these variations of the sediment transport will be put into relation to the evolution of the influencing variables as described in the previous chapters.

Chapter 8 is the concluding chapter.

2. SEDIMENTATION IN DEURGANCKDOK

2.1 PROJECT AREA: DEURGANCKDOK

Deurganckdok is a tidal dock situated between Liefkenshoek and Doel on the left bank in the Lower Sea Scheldt. Deurganckdok has the following characteristics:

1. The dock has a total length of 2750 m and is 450 m wide at the Scheldt end and 400 m wide at the inward end of the dock.
2. The bottom of Deurganckdok is located at a depth of -17 m TAW in the transition zones between the quay walls and the central trench and of -19 m TAW in the central trench.
3. The quay walls reach up to +9 m TAW.

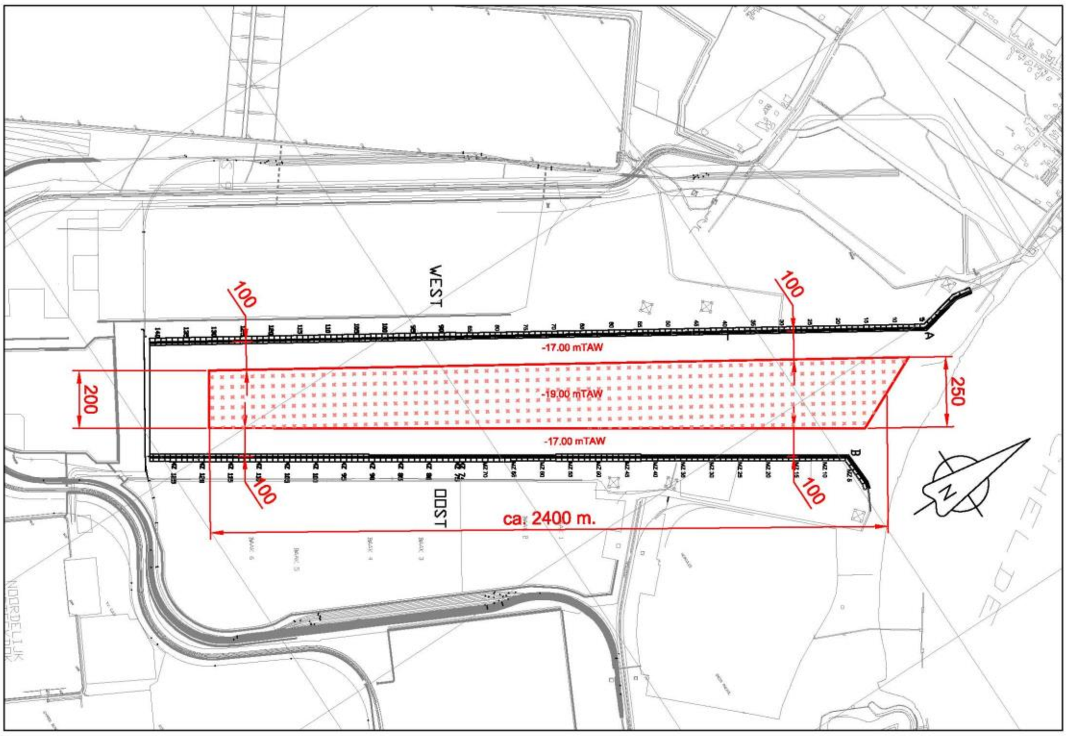

Figure 2-1: Overview of Deurganckdok

The dredging of the dock was performed in 3 phases between the start on February 2005 and finalization on February 2008. A Current Deflecting Wall (CDW) was constructed at the entrance of Deurganckdok in 2010–2011 with the intended purpose of reducing the yearly sedimentation in the dock. The CDW was completed in August 2011.

Other main construction works which have been carried out near the dock since the opening of Deurganckdok are summarized in Table 2-1.

Table 2-1: Overview of construction works since the opening of Deurganckdok.

Date	**Description**
18th February 2005	Deurganckdok dike between the Scheldt and the dock was opened
18th Feb 2005 – 1st Aug 2005	Dredging Phase 2 (end)
Feb 2007 – Feb 2008	Dredging Phase 3, dock extended from 1500 to 2500 m
Jul 2008 – Aug 2010	Deepening and widening of the Scheldt navigation channel in Belgium (spread over a long period, exact timing not known)
Nov 2009 – Jun 2010	Dredging of the entrance sill
Apr 2010 – Aug 2011	Construction of the Current Deflecting Wall (CDW)
> Mar 2011	Change of maintenance depth -15.9 m / -17.5 m / -15.2 m in quays / trench / entrance (included in maintenance dredging)
> Nov 2011	Construction of the 2nd Waaslandlock at the landward end of DGD

2.2 OVERVIEW OF THE STUDIED PARAMETERS

The purpose of this study entails evaluating the external effects on the siltation in the Deurganckdok (DGD) and is based on the analysis and reporting of measurement data. The analysis of the measurement data contains two main components: the derivation of a yearly mass balance of the dock, and the analysis of sediment exchange mechanisms including a conceptual sedimentation model, which uses results from the mass balance, boundary conditions and measurement data at the entrance of Deurganckdock. Analysis and reporting of the natural and human conditions in the Lower Sea Scheldt would provide more insight into the mechanisms causing the siltation in Deurganckdok.

The sediment balance comprises a number of sediment transport modes: deposition, influx from capital dredging works, internal replacement and removal of sediments due to maintenance dredging. (Figure 2-2).

A net deposition can be calculated from a comparison with a chosen initial condition t0 (Figure 2-3). The mass of deposited sediment is determined from the integration of bed density profiles recorded at grid points covering the dock. Subtracting bed sediment mass at t0 leads to the change in mass of sediments present in the dock (mass growth). Adding cumulated dry matter mass of dredged material removed since t0 and subtracting any sediment influx due to capital dredging works leads to the total cumulated mass entered from the river Scheldt since t0.

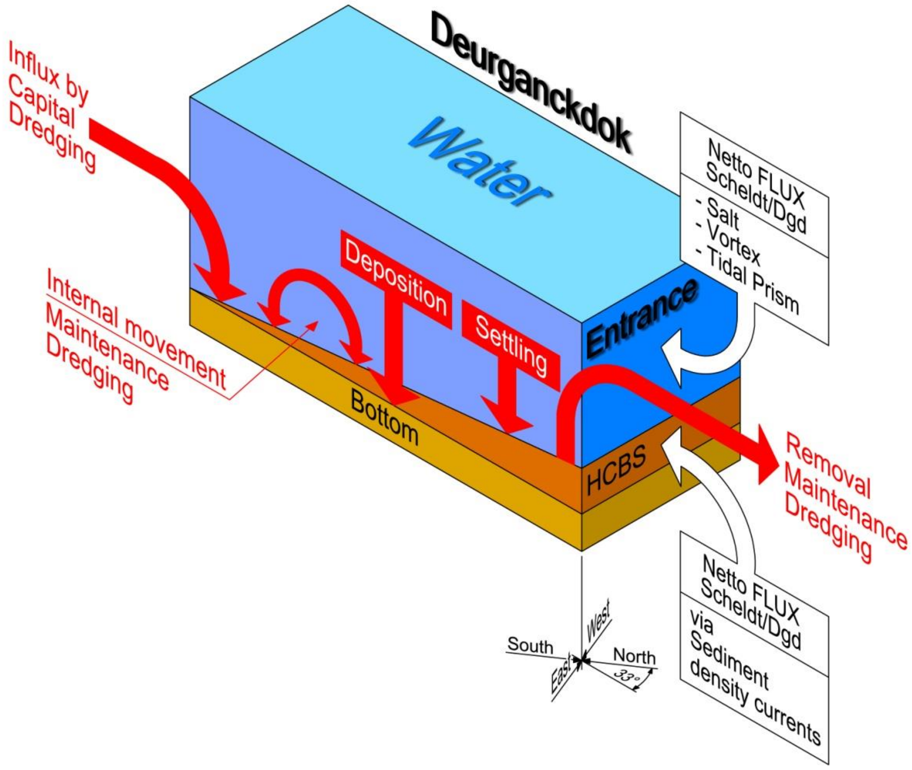

Figure 2-2: Elements of the sediment balance and transport mechanism.

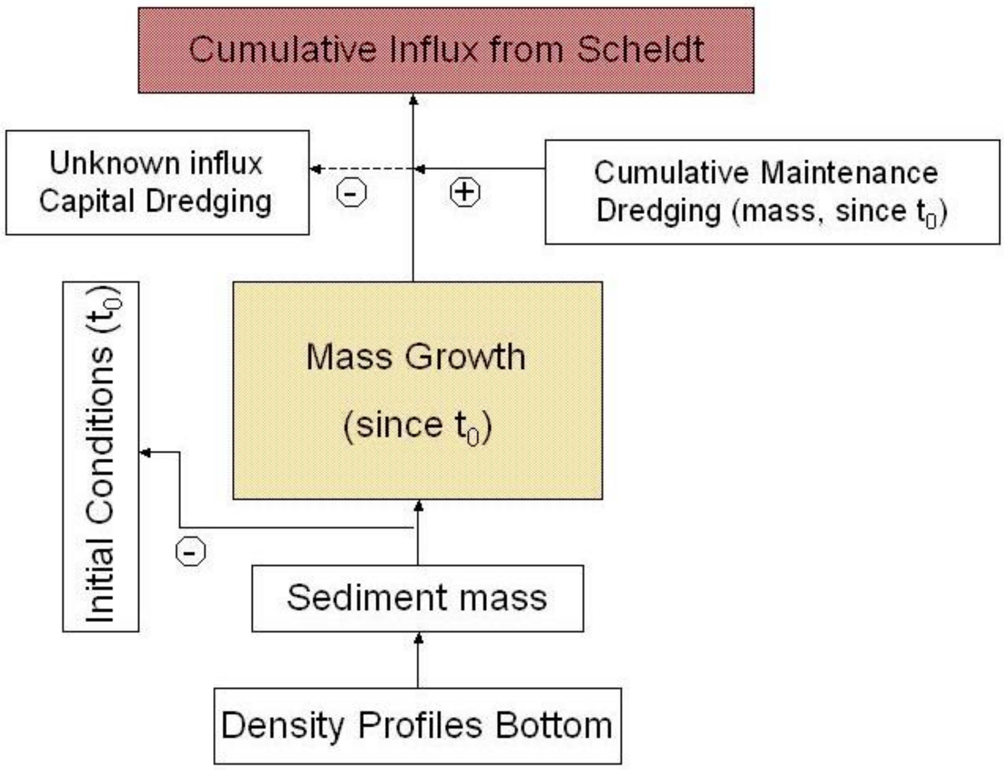

Figure 2-3: Determining a sediment balance.

Concerning the sediment exchange, the following mechanisms will be aimed in this study:

- Tidal prism, i.e. the extra volume in a water body due to high tide
- Vortex patterns due to passing tidal current
- Density currents due to salinity gradient between the River Scheldt and the dock
- Density currents due to highly concentrated benthic suspensions.

These aspects of hydrodynamics and sediment transport have been landmark in determining the parameters to be measured during the project. Measurements have focused on three types of timescales: 1/ one tidal cycle 2/ one neap-spring cycle 3/ seasonal variation within one year.

The following data have been collected to understand these mechanisms:

- Monitoring upstream discharge in the River Scheldt.
- Monitoring Salinity and sediment concentration in the Lower Sea Scheldt at permanent measurement locations at Oosterweel, up and downstream of the Deurganckdok.
- Long-term measurements of salinity and suspended sediment distribution at the entrance of Deurganckdok.
- Monitoring dredging activities at entrance channels towards the Kallo, Zandvliet and Berendrecht locks as well as dredging and dumping activities in the Lower Sea Scheldt.
- In situ calibrations were conducted on several dates to calibrate all turbidity and conductivity sensors.

2.3 OBJECTIVES OF THE REPORT

This report will deal with the long-term stationary measurements to determine the environmental conditions in the Lower Sea Scheldt between April 2010 and March 2012. It will describe the results of the analysis of the long-term measurements in the Lower Sea Scheldt. Because their long duration, it will be possible to study the variations of the measured variables on different time scales (ebb/flood, tide, spring tide/average tide/neap tide, seasons). The factual data reports of these data are recorded in reports: IMDC (2012f) and IMDC (2012p)

3. TIDE AND DISCHARGE

This chapter will provide a detailed description of the analysis' general framework. Firstly, the execution of the measurement campaign will be summarized. A description is then given of the measurement data processing used to carry out the analysis and finally the boundary conditions of the aforementioned analysis (tide, discharge and precipitation) will be presented.

3.1 DESCRIPTION OF MEASUREMENTS CAMPAING

Permanent long-term and stationary point measurements were carried out by Flanders Hydraulics Research in the Lower Sea Scheldt at Prosperpolder, Buoy 84, Liefkenshoek and Oosterweel (Figure 3-1). With the exception of Liekenshoek, the factual data for these locations for the period between April 2010 and March 2012 are reported in IMDC (2012f) and IMDC (2012p). Factual data regarding Liefkenshoek is reported as part of this project in report 2.11. More in-depth detail is presented and described in these factual data reports.

The measurement locations: Buoy 84 and the stations in Oosterweel, Prosperpolder and Liefkenshoek provide the data for the following analysis. At Buoy 84 and at Oosterweel, measurements have been carried out at two different depths. The location, depth and measurement period for each instrument is given in Table 3-1. Reference is made to the data reports for a description of periods for which no data or incorrect data have been logged.

Table 3-1: UTM Coordinates of the locations and depth of the instruments (downstream top).

Location	Easting [UTM ED50]	Northing [UTM ED50]	Period	[m] above bottom	Elevation [m TAW]
Prosperpolder	586 307	5 689 501	Apr2010 – Mar2012	2.5	-1.5
Buoy 84	588 971	5 686 097	Apr2010 – Mar2012	3.3	-5.6
				0.8	-8.1
Liefkenshoek	589 731	5 683 787	Aug2010 – Mar 2012	2.0	-1.5
Oosterweel	595 574	5 677 278	Apr2010 – Mar2012	4,5	-2.3
				1.0	-5.8

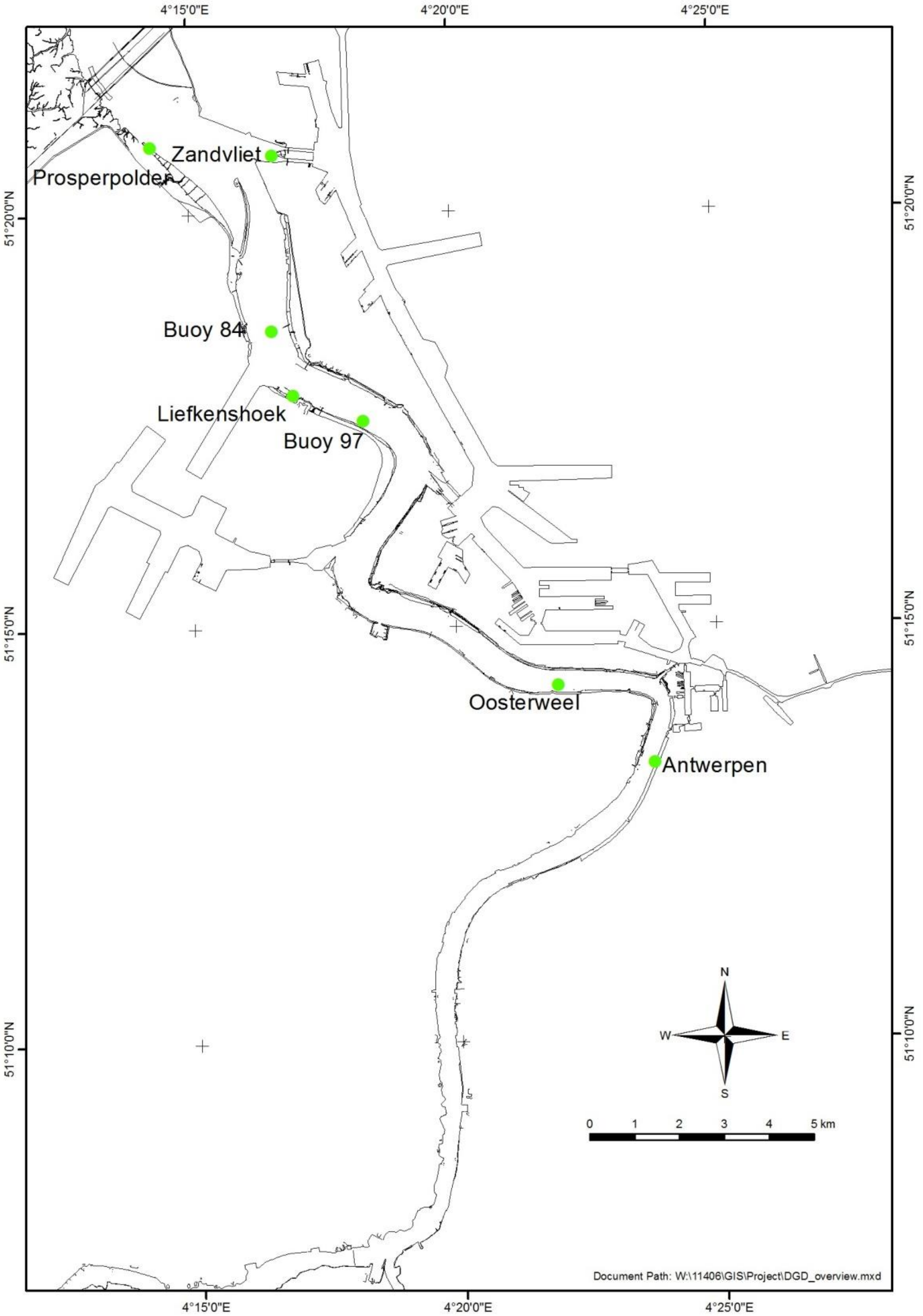

Figure 3-1: Overview of the measurement locations on the Sea Scheldt.

Aanderaa RCM9 and Aanderaa SeaGuard instruments were used to measure the flow velocity and direction, temperature, pressure, conductivity and turbidity. A CTD-instrument manufactured by Valeport Ltd was used to measure salinity at Liefkenshoek. The measurement frequency of all the instruments was 10 minutes.

The variables analyzed in this report (and presented in the data reports) are: flow velocity and direction, salinity, temperature and sediment concentration. Salinity is derived from the pressure, conductivity and the temperature. Sediment concentration is derived from the calibration of the turbidity meter. For more info about the sediment concentration calibration see factual data reports IMDC (2012f) and IMDC (2012p). No velocity data was recorded for Prosperpolder and Liefkenshoek.

Tidal data were provided by Flanders Hydraulics Research in the form of water level readings taken every 10 minutes in Prosperpolder, Liefkenshoek and Antwerp. Prosperpolder was used as a tidal station for the measurement location Prosperpolder, Liefkenshoek for Buoy 84 and measurement location Liefkenshoek, and Antwerp for the measurement location Oosterweel.

3.2 DATA PROCESSING

Due to the different measurement times for the various instruments, the data were interpolated at fixed times before being analyzed. These interpolated times correspond with the times of the 10 minute tide data of Flanders Hydraulics Research.

In order to reach a conclusion regarding the variations on the various time scales, the data were sorted out and grouped per tide, ebb or flood. The aim was to be able to calculate minimum & maximum values, amplitude and average values for the variables per episode (tide, ebb and flood). It has to be underlined, that the term amplitude as used here means the difference between a variable minimum and maximum within an episode. The tides were then classified as neap tide, average tide and spring tide in order to get the average tidal curves.

3.2.1 Tide, ebb, flood and slack water

In order to be able to calculate the average or extreme values for ebb, flood and tidal periods, the limits of these episodes have to be determined first. The approach was that a tide, an ebb, a flood, is time-delimited by the moments of slack water. These have been defined as the minimal values in flow velocity in pre-determined time intervals. These intervals were determined using a series of average times of high and low tide in an astronomical model of the tidal water level times in Antwerp. The aim is to produce a series of time intervals wide enough (about half a tide) and approximately centered on a moment of low or high tide in order to seek the minimum velocity within this interval, determining the moment of the corresponding low or high slack water. Because of the measurement frequency, the time tags of slack water were determined with an accuracy of 10 minutes.

Once the slack water time tags were known, the measurement data were classified per flood (from time of low water slack – LWS – to high water slack– HWS), per ebb (from HWS to LWS) and tide (flood and ebb, LWS1 – LWS2) and calculations were made for the minimum, maximum, amplitude (min-max), and the average value per episode and per analyzed variable. Note that at Prosperpolder and Liefkenshoek, where no velocity data were measured, the classification of the data occurred using the salinity instead of the water level data.

3.2.2 Neap tide - Spring tide cycle

Spring tide is defined as the first tide immediately following the fifth moon passage at Ukkel, and should be calculated from the time of new or full moon. Neap tide is determined in the same way, from the time of the first and the last quarter (FHR, 2009).

In order to avoid having to use an astronomic model, an approach was used in which the difference between the various tidal types is calculated using the measured tidal characteristics. This approach is based on the fact that spring tides are characterized by a larger – and neap tide by a smaller – amplitude than an average tide. That is why in this analysis the tides observed with the largest amplitudes are considered to be spring tides and those with the smallest amplitudes are neap tides. If Δh_{neap} stands for the tidal range of an average neap tide, Δh_{spring} for the tidal difference of an average spring tide, and Δh_{aver} for the tidal difference of an average tide, then a neap, spring and average tide will be defined as follows (Δh is the measured tidal range for a particular tide):

- Neap tide: $\Delta h \leq 0.5\ (\Delta h_{neap} + \Delta h_{aver})$
- Spring tide: $\Delta h \geq 0.5\ (\Delta h_{spring} + \Delta h_{aver})$
- Average tide: $0.5\ (\Delta h_{neap} + \Delta h_{aver}) < \Delta h < 0.5\ (\Delta h_{spring} + \Delta h_{aver})$

The coefficients Δh_{neap}, Δh_{aver} and Δh_{spring} were determined in every tidal location by multiplying the average amplitude of a neap, average and spring tide for the decade 1991–2000 respectively in Prosperpolder, Liefkenshoek and Antwerp (see §3.3.1.3) with a correction factor, representing the relation of the average tidal difference in the tidal location during the previous decade and the average tidal difference observed during the period studied in this report.

The limits resulting from this, between a neap tide, an average tide and a spring tide, are illustrated in Table 3-2. In Liefkenshoek for example, a tide with an amplitude smaller than 4.68 m is regarded as a neap tide, with an amplitude higher than 5.47 m as a spring tide. The tides in between are regarded as average tides.

Table 3-2: Considered amplitude limit [m] between a neap, an average and a spring tide in Prosperpolder, Liefkenshoek and Antwerp.

	Prosperpolder	Liefkenshoek	Antwerp
Neap – Average Limit	4.60	4.68	4.86
Spring – Average Limit	5.38	5.47	5.51

Table 3-3 gives the number of neap, average and spring tides recorded during the measurement period according to the above classification for the available tidal locations. The difference in number of tides observed between the various locations is caused by the fact that sometimes data are missing in the tide data received. It can be observed that classification follows a relation of 25% neap tide, 42% average tide and 33% spring tide

Once the various tides have been classified per category, the average tidal curves are calculated for all variables. These were obtained by classification for each tide from a certain type of all available values per time tag (that is every 10 minutes) compared with HW. Then an average value is calculated for each time tag related to HW.

Additionally, the measurements are classified per trimester, per summer, winter or year. Here winter is defined as the period between October and March, and summer the period between April and September by analogy with analyses of similar long-term measurement campaigns.

Table 3-3: Amount of neap, average, and spring tides measured during considered period.

2010–2011		Apr-Jun	Jul-Sep	Oct-Dec	Jan-Mar	Summer	Winter	Year 1	Total Period
Prosperpolder	Neap	33	44	50	44	77	94	171	322
	Avg	74	64	73	53	138	126	264	551
	Spring	64	52	47	56	116	103	219	428
	All	171	160	170	153	331	323	654	1301
Liefkenshoek	Neap	8	46	47	48	54	95	149	280
	Avg	21	67	81	54	88	135	223	456
	Spring	23	65	50	56	88	106	194	383
	All	52	178	178	158	230	336	566	1119
Antwerp	Neap	33	46	4	43	79	47	126	269
	Avg	86	74	16	63	160	79	239	493
	Spring	54	52	8	54	106	62	168	356
	All	173	172	28	160	345	188	533	1118
2011–2012		**Apr-Jun**	**Jul-Sep**	**Oct-Dec**	**Jan-Mar**	**Summer**	**Winter**	**Year 2**	**Total Period**
Prosperpolder	Neap	35	30	43	43	65	86	151	322
	Avg	86	58	85	58	144	143	287	551
	Spring	44	68	35	62	112	97	209	428
	All	165	156	163	163	321	326	647	1301
Liefkenshoek	Neap	37	34	45	15	71	60	131	280
	Avg	79	59	84	11	138	95	233	456
	Spring	58	68	47	16	126	63	189	383

2010–2011		Apr-Jun	Jul-Sep	Oct-Dec	Jan-Mar	Summer	Winter	Year 1	Total Period
	All	174	161	176	42	335	218	553	1119
Antwerp	Neap	31	37	48	27	68	75	143	269
	Avg	77	59	81	37	136	118	254	493
	Spring	36	70	40	42	106	82	188	356
	All	144	166	169	106	310	275	585	1118

3.3 BOUNDARY CONDITIONS OF THE ANALYSIS

3.3.1 Tidal variations

3.3.1.1 Tide measurements during the measurement campaign

The digitalized tidal series with a measurement frequency of 10 minutes in Prosperpolder, Liefkenshoek and Antwerp was provided by Flanders Hydraulic Research. The accuracy thereof is indicated with 2 cm for height and 2 minutes for time (FHR, 2009).

In Annex-Figure B-1 to Annex-Figure B-3 the course of HW, LW and the tidal amplitude per tide over the measurement period is presented for the various tidal locations. The periodic cycles between tides with a large amplitude (regarded as spring tide) and with a low amplitude (regarded as neap tide) are very clear.

3.3.1.2 Average tidal curves during the measurement campaign

From the tidal data provided, the average tidal curves were calculated for the tide gauges, on the basis of the tidal data provided; see Annex-Figure B-4 to Annex-Figure B-6.

The averages for HW & LW levels, tidal amplitude, and the duration of rise & fall could all be determined from these curves; see Table 3-4 and Table 3-5. Since Flanders Hydraulics Research provided the data on the basis of 10 minute intervals the level of precision – when determining the duration calculated for rising, falling and the tide – amounts to 20 minutes.

Table 3-4: Average HW, LW [m TAW] and tidal amplitude [m] for a neap, an average and a spring tide at Prosperpolder, Liefkenshoek and Antwerp, April 2010–March 2012.

Survey 2010–2011	Neap tide			Average tide			Spring tide		
	HW	LW	Amp	HW	LW	Amp	HW	LW	Amp
Prosperpolder	4.55	0.23	4.31	5.06	-0.13	5.19	5.48	-0.39	5.87
Liefkenshoek	4.62	0.30	4.32	5.20	-0.07	5.27	5.62	-0.33	5.95
Antwerp	4.83	0.23	4.60	5.31	-0.08	5.40	5.67	-0.35	6.03
Survey 2011-2012	Neap tide			Average tide			Spring tide		
	HW	LW	Amp	HW	LW	Amp	HW	LW	Amp
Prosperpolder	4.63	0.30	4.33	5.07	-0.13	5.20	5.46	-0.40	5.86
Liefkenshoek	4.65	0.39	4.25	5.16	-0.11	5.27	5.54	-0.43	5.97
Antwerp	4.86	0.35	4.51	5.32	-0.07	5.39	5.66	-0.38	6.04

Table 3-5: Average duration [h:mm] of rising and falling for an averaged neap, average and spring tide at Prosperpolder, Liefkenshoek and Antwerp, April 2010 – March 2012.

	Neap tide			Average tide			Spring tide		
	Flood	Ebb	Tide	Flood	Ebb	Tide	Flood	Ebb	Tide
Prosperpolder	06:10	06:30	12:40	05:50	06:40	12:30	05:40	06:40	12:20
Liefkenshoek	06:00	06:30	12:30	05:40	06:40	12:20	05:30	06:50	12:20
Antwerp	06:00	06:30	12:30	05:50	06:40	12:30	05:30	06:50	12:20

3.3.1.3 Comparison with the decade values and previous investigation

The averages (water levels and duration) regarding tide, neap tide and spring tide recorded during the period 1991–2000 in the tidal locations of Prosperpolder, Liefkenshoek and Antwerp were provided by Flanders Hydraulics Research and are shown in Table 3-7 and Table 3-9. When comparing these tables with Table 3-4 and Table 3-5, we find that on the basis of amplitude the classification of tides in various categories delivers results that are sufficiently close to the astronomical reality in terms of level of high & low water levels, amplitude and duration of the episodes.

A comparison of the present results with the results from the previous investigations (Table 3-6 and Table 3-8) shows that the tidal parameters obtained from the investigations are comparable with slightly higher tidal amplitudes than during the 2008–2010 period. Compared to the decadal values of 1991–2000, tidal amplitudes are 10 to 15 cm higher in the 2010–2012 period. These differences are due to the stronger lunar nodal factor during this period, compared to the 1991–2000 average.

Table 3-6: Averaged HW, LW [m TAW] and tidal amplitude [m] for a neap, an average and a spring tide at Prosperpolder, Liefkenshoek and Antwerp for April 2008 to March 2010.

Survey 2008–2010	Neap tide			Average tide			Spring tide		
	HW	LW	Amp	HW	LW	Amp	HW	LW	Amp
Prosperpolder	4.34	0.12	4.22	4.87	-0.25	5.11	5.34	-0.48	5.83
Liefkenshoek	4.67	0.35	4.32	5.20	-0.04	5.24	5.66	-0.30	5.96
Antwerp	4.79	0.32	4.48	5.25	-0.06	5.31	5.68	-0.31	6.00

Table 3-7: Averaged HW, LW [m TAW] and tidal amplitude [m] for a neap, an average and a spring tide at Prosperpolder, Zandvliet, Liefkenshoek and Antwerp for the decade 1991–2000 (FHR, 2009).

	Neap tide			Average tide			Spring tide		
	HW	LW	Amp	HW	LW	Amp	HW	LW	Amp
Prosperpolder	4.56	0.41	4.15	5.12	0.08	5.04	5.55	-0.16	5.71
Liefkenshoek	4.63	0.39	4.24	5.19	0.06	5.13	5.63	-0.18	5.81
Antwerp	4.77	0.34	4.43	5.29	0.00	5.29	5.72	-0.23	5.95

Table 3-8: Average duration [h:mm] of rising and falling for an averaged neap, average and spring tide at Prosperpolder, Liefkenshoek and Antwerp for April 2008 to March 2010.

	Neap tide			Average tide			Spring tide		
	Flood	Ebb	Tide	Flood	Ebb	Tide	Flood	Ebb	Tide
Prosperpolder	06:10	06:20	12:30	05:50	06:40	12:30	05:40	06:50	12:30
Liefkenshoek	06:00	06:40	12:40	05:40	06:40	12:20	05:20	06:50	12:10
Antwerp	05:50	06:40	12:30	05:30	06:50	12:20	05:10	07:10	12:20

Table 3-9: Average duration [h:mm] of rising and falling for an averaged neap, average and spring tide at Prosperpolder, Liefkenshoek and Antwerp for the decade 1991–2000 (FHR, 2009).

	Neap tide			Average tide			Spring tide		
	Flood	Ebb	Tide	Flood	Ebb	Tide	Flood	Ebb	Tide
Prosperpolder	6:04	6:36	12:40	5:42	6:43	12:25	5:27	6:51	12:18
Liefkenshoek	6:00	6:40	12:40	5:34	6:51	12:25	5:17	7:02	12:19
Antwerp	5:55	6:44	12:39	5:25	7:01	12:26	5:01	7:18	12:19

3.3.1.4 Tidal effects

The Scheldt can be considered a macro tidal estuary, this means to say that the tidal amplitude is somewhat (approximately) larger than 4 m. The tidal amplitude largely determines the potential the flow has to mix fresh water with salt water and to transport sediments. Therefore, it is important to know the general effects of the tide in the Scheldt.

On the one hand the tidal wave In estuaries is significantly changed due to the side effects from bottom friction of the flow, and on the other hand through the narrowing of the estuaries in the upstream direction (convergence). Dyer (1995) states that on the one hand, convergence causes a partial reflection of the tidal wave and on the one hand the compression thereof, in an increasingly smaller cross section, which results in an increase of the tidal amplitude. Bottom friction has the opposite effect; it will increase with the decreasing water depth and increasing flow velocity due to which energy will be extracted from the tidal wave and the amplitude thereof will decrease. In the Lower Sea Scheldt and the Western Scheldt the convergence effects are larger than the friction effects, which is proven by the fact that the tidal amplitude increases starting from the estuary (Vlissingen) to Schelle and then decreases upstream of Schelle. This phenomenon is indicated as “hyper synchronous”; (see Dyer, 1995. Table 3-10 provides information about some tidal gauges from the Scheldt basin regarding the average tidal amplitudes. The values of the tidal amplitudes also allow the Scheldt to be split into two parts; that means to say the downstream part from the estuary to somewhere next to Schelle, and an upstream part from Schelle to Gentbrugge. This report will deal extensively with the downstream section of the river.

Tidal amplitude in the Lower Sea Scheldt is relatively large when compared to the water depth; the relation between both variables is about 0.3. For estuaries with a relatively large relation between tidal amplitude and water depth (> 0.3) there is an important asymmetry in the tide (see Annex-Figure B-4 to Annex-Figure B-6) and in the flow velocity curves (see Chapter 3). The largest flow velocities appear during flood. This asymmetry in the tidal curve is due to the fact that during the beginning of the flood the friction effects are larger than at the end of the flood when the water is deeper. In the Lower Sea Scheldt the convergence effect on the tidal amplitude is greater than the effect of the friction, and that is why the propagation velocity of the tidal wave increases (Savenije & Veling E, 2005), see Table 3-10, giving an indication of the average delay of the moment of HW compared to Vlissingen and the average propagation velocity of the HW. The increasing propagation velocity of the tidal wave (as far as Antwerp) causes the high water to propagate increasingly faster from the estuary while the low waters stay behind. The result thereof is a decreased flood duration, an increased ebb duration and, increasingly, a more asymmetric velocity course and the tidal flow with a typical flood-dominating character. The flood dominating character of the flow is most distinct for spring tides. For a neap tide, the low waters are higher and the high waters are lower, hence the friction effects are somewhat less important at the beginning of the flood and somewhat more important at the end in comparison to spring tide.

Table 3-10: Tidal amplitude [m] for an averaged spring, average and neap tide, duration [h:mm] rising and falling, delay of HW compared to Vlissingen, distance to mouth [km] and propagation velocity of HW [km/h] at several tidal gauges of the Scheldt for the decade 1991–2000 (FHR, 2009).

	Aver. Tidal amplitude.			Average Duration		Deceleration HW with respect to Vlissingen (hh.min)	Distance to mouth (km)	Propagation velocity HW (km/h)
	neap tide (m)	aver tide (m)	spring tide (m)	rising (hh.min)	falling (hh.min)			
Vlissingen	3.06	3.89	4.53	5:57	6:28	0:00	2.00	-
Hansweert	3.68	4.49	5.09	6:02	6:23	0:56	35.80	36.21
Prosperpolder	4.15	5.04	5.71	5:42	6:43	1:25	55.98	41.75
Antwerp	4.43	5.29	5.95	5:25	7:01	1:45	77.60	64.86
Schelle	4.61	5.42	6.01	5:30	6:55	2:23	91.23	21.52
St. Amands	4.05	5.11	5.59	4:59	7:26	2:53	108.77	35.08
Dendermonde	3.72	4.14	4.43	4:51	7:34	3:31	121.77	20.53
Melle	2.23	2.38	2.52	4:18	8:08	5:14	150.79	16.90

3.3.2 Fresh water discharge and precipitation

Flanders Hydraulics Research has collected discharge data in a number of gauging stations situated outside the tidal influence. These discharges are then converted into discharge at the mouth of the various tributaries and into a total upstream discharge on the Scheldt at Schelle, see AZ (1974).

The stations are located at Melle (Scheldt), Appels (Dender), Eppegem (Zenne), Wilsele-Wijgmaal (Dijle), Hulshout (Grote Nete) and Grobbendonk (Kleine Nete). The discharge at Melle and Dendermonde is measured by means of an acoustic discharge meter, while in other stations the water height is measured and the discharge is then calculated on the basis of the calibrated relation with the water height. Discharge at the mouth of the rivers is determined from the discharge monitored at the stations by comparing the surface of the hydrographic basin at the mouth and the one at the station, assuming thereby that the flow is proportional to the surface. In terms of multiplication factors, the following results are obtained from the discharge monitored at the station: for the Zenne 1.08, for the Dijle 1.12, for the Kleine Nete 1.46 and for the Grote Nete 1.82. The surplus flow produced by the Durme, the Beneden-Nete, the Rupel and the discharge from the Scheldt located between Melle and Schelle is calculated by comparing their basin with the surface of the hydrographic basin of the rivers measured, showing that the sum of the flows may be obtained by dividing the total discharge – of the monitored rivers – by 5.05. The total discharge at Schelle can now be found by adding up all flows. By computing the total discharge in this manner, it is assumed that the concentration time is equal in all rivers, that there is no phase shift between the flow at the mouth of a tributary and the discharge at Schelle and that the precipitation is equally distributed over the complete hydrographic basin of the Scheldt.

During the measurement period (April 2010 – March 2012), the average fresh water discharge at Schelle was 98.40 m³/s, which is in between the extreme decade-average values, in specific terms, those ranging from 19 m³/s to 845 m³/s. These data compare well with the data obtained from April 2008 to March 2010 (IMDC 2013b) where the average upper discharge at Schelle was 102 m³/s, with extreme decade-average values between 26 m³/s and 543 m³/s.

It is important to mention that a flooding event occurred in November 2010, for this reason the maximum extreme value is much higher. In spite of this episode, the average discharge value is slightly lower, and in addition to this, the average discharge for the period 2007–2008 is higher than the period 2008–2010. Therefore, a clear downward trend is observed along the years.

The monthly statistics of the fresh water discharge shown in Table 3-11 and Table 3-12 present the daily and decade-average discharge values during the measurement period. These values are based on daily discharge calculations. A comparison of the decade-averaged discharge with the long-term decade-averaged discharge shows that the fresh water discharge in the Scheldt indeed showed average characteristics in the current measurement period Annex-Figure B-7.

Table 3-11: Statistics of the monthly fresh water discharge (m^3/s) at Schelle for the period April 2010 – March 2011.

	Apr 2010	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan 2011	Feb	Mar	Survey Year 1
Min.	47	42	28	27	26	40	42	60	94	84	78	62	26
Max.	187	143	91	148	371	282	167	845	284	656	235	163	845
Avg.	82	66	45	44	81	83	85	240	137	243	115	84	109
Std.	36	25	16	22	80	55	36	211	50	141	43	23	59

Table 3-12: Statistics of the monthly fresh water discharge (m^3/s) at Schelle for the period April 2011 – March 2012.

	April 2011	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	January 2012	Feb	Mar	Survey Year 2
Min.	40	19	24	30	33	32	31	34	42	94	57	58	19
Max.	86	45	113	116	278	182	85	60	639	428	219	434	639
Avg.	55	34	49	48	84	59	48	42	202	201	105	129	88
Std.	12	5	17	18	61	30	12	6	156	85	41	106	48

4. FLOW VELOCITY AND DIRECTION

The flow velocity is one of the determining factors for the suspended sediment transport and a high degree of correlation is expected between these two variables. In this chapter, first of all flow measurements will be analyzed in terms of maximum and average flow velocity and average flow direction and then the average flow velocity curves will be presented and analyzed in terms of moments of maximum flow velocity and of slack water.

4.1 MAXIMUM AND AVERAGE VALUES PER EBB/FLOOD

Table 4-1 and Table 4-2 display the monthly averages of the maximum ebb and flood flow velocities for neap tide, average tide and spring tide conditions in the various measurement locations. Table 4-3 and Table 4-4 display the monthly averages of the average flow velocities and directions per ebb and Table 4-5 and Table 4-6 display the monthly averages of the average flow velocities and directions per flood and for an average neap tide, an average tide and an average spring tide. Whenever there is a dash (-) in the table, there was no or only bad quality data available.

The maximum and average flow velocities for ebb and flood and the flow direction for the maximum ebb and flood velocities for the complete measurement period are given in Annex-Figure C-1 to Annex-Figure C-12.

A comparison of the present data, with that of data for the period April 2008 – March 2010 (IMDC, 2013b) shows that the velocity data during both periods display very similar characteristics. With exception of the velocity of Oosterweel bottom which is significant lower compared to the previous measuring period since replacing the RCM-9 by RCM SeaGuard at the end of the year 2010 (Annex-Figure C-22a). As can be expected, assuming a logarithmic velocity profile, for both datasets the velocity measured by the top instrument is larger than the one measured by the bottom instrument.

Both datasets also indicate a strong connection between the tidal amplitude and the velocity course. The tables indicate that in both datasets the maximum and average velocities increase from neap tide to spring tide.

Table 4-1: Maximal ebb phase velocity [m/s] for each month and measurement station.

		Apr 2010	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan 2011	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan 2012	Feb	Mar	Total period
Buoy 84 (-8.1 m TAW)	Neap tide	0.56	-	-	0.54	0.52	0.54	0.52	0.53	0.54	0.57	0.58	0.57	0.58	0.55	0.57	0.57	0.53	0.45	0.47	0.49	0.41	0.40	0.47	-	0.52
	Avg tide	0.65	-	0.58	0.58	0.58	0.56	0.57	0.61	0.59	0.58	0.65	0.68	0.64	0.62	0.59	0.61	0.57	0.54	0.54	0.52	0.50	0.51	0.59	-	0.58
	Spring tide	0.67	-	0.60	0.61	0.60	0.61	0.62	0.60	0.63	0.69	0.67	0.71	0.68	0.66	0.61	0.64	0.63	0.56	0.58	0.53	0.54	0.59	0.62	-	0.63
Buoy 84 (-5.6 m TAW)	Neap tide	-	-	-	0.64	0.61	0.62	0.65	0.67	0.64	0.67	0.68	0.70	0.68	0.63	0.65	0.66	0.63	0.54	0.57	0.64	0.51	0.54	0.52	0.55	0.62
	Avg tide	-	-	0.66	0.69	0.68	0.66	0.70	0.73	0.70	0.69	0.77	0.78	0.73	0.71	0.69	0.70	0.67	0.64	0.63	0.69	0.61	0.66	0.66	0.62	0.69
	Spring tide	-	-	0.72	0.70	0.72	0.72	0.76	0.74	0.77	0.80	0.85	0.86	0.80	0.79	0.72	0.75	0.75	0.67	0.70	-	0.69	0.72	0.70	0.71	0.75
Oosterweel (-5.8 m TAW)	Neap tide	0.63	0.72	0.73	0.69	0.69	0.70	-	-	0.72	0.60	0.66	0.63	0.63	0.62	0.64	0.64	0.68	0.64	0.64	0.70	0.68	0.63	0.65	0.76	0.66
	Avg tide	0.68	0.75	0.76	0.73	0.75	0.75	-	-	0.74	0.68	0.70	0.71	0.74	0.68	0.69	0.66	0.75	0.72	0.72	0.75	0.75	0.67	0.76	-	0.72
	Spring tide	0.73	0.76	0.79	0.78	0.79	0.80	-	-	0.76	0.64	0.76	0.78	0.78	0.75	0.71	0.70	0.76	0.77	0.76	0.81	0.72	0.69	0.77	-	0.75
Oosterweel (-2.3 m TAW)	Neap tide	0.84	0.94	0.94	0.89	0.89	0.89	0.93	0.82	0.87	-	0.85	0.87	0.86	0.83	0.83	0.85	0.91	0.86	0.88	0.92	0.91	0.84	0.83	0.96	0.88
	Avg tide	0.89	0.98	0.97	0.94	0.96	0.97	1.03	0.89	0.92	-	0.95	0.92	0.97	0.89	0.91	0.90	0.97	0.97	0.95	1.01	0.97	0.89	1.03	1.04	0.95
	Spring tide	0.96	0.99	1.01	1.00	1.01	1.02	1.07	0.96	0.95	-	0.98	0.99	1.06	0.88	0.91	0.90	1.00	1.02	1.01	1.06	0.94	0.93	1.06	1.04	0.99

Table 4-2: Maximal flood phase velocity [m/s] for each month and measurement station.

		Apr 2010	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan 2011	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan 2012	Feb	Mar	Total period
Buoy 84 (-8.1 m TAW)	Neap tide	0.70	-	-	0.74	0.74	0.72	0.70	0.75	0.72	0.75	0.77	0.76	0.76	0.74	0.75	0.66	0.69	0.69	0.68	0.70	0.69	0.64	0.74	-	0.72
	Avg tide	0.90	-	0.95	0.90	0.86	0.94	0.93	0.93	0.93	0.90	1.02	0.90	0.94	0.88	0.90	0.83	0.87	0.89	0.92	0.90	0.83	0.75	1.08	-	0.90
	Spring tide	1.09	-	1.01	1.02	1.07	1.08	1.01	1.05	1.01	1.13	1.01	1.10	1.15	1.03	0.99	1.01	1.06	1.03	1.05	0.98	0.97	0.94	1.24	-	1.05
Buoy 84 (-5.6 m TAW)	Neap tide	-	-	-	0.82	0.83	0.80	0.79	0.83	0.78	0.83	0.87	0.87	0.82	0.82	0.85	0.77	0.77	0.78	0.78	0.82	0.81	0.72	0.76	0.82	0.81
	Avg tide	-	-	0.97	1.03	0.97	1.05	1.05	1.06	1.04	1.00	1.16	1.03	1.05	1.00	1.01	0.95	1.00	1.05	1.07	0.98	0.94	0.92	1.12	1.04	1.02
	Spring tide	-	-	1.14	1.06	1.19	1.21	1.19	1.17	1.16	1.27	1.35	1.29	1.29	1.19	1.13	1.15	1.19	1.23	1.23	-	1.08	1.14	1.31	1.26	1.21
Oosterweel (-5.8 m TAW)	Neap tide	0.69	0.68	0.70	0.70	0.70	0.70	-	-	0.78	0.73	0.67	0.70	0.65	0.70	0.72	0.65	0.65	0.67	0.71	0.72	0.74	0.73	0.63	0.74	0.70
	Avg tide	0.91	0.86	0.84	0.87	0.87	0.90	-	-	0.87	0.88	0.92	0.90	0.85	0.84	0.81	0.75	0.85	0.86	0.86	0.86	0.83	0.81	0.86	-	0.85
	Spring tide	1.10	0.95	0.93	0.97	1.02	1.07	-	-	0.99	1.05	1.03	1.03	1.02	0.92	0.88	0.90	0.94	0.94	0.96	0.94	0.92	0.97	1.01	-	0.98
Oosterweel (-2.3 m TAW)	Neap tide	0.80	0.76	0.78	0.77	0.76	0.76	0.81	0.80	0.78	-	0.80	0.81	0.78	0.80	0.84	0.77	0.81	0.76	0.83	0.85	0.87	0.87	0.74	0.81	0.80
	Avg tide	1.00	0.93	0.92	0.95	0.97	0.98	0.98	0.99	0.95	-	1.09	1.02	1.02	0.98	1.01	0.99	1.05	0.98	1.04	1.02	1.02	1.00	1.02	0.99	0.99
	Spring tide	1.20	1.07	1.01	1.05	1.11	1.15	1.14	1.08	1.02	-	1.38	1.20	1.21	1.17	1.09	1.11	1.18	1.20	1.23	1.17	1.15	1.20	1.19	1.12	1.15

Table 4-3: Averaged ebb phase velocity [m/s] for each month and measurement station.

		Apr 2010	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan 2011	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan 2012	Feb	Mar	Total Period
Buoy 84 (-8.1 m TAW)	Neap tide	0.30	-	-	0.32	0.28	0.29	0.30	0.30	0.30	0.32	0.33	0.32	0.32	0.30	0.30	0.33	0.28	0.25	0.26	0.27	0.24	0.22	0.26	-	0.29
	Avg tide	0.36	-	0.36	0.34	0.33	0.32	0.34	0.34	0.33	0.33	0.37	0.36	0.35	0.34	0.32	0.36	0.34	0.31	0.28	0.29	0.27	0.27	0.32	-	0.33
	Spring tide	0.40	-	0.37	0.36	0.35	0.35	0.38	0.35	0.36	0.38	0.38	0.40	0.38	0.36	0.34	0.36	0.39	0.32	0.32	0.29	0.27	0.29	0.34	-	0.36
Buoy 84 (-5.6 m TAW)	Neap tide	-	-	-	0.39	0.37	0.39	0.39	0.39	0.39	0.39	0.41	0.42	0.40	0.38	0.35	0.40	0.36	0.31	0.30	0.35	0.29	0.28	0.29	0.29	0.36
	Avg tide	-	-	0.43	0.43	0.41	0.42	0.43	0.44	0.42	0.41	0.47	0.46	0.45	0.43	0.40	0.43	0.42	0.37	0.32	0.36	0.33	0.31	0.35	0.33	0.41
	Spring tide	-	-	0.47	0.43	0.44	0.44	0.49	0.45	0.46	0.47	0.50	0.52	0.50	0.46	0.42	0.44	0.48	0.38	0.37	-	0.33	0.33	0.37	0.36	0.44
Oosterweel (-5.8 m TAW)	Neap tide	0.42	0.48	0.50	0.47	0.46	0.46	-	-	0.46	0.38	0.41	0.40	0.40	0.41	0.39	0.40	0.42	0.40	0.42	0.45	0.43	0.39	0.41	0.47	0.43
	Avg tide	0.48	0.55	0.54	0.52	0.52	0.52	-	-	0.50	0.45	0.46	0.46	0.47	0.44	0.45	0.45	0.49	0.47	0.46	0.50	0.47	0.44	0.51	-	0.49
	Spring tide	0.53	0.56	0.57	0.56	0.57	0.57	-	-	0.53	0.44	0.49	0.53	0.50	0.48	0.47	0.47	0.51	0.51	0.49	0.54	0.49	0.47	0.53	-	0.51
Oosterweel (-2.3 m TAW)	Neap tide	0.57	0.63	0.65	0.62	0.61	0.61	0.63	0.55	0.59	-	0.57	0.59	0.59	0.59	0.57	0.58	0.61	0.58	0.61	0.64	0.61	0.53	0.55	0.61	0.60
	Avg tide	0.64	0.71	0.70	0.67	0.68	0.68	0.72	0.63	0.66	-	0.67	0.65	0.68	0.63	0.64	0.64	0.69	0.68	0.68	0.71	0.66	0.59	0.69	0.67	0.67
	Spring tide	0.69	0.73	0.74	0.71	0.74	0.72	0.76	0.69	0.68	-	0.69	0.73	0.73	0.66	0.68	0.67	0.71	0.72	0.72	0.76	0.68	0.64	0.73	0.69	0.71

Table 4-4: Averaged flood phase velocity [m/s] for each month and measurement station.

		Apr 2010	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan 2011	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan 2012	Feb	Mar	Total Period
Buoy 84 (-8.1 m TAW)	**Neap tide**	0.45	-	-	0.48	0.48	0.45	0.46	0.45	0.45	0.46	0.48	0.49	0.50	0.47	0.47	0.43	0.44	0.42	0.42	0.43	0.42	0.37	0.41	-	0.45
	Avg tide	0.56	-	0.58	0.55	0.53	0.55	0.55	0.55	0.55	0.54	0.58	0.55	0.57	0.55	0.56	0.53	0.54	0.53	0.52	0.50	0.48	0.44	0.59	-	0.54
	Spring tide	0.63	-	0.60	0.58	0.60	0.59	0.58	0.59	0.58	0.60	0.57	0.62	0.63	0.59	0.59	0.59	0.60	0.56	0.56	0.51	0.53	0.51	0.64	-	0.59
Buoy 84 (-5.6 m TAW)	**Neap tide**	-	-	-	0.51	0.52	0.49	0.51	0.49	0.49	0.51	0.53	0.54	0.52	0.53	0.51	0.49	0.48	0.48	0.48	0.50	0.47	0.43	0.45	0.49	0.50
	Avg tide	-	-	0.60	0.61	0.58	0.61	0.60	0.62	0.61	0.60	0.66	0.62	0.62	0.60	0.61	0.59	0.60	0.59	0.59	0.58	0.54	0.52	0.62	0.57	0.60
	Spring tide	-	-	0.65	0.61	0.64	0.65	0.66	0.64	0.65	0.68	0.71	0.70	0.70	0.66	0.65	0.66	0.65	0.63	0.65	-	0.60	0.62	0.67	0.63	0.66
Oosterweel (-5.8 m TAW)	**Neap tide**	0.46	0.47	0.48	0.49	0.48	0.47	-	-	0.49	0.45	0.44	0.44	0.42	0.44	0.43	0.43	0.43	0.42	0.45	0.47	0.46	0.45	0.41	0.47	0.45
	Avg tide	0.55	0.55	0.54	0.55	0.55	0.56	-	-	0.53	0.53	0.53	0.51	0.50	0.49	0.50	0.48	0.52	0.52	0.52	0.53	0.52	0.51	0.54	-	0.53
	Spring tide	0.61	0.58	0.57	0.58	0.59	0.61	-	-	0.54	0.58	0.57	0.56	0.55	0.52	0.52	0.53	0.54	0.55	0.56	0.55	0.55	0.56	0.57	-	0.56
Oosterweel (-2.3 m TAW)	**Neap tide**	0.54	0.53	0.54	0.54	0.54	0.54	0.57	0.54	0.54	-	0.56	0.55	0.54	0.56	0.56	0.54	0.54	0.53	0.58	0.60	0.58	0.56	0.50	0.55	0.55
	Avg tide	0.61	0.61	0.60	0.61	0.62	0.63	0.63	0.64	0.60	-	0.66	0.63	0.63	0.60	0.62	0.63	0.66	0.63	0.65	0.65	0.65	0.64	0.64	0.62	0.63
	Spring tide	0.68	0.66	0.63	0.64	0.65	0.67	0.68	0.65	0.60	-	0.73	0.69	0.69	0.66	0.64	0.66	0.68	0.68	0.70	0.70	0.68	0.69	0.69	0.67	0.67

Table 4-5: Averaged ebb phase direction [deg] for each month and measurement station.

		Apr 2010	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan 2011	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan 2012	Feb	Mar	Total Period
Buoy 84 (-8.1 m TAW)	**Neap tide**	350	-	-	352	352	354	354	350	355	351	353	351	352	355	352	357	352	351	345	348	352	348	347	-	351
	Avg tide	355	-	353	352	352	356	357	355	357	355	355	355	355	352	354	354	357	355	354	355	353	350	353	-	354
	Spring tide	359	-	355	355	354	359	357	356	358	354	358	356	356	352	355	355	355	354	351	359	352	354	353	-	355
Buoy 84 (-5.6 m TAW)	**Neap tide**	-	-	-	356	358	360	2	3	360	2	358	0	357	356	359	356	1	360	0	5	357	356	3	1	360
	Avg tide	-	-	357	356	358	1	6	1	2	4	0	3	0	2	1	354	2	2	2	4	358	357	3	2	0
	Spring tide	-	-	2	357	359	2	2	4	4	7	358	4	358	3	2	359	1	3	4	-	358	359	3	4	2
Oosterweel (-5.8 m TAW)	**Neap tide**	270	270	272	270	272	271	-	-	268	263	265	267	266	267	268	262	269	269	265	268	268	269	269	270	268
	Avg tide	271	270	270	270	271	272	-	-	268	265	264	266	266	266	268	263	267	268	268	265	265	268	269	-	268
	Spring tide	271	271	272	272	271	271	-	-	268	263	264	266	267	267	269	264	265	268	268	264	269	267	268	-	268
Oosterweel (-2.3 m TAW)	**Neap tide**	263	260	262	260	264	263	264	263	263	-	266	265	264	265	265	262	265	258	259	264	266	264	260	262	263
	Avg tide	261	260	263	260	264	263	264	259	260	-	264	264	263	263	264	263	263	258	258	264	264	262	261	261	262
	Spring tide	260	260	261	260	264	262	262	261	263	-	264	264	264	262	262	262	262	259	259	264	265	261	261	261	262

Table 4-6: Averaged flood phase direction [deg] for each month and measurement station.

		Apr 2010	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan 2011	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan 2012	Feb	Mar	Total Period
Buoy 84 (-8.1 m TAW)	**Neap tide**	191	-	-	190	192	194	192	193	191	188	189	188	187	193	190	191	191	195	190	186	185	190	192	-	190
	Avg tide	183	-	183	185	186	187	186	184	182	183	180	185	182	185	190	189	188	188	187	185	183	185	184	-	185
	Spring tide	181	-	182	184	183	186	183	182	179	179	191	180	179	182	189	185	186	186	182	185	182	181	181	-	183
Buoy 84 (-5.6 m TAW)	**Neap tide**	-	-	-	189	192	195	190	195	190	196	191	192	189	191	194	190	196	194	188	187	190	191	187	187	191
	Avg tide	-	-	185	185	187	189	187	186	187	191	184	190	184	189	188	186	190	190	185	186	187	185	184	185	187
	Spring tide	-	-	181	183	186	185	182	185	185	188	182	185	180	189	187	184	185	185	185	-	186	186	184	183	184
Oosterweel (-5.8 m TAW)	**Neap tide**	95	97	95	97	95	96	-	-	91	91	90	91	91	89	96	90	98	89	88	94	95	91	94	88	93
	Avg tide	96	97	96	97	96	95	-	-	90	90	93	91	93	89	92	91	98	91	89	95	94	94	91	-	93
	Spring tide	96	96	95	96	96	94	-	-	91	90	92	91	92	91	92	94	97	92	90	95	91	94	92	-	93
Oosterweel (-2.3 m TAW)	**Neap tide**	97	98	97	97	94	93	95	95	96	-	94	96	93	94	91	96	88	95	97	96	90	94	92	90	94
	Avg tide	98	97	96	97	92	93	95	96	95	-	94	96	93	91	95	92	90	95	97	95	90	93	92	89	94
	Spring tide	97	97	96	96	92	92	96	96	94	-	93	96	92	91	95	92	92	95	98	96	93	94	93	89	94

4.2 TIDAL AVERAGE VELOCITY CURVE

The tidal-average velocity curve has been calculated for each measurement location. The tidal-average velocity course is presented in those curves on the basis of the time related to HW, and for an average neap tide, an average tide and an average spring tide; see Annex-Figure C-13 to Annex-Figure C-16. These figures clearly show the asymmetric character of the velocities (see §3.3.1.4). Besides the asymmetry, which is the result of the convergence and friction effects in the estuary, the velocity curves in the measurement locations are influenced by local effects. All locations are situated at the edge or on the outside of the navigation channel (ebb channel), and hence the local geometry and bathymetry dominate the velocity curve, especially during the flood (whirlpool formation, embankments, vertical constructions).

The tidal-average curves allow the average values and the time of maximum flow velocity during ebb and flood for an average neap tide, an average tide and an average spring tide, to be determined; see Table 4-7. The maximum flow velocity during ebb and flood is larger during a spring tide than during a neap tide and in addition to this the increase in maximum flow velocity is larger during flood than during ebb. The maximum flood velocity during a spring tide in the measurement locations is 33.75% larger than during a neap tide, while the maximum ebb velocity is only 9.5% larger during a spring tide than during a neap tide; see § 3.2.2.

These results can be compared with the data from April 2008 – March 2010 (IMDC 2013b). For this series, the results obtained show a similar trend as previous reporting period. The maximum flow velocity (for ebb and flood) is larger during a spring than during a neap tide and also the maximum velocities are also larger during flood. Moreover, the comparison between maximum velocities during spring and a neap tide show the following values: 36.67 (flood) and 9.5 (ebb). It can be concluded therefore that the behavior for both periods is very similar.

Maxiumum velocity data taken at all measurement locations is always observed during flood. This maximum in the flood flow is always observed approximately 1 hour before HW. During a neap tide, the maximum flood flow is generally observed earlier (about 1h20 before HW) than during spring tide (about 0h50 before HW). At ebb, the course is more regular (less distinct peaks). At the location furthest downstream (Buoy 84), the maximum at ebb is generally observed at 2h40 after HW, independently of the tidal strength. Further upstream in Oosterweel the maximum ebb values are spread from 3h30 to 4h10 after HW. It clearly proved the influence of the estuaries on the river dynamic.

Table 4-7: Average tide curve for the flow velocity. Value [m/s] and time to HW [h:min] of the maximum velocity for the flood and the ebb phase for an averaged neap, average and spring tide, April 2010–March 2012.

Location	Instrument depth	Tidal phase	Velocity		Time to HW	
			Flood	Ebb	Flood	Ebb
Buoy 84	-8.1 m TAW	Neap	0.66	0.48	-1:20	02:50
		Average	0.86	0.53	-1:0	02:40
		Spring	1.03	0.58	-0:50	02:50
Buoy 84	-5.8 m TAW	Neap	0.74	0.57	-1:20	02:40
		Average	0.97	0.64	-1:0	02:40
		Spring	1.18	0.68	-0:50	02:40
Oosterweel	-5.8 m TAW	Neap	0.58	0.56	-1:20	03:10
		Average	0.72	0.60	-1:10	04:00
		Spring	0.84	0.63	-0:50	03:50
Oosterweel	-2.3 m TAW	Neap	0.70	0.78	-1:10	03:40
		Average	0.83	0.84	-1:0	04:00
		Spring	0.98	0.88	-0:50	03:50

Slack water means to say the moment when the ebb flow changes into flood flow. In theory, this is the moment when the velocity equals zero. Due to the appearance of among others things, whirlpools, secondary flows, horizontal and vertical salinity gradients, the flow velocity never equals zero, and hence the moment of slack water in the measurement data is taken as the moment of minimum velocity. The velocity data indicate that both low and high water slack in general appear earlier during neap tide than during spring tide, see Table 4-8.

The tidal-averaged flow directions are displayed in Annex-Figure C-17 to Annex-Figure C-20. Note that no standard deviations are plotted in this figure, as they are not adequately defined for directional data. These figures indicate that the flow gradually changes its direction at Buoy 84, where slack lasts for a certain length of time (±1h00). After that, the flow direction shows a strange trend since the curve suddenly goes down, staying almost at 0 for 4 hours on top, and for 2 hours at the bottom. At Oosterweel, the transition at high slack water is rather fast, whereas the low water slack tide shows a more gradual transition. Earlier through-tide measurements indicate that the low water slack commences at a different moment depending on the location of the measurement point in the cross section. The flow direction in the measurement points in shallower regions changes earlier than in the measurement points located in the navigation channel. This phase shifting in low water slack over a cross section can take about 1 hour. Along the width of the river high water slack is more synchronic. These differences observed in the slack time period, result from the ebb flow which in fact for the most part follows the main channel while the flood flow spreads more over the entirety of the sections and is reaches its maximum in the regions close to the banks. Other effects influencing the moment of slack are the vertical and horizontal salinity gradients. The Scheldt is known to be a well-mixed estuary, but even small vertical salinity gradients can have an important influence on the flow pattern (Winterwerp et al., 2006).

Table 4-8: Average tide curve for the flow velocity. Time to HW of the low (LSW) and high (HSW) slack water and duration of the rising, falling and of the tide for an averaged neap, average and spring tide, April 2010 – March 2012.

Location	Instrument Depth	Tidal phase	LSW 1	HSW	LSW 2	LSW 1 to HSW	HSW to LSW 2	Total
Buoy 84	-8.1 m TAW	Neap	-6:00	00:50	06:30	06:50	05:40	12:30
		Average	-5:30	01:00	06:50	06:30	05:50	12:20
		Spring	-5:20	01:00	07:00	06:20	06:00	12:20
Buoy 84	-5.8 m TAW	Neap	-5:50	00:50	06:40	06:40	05:50	12:30
		Average	-5:30	00:50	06:50	06:20	06:00	12:20
		Spring	-5:20	01:00	07:00	06:20	06:00	12:20
Oosterweel	-5.7 m TAW	Neap	-5:30	00:40	07:00	06:10	06:20	12:30
		Average	-5:10	00:50	07:10	06:00	06:20	12:20
		Spring	-5:00	00:50	07:20	05:50	06:30	12:20
Oosterweel	-2.1 m TAW	Neap	-5:20	00:40	07:10	06:00	06:30	12:30
		Average	-5:10	00:50	07:10	06:00	06:20	12:20
		Spring	-5:00	01:00	07:20	06:00	06:20	12:20

4.3 CONCLUSION

In general, the velocity data recorded from April 2010 to March 2012 corresponds to the data measured from April 2008 to March 2010. This was expected because the tide and discharge exert significant influence on the flow velocity, and both of show similar characteristics in the measurement periods compared. With the exception of the velocity of Oosterweel bottom which is significant lower compared to the previous measuring period since replacing the RCM-9 by RCM SeaGuard at the end of the year 2010 (Annex-Figure C-22b).

5. SALINITY

Salt concentration or salinity is used as an indicator for seawater and is also analyzed in this sense. It is assumed that the interaction and exchange processes between salt and fresh water is one of the determining factors for the sediment transport. In this chapter, first of all the minimum, maximum, and average values are presented, paying attention to the identification of salt and fresh water and mixtures thereof. Then the salinity amplitude is analyzed, stressing the various regimes of interaction between tidal-related and discharge-related flow processes, including the location of the salt penetration front. The tidal-average salinity curves and the analysis of these in terms of time and duration of slack water follow. Finally, high salinity gradients, which might cause density currents, are tracked.

5.1 MINIMUM, MAXIMUM AND AVERAGE VALUES

Table 5-2 and Table 5-4 indicate the minimum, maximum and average monthly salinity for the various measurement locations during the period April 2010 – March 2012. In Annex-Figure D-1 to Annex-Figure D-7 those values are represented in addition to the values shown for the discharge in the River Scheldt at Schelle.

The highest salinity concentration appears at Buoy 84 (bottom) and at Prosperpolder (both situated downstream), whereas the lowest concentration appears at Oosterweel (situated furthest upstream). Whereby, the salinity clearly decreases gradually in upstream direction. In all locations, we find a higher salinity during the period: July-December; particularly the first year in July and the second year in November. The highest salinity (21.60) was measured in Buoy 84 (bottom) in November 2011. The lowest salinity was measured at Oosterweel Top (0.14) in January 2012. For the previous period, April 2008–March 2010, the maximum concentrations were measured at Prosperpolder (20.39) in October 2009 and the minimum concentration was at Oosterweel Top (0.07) in March 2010.

The monthly averaged salinities for most of these instruments show that readings of salinity levels taken at the upper and lower instrument locations are very similar (they are slightly lower at the upper instrument), which means that stratification is not important and that the Scheldt estuary can be classified as well-mixed (Dyer, 1995). No attempt was made to compare minimum and maximum salinity rates recorded at the upper and lower instrument locations, as these are very sensitive to missing data. Monthly averaged salinity rates show comparable values to those measured from April 2008 – March 2010 (IMDC, 2013b), but in general they are slightly lower for this period, being that the concentration is approximately 0.01% lower for the stations Buoy and Oosterweel.

It can be observed that the average salinity response to wet and dry periods is quite different in the Lower Sea Scheldt. At all locations except for Oosterweel Top, the average salinity increases with the same rate during dry periods. The salinity increase is due to dispersion of salt from downstream and shows a rate of about 2 to 3 ppt per month for all of these stations. This is a faster increase compared to the 2008–2010 period (Annex-Figure D-38 to Annex-Figure D-41). It was probably caused by the earlier start of the dry period (March), and the complete absence of fresh water discharges above 100 m³/s for four months, while in the previous period, four short rainfall events occurred, resulting in momentary discharges of 150-200 m³/s.

In contrast, the response of fresh water discharge peaks (fall and winter) is much sharper. The response time near Deurganckdok was previously determined at about 7 days by IMDC (2010c).

Table 5-1: Classification of the homoiohaline waters (Dahl, 1956).

<table>
<tr><th colspan="3">Classification</th><th>Salinity in ppt</th></tr>
<tr><td>Fresh water</td><td colspan="2"></td><td>0.0-0.5</td></tr>
<tr><td rowspan="3">Brackish water</td><td>Oligohaline</td><td>Slightly brackish water</td><td>0.5-5.0</td></tr>
<tr><td>Mesohaline</td><td>Moderately brackish water</td><td>5.0-18.0</td></tr>
<tr><td>Polyhaline</td><td>Very brackish water</td><td>18.0-30.0</td></tr>
<tr><td rowspan="2">Salt water</td><td colspan="2">Euhaline</td><td>30.0-35</td></tr>
<tr><td colspan="2">Metahaline</td><td>36-40</td></tr>
</table>

Table 5-2: monthly maximal salinity [ppt] for each measurement station: April 2010 – March 2012.

	Apr '10	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan '11	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan '12	Feb	Mar	Total Period
Prosperpolder (- 1.5 m TAW)	12.22	11.99	15.41	17.35	18.07	15.48	15.45	14.05	9.46	9.72	9.13	11.71	14.76	16.89	17.73	17.54	17.96	17.01	19.17	-	16.13	7.76	11.41	10.38	19.17
Buoy 84 (-8.1 m TAW)	9.57	-	15.65	17.12	18.14	15.29	15.06	13.54	8.54	8.34	8.35	11.45	13.88	16.68	18.25	17.07	16.97	17.69	19.66	21.6	20.63	7.92	9.60	-	21.60
Buoy 84 (-5.6 m TAW)	-	-	13.43	14.69	15.46	13.01	12.82	11.71	7.19	7.00	7.09	9.79	11.96	14.25	15.47	14.42	14.4	15.00	16.68	17.27	17.36	6.78	9.52	8.53	17.36
Liefkenshoek (-1.5 mTAW)	7.74	9.98	11.93	13.33	13.21	10.66	10.71	9.67	5.19	5.27	5.07	7.49	9.89	12.44	13.37	12.2	13.06	11.98	14.08	15.46	15.03	4.98	7.06	7.09	15.46
Oosterweel (- 5.8 m TAW)	7.09	8.53	10.44	11.76	12.42	9.45	-	-	4.17	4.06	4.41	6.05	8.96	11.25	12.51	11.69	11.39	11.47	13.26	14.99	14.65	3.91	6.32	5.22	14.99
Oosterweel (- 2.3 m TAW)	7.06	8.45	10.44	11.76	12.45	9.45	8.97	8.16	3.82	-	4.38	6.38	8.87	11.18	12.44	11.62	11.29	11.45	13.15	14.84	14.44	3.88	6.32	5.41	14.84

Table 5-3: monthly minimal salinity [ppt] for each measurement station: April 2010 – March 2012.

	Apr '10	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan '11	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan '12	Feb	Mar	Total Period
Prosperpolder (-1.5 m TAW)	5.15	7.1	9.76	10.89	10.09	9.02	8.81	1.73	3.51	1.36	2.68	4.04	7.67	10.54	13.02	10.93	11.21	10.8	12.45	-	3.76	2.44	4.28	4.06	1.36
Buoy 84 (-8.1 m TAW)	5.02	-	11.47	12.18	10.25	9.17	8.50	1.22	3.37	0.99	2.51	3.66	7.43	10.47	13.05	11.69	10.58	10.82	13.36	15.25	3.48	1.88	3.38	-	0.99
Buoy 84 (-5.6 m TAW)	-	-	8.71	10.38	8.83	7.77	7.06	0.92	2.75	0.81	1.95	2.88	6.28	8.79	10.98	9.86	8.62	8.9	11.23	12.85	2.70	1.47	3.29	2.23	0.81
Liefkenshoek (-1.5 m TAW)	3.28	5.1	6.6	8.71	6.57	5.48	5.17	0.70	2.00	0.63	1.60	2.10	5.28	6.95	9.28	8.23	6.51	6.99	9.16	10.72	1.78	1.12	2.64	1.54	0.63
Oosterweel (-5.8 m TAW)	0.50	1.09	1.38	2.45	1.29	0.86	-	-	0.51	0.18	0.43	0.44	1.07	2.02	3.68	2.59	0.86	1.20	2.64	3.69	0.24	0.29	0.45	0.77	0.18
Oosterweel (-2.3 m TAW)	0.50	0.94	1.3	2.45	1.22	0.86	0.67	0.14	0.29	-	0.45	0.39	0.97	1.95	3.56	2.55	0.79	1.17	2.53	3.58	0.17	-	0.5	0.42	0.14

Table 5-4: Monthly averaged salinity [ppt] for each measurement station.

	Apr '10	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan '11	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan '12	Feb	Mar	Total Period
Prosperpolder (- 1.5 m TAW)	7.68	8.69	12.26	13.46	13.74	11.91	11.87	7.07	5.98	4.26	5.58	7.60	10.80	13.47	15.09	14.05	14.35	13.47	15.38	-	7.07	4.91	7.52	7.00	10.42
Buoy 84 (-8.1 m TAW)	7.08	-	13.24	14.32	14.26	11.88	11.80	6.72	5.82	3.27	5.15	7.24	10.61	13.50	15.34	14.17	14.20	13.62	15.93	18.04	12.26	4.97	5.93	-	11.28
Buoy 84 (-5.6 m TAW)	-	-	10.80	12.24	12.25	10.11	10.07	5.69	4.85	2.73	4.31	6.16	9.09	11.45	12.98	11.96	11.94	11.42	13.39	14.64	10.28	4.22	6.07	5.78	9.16
Liefkenshoek (-1.5 mTAW)	5.34	7.24	9.47	11.20	11.04	8.57	8.45	4.76	3.77	2.18	3.71	5.00	7.48	9.47	11.02	10.25	10.03	9.65	11.59	12.98	8.44	3.33	5.16	4.81	7.96
Oosterweel (- 5.8 m TAW)	2.99	4.26	5.74	7.69	6.94	4.79	-	-	1.74	0.95	1.68	2.40	4.75	6.82	8.47	7.64	6.37	6.03	8.12	9.63	5.02	1.44	2.49	4.53	5.12
Oosterweel (- 2.3 m TAW)	2.95	4.23	5.69	7.65	6.88	4.77	4.09	2.04	1.57	-	1.97	2.58	4.67	7.03	8.36	7.55	6.29	5.93	7.99	9.38	4.98	1.42	2.51	2.29	5.08

5.2 AVERAGE TIDAL CYCLES OF SALINITY

A tidal salinity curve was drawn up for each measurement location. The course of the tide, with which the variation in salinity is determined in relation to time, is expressed in comparison with high tide for neap tide, average tide and spring tide; see Annex-Figure D-20 to Annex-Figure D-37. With these curves, the average time tags of maximum and minimum salinity may be determined in function of the tidal amplitude (Table 5-5). Because the data have been measured with a frequency of 10 minutes, there is an inaccuracy in the time tags calculated amounting to 10 minutes at most. A graph is presented for each location displaying neap, mid and spring tides. In each of these graphs, five plots are shown: one plot showing the average tidal cycles for the four seasons together, and four plots showing average and 5+95 percentiles tidal cycles separately per season. Summer is defined as July–August–September and the consecutive seasons per three months starting from October.

Extreme values in salinity may also be used to calculate the times of slack water. The moment of low and high water slack will then be defined as the moment of minimum and maximum salinity, respectively.

Table 5-5: Average tidal curve for the relative salinity. Time to HW of the moments of minimum (Min1 & Min2) and maximum (Max) salinity and duration of the rising, falling and for the tide for an averaged neap, average and spring tide, April 2010 – March 2012.

Location	**Instrument depth**	**Tidal phase**	*Min 1*	*Max*	*Min 2*	*Min 1 to Max*	*Max to Min 2*	*Total Duration*
Prosperpolder	-1.5 m TAW	Neap	-4:50	00:20	07:40	05:10	07:20	12:30
		Average	-4:40	00:30	07:50	05:10	07:20	12:30
		Spring	-4:20	00:30	08:00	04:50	07:30	12:20
Buoy 84	-8.1 m TAW	Neap	-4:50	00:20	07:50	05:10	07:30	12:40
		Average	-4:30	00:40	07:50	05:10	07:10	12:20
		Spring	-4:20	00:50	08:00	05:10	07:10	12:20
Buoy 84	-5.8 m TAW	Neap	-4:50	00:10	07:40	05:00	07:30	12:30
		Average	-4:40	00:40	07:50	05:20	07:10	12:30
		Spring	-4:20	00:40	08:00	05:00	07:20	12:20
Liefkenshoek	-1.5 m TAW	Neap	-5:0	01:10	07:40	06:10	06:30	12:40
		Average	-4:40	01:40	07:50	06:20	06:10	12:30
		Spring	-4:20	01:40	08:00	06:00	06:20	12:20
Oosterweel	-5.7 m TAW	Neap	-5:40	00:40	07:00	06:20	06:20	12:40
		Average	-5:20	00:40	07:10	06:00	06:30	12:30
		Spring	-5:00	00:40	07:20	05:40	06:40	12:20
Oosterweel	-2.1 m TAW	Neap	-5:20	00:40	07:10	06:00	06:30	12:30
		Average	-5:20	00:40	07:10	06:00	06:30	12:30
		Spring	-5:00	01:10	07:20	06:10	06:10	12:20

In general, we note that both the moments of minimum and maximum salinity appear earlier during neap tide than during spring tide. That is why a “flood” takes longer and an “ebb” is shorter at neap tide than at spring tide.

The time tags of minimum and maximum salinity, used to determine moments of slack water and mentioned in Table 5-5, can only be applied locally. The measurement locations are only situated at one point, vertically and close to the river bank. The effects of vertical stratification (the vertical salinity gradient is the largest around slack water), of horizontal stratification (over the cross section), of two-layered flows (especially around LW-slack) and of local flow phenomena (whirlpool formation, access channels, secondary flows, etc.) can have a strong influence on the moment of slack water.

5.3 SALINITY AMPLITUDE

Annex-Table D-1 and Annex-Table D-2 display the average difference between minimum and maximum and salinity per tide (salinity amplitude) and per measurement location for an average neap tide, an average tide and an average spring tide over various periods; see also Annex-Figure D-1 to Annex-Figure D-7. It is important to know the salinity amplitude and its variations because these are the main reason density flows arise. Density flows causes increased water exchange between the access channels or the Deurganckdok and the river. Hence, they can be responsible for an important part of the important sediment transports.

The various figures and tables (especially Annex-Table D-1, Annex-Figure D-7) show that the salinity amplitude is determined by the relative strength of the two flow mechanisms mentioned above: on the one hand the tide-related flow mechanism of which the strength is influenced by the neap tide/spring tide cycles and by storms, and for which the tidal amplitude can constitute a good indicator of the strength, and on the other hand, discharge-related flow mechanisms of which the strength is influenced by precipitation and for which the absolute salinity constitutes a good indicator of the strength. It goes without saying that the distance to the estuary mouth also plays an important role in the interaction between both mechanisms.

In a normal situation (that is to say without extreme precipitation), the tidal amplitude seems to have a dominant effect on the salinity amplitude in the measurement locations downstream, while the salinity of the discharge water has an important effect on the salinity amplitude in the measurement locations upstream. When extreme precipitation occurs, for instance such as that in November 2010, the salinity drops quickly and takes a long time to recover to the normal salinity level.

When discharge increases, the fresh water head pushes the salinity front downstream. At one point, the salinity minimum at low tide will reach the fresh water threshold more easily in periods with high precipitation. When a certain “critical” discharge history is exceeded the salinity front is pushed so far downstream that it causes the tidal salinity amplitude at that location to drop to near to zero. At the mouth at the other end, the fresh water is fully diffused in the seawater, so that no front is observed and both the minimum & maximum salt concentrations during a tide are close to the seawater threshold.

Hence, the variations in discharge cause the longitudinal salt profile to undergo constant change. The variations due to the discharge are not symmetric. For a high discharge, the salinity will very suddenly decrease, while a decreasing discharge will cause the salinity to slowly increase. The salinity front will slowly but continuously propagate due to diffusion and vertical flow velocity gradients (dispersion), as a result of which high salinity values may also be measured in the upstream locations, until the discharge is sufficiently high to push the salinity front downstream (backflow).

The effect of the absolute salinity value (as an indicator of the relative strength of the upper discharge) on the salinity amplitude may also be observed in the measurement locations upstream (i.e. Oosterweel) where the salinity strongly decreases just after the discharge peaks. (Annex-Figure D-14 to Annex-Figure D-19)

The tidal effects work on a shorter time scale (one or several tides, neap spring variation) compared to the effect of a high discharge (wet & dry periods, seasons) but can be felt with decreasing force from downstream to upstream at all locations.

Due to the interaction between these two kinds of mechanisms, and on the basis of the salinity amplitude, several regimes were distinguished, each one with a different grade of correlation between tidal and salinity amplitude. The correlation can be illustrated by studying the magnitude of the cross-correlation coefficient of tidal and salinity amplitude (Annex-Figure D-8 to Annex-Figure D-13). In these correlation plots, it is indeed possible to observe that there is limited variation in the position of the fitted line for Prosperpolder, Buoy 84 and Liefkenshoek. For Oosterweel, the effect of another factor on salinity amplitude, namely the upstream discharge, is clearly visible.

- Saline regime: This is the regime that dominates in the location furthest downstream in normal situations where the effect of diffusion and backflow is hardly felt. There is insufficient fresh water to form a contrast with the salt water. Both the minimum & maximum and values in salinity are high, which results in the salinity amplitude remaining moderate and fairly constant.
- Greatly brackish regime: For this regime, the two types of mechanisms are in balance. The contrast between minimum & maximum values of the salinity depends both on tidal amplitude and on discharge, which also determines the average value. Here, the salinity amplitude is the largest when compared with the other regimes.
- Slightly brackish regime: This regime occurs when discharge is strong enough and the location upstream is enough to keep the salt penetration front downstream of the measurement location during the lower part of the tide. In this sense, the effects of diffusion and backflow become more important than the tidal effects. The maximum salinity values will decrease compared with the above described regime, while the minimum values equal the fresh water threshold, as a result of which the values of the salinity amplitude and the connection with the tidal force will decrease.
- Fresh water regime: This regime occurs when the discharge is so large compared with the tidal amplitude that the saline front will remain in the downstream location during the whole tide. The tidal effect will only be felt by the propagation of the water wave. The salinity will strive to reach a constant value with an amplitude nearing zero. This regime occurs at Oosterweel during winter when the fresh water discharge is abundant.

Although the denomination was inspired by the Dahl classification (1956), it has to be noted that the salinity values dominating per regime do not correspond with the values in Table 5-1.

At Buoy 84 and Prosperpolder, the saline regime dominates in summer conditions. In high discharge conditions, Buoy 84 and Prosperpolder can experience greatly brackish conditions. At buoy 84 and Prosperpolder (and Deurganckdok) slightly brackish conditions occur for short periods in years with high river runoff. At Liefkenshoek the greatly brackish regime dominates, although in periods of high discharge coupled with low amplitudes, a slightly brackish or even a fresh water regime can occur. In Oosterweel, both the greatly brackish and the slightly brackish regimes occur. After extreme rainfall periods, such as those in January 2011, both at Liefkenshoek and Oosterweel, the fresh water regime prevails.

For a greatly brackish regime, the salinity amplitudes reach their highest values.

In more upstream locations and/or for higher flows compared to the tidal amplitude, the slightly brackish regime dominates. The salinity amplitude for this regime is smaller but due to the fact that the saline front is shifting to, and from along, the location during the tide, high longitudinal gradients in salinity and therefore high sediment concentrations may be expected.

5.4 LONGITUDINAL GRADIENTS

High longitudinal gradients of salinity may cause density flows and hence sediment transport. Longitudinal gradients will be assessed here by using an estimate formula:

$$\partial S / \partial x = \left(dS / dt \right) 1/V = \frac{S_{i+1} - S_i}{t_{i+1} - t_i} \frac{1}{\overline{\overline{V_{i,i+1}}}}$$

with S_i the salinity in at time i, t_i the time i, $1\overline{V_{i,i+1}}$ the average flow velocity between time tags i and i+1.

The data show that for the station Buoy 84 (Top and Bottom), the gradients are larger during ebb than during flood. Whereas for Oosterweel the gradients are slightly larger during flood. This observation is completely the opposite of the findings of IMDC (2008), which shows larger gradients during flood than during ebb for Buoy 84, and larger gradients during ebb for the Oosterweel measurement stations. On the other hand, no clear relation can be derived between the gradients and the tidal amplitude. In general, the largest gradients found are for the greatly brackish regime, the smallest for the fresh water regime. Intermediate values are obtained for a slightly brackish regime. The differences between the ebb and flood salinity gradient might be caused by the difference in flow velocity between the left and right bank. The velocities measured at the measurement stations might therefore not be fully representative for the propagation velocity for the complete salt wedge.

The above formula is calculated for each measurement time (that is every 10 minutes). Per episode (tide, ebb, flood), the monthly average value has been calculated Table 5-7 and Table 5-8 give the monthly average gradients for ebb and flood, as well as the dominating regimes. Table 5-6 displays the average values per trimester for the tidal averages.

Since the greatly brackish regime is also characterized by a high salinity, the regime goes hand in hand with the highest spatial variations in salinity of all, and hence represents the critical condition in terms of sediment transport caused by salt and fresh water exchanges and mixing processes.

Table 5-6: Quarterly average value of the tide averaged horizontal salinity gradient [ppt/km] and flow regime of each measurement station.

Location	Tidal phase	Apr-Jun 2010	Jul-Sep 2010	Oct-Dec 2010	Jan-Mar 2011	Apr-Jun 2011	Jul-Sep 2011	Oct-Dec 2011	Jan-Mar 2012
Buoy 84 (-8.1 m TAW)	Neap tide	0.45	0.51	0.50	0.43	0.54	0.60	0.66	0.66
	Avg tide	0.43	0.51	0.51	0.46	0.54	0.56	0.79	0.57
	Spring tide	0.48	0.57	0.53	0.54	0.63	0.63	0.79	0.53
Buoy 84 (-5.6 m TAW)	Neap tide	-	0.37	0.42	0.34	0.40	0.50	0.56	0.48
	Avg tide	0.34	0.41	0.37	0.36	0.44	0.44	0.63	0.49
	Spring tide	0.37	0.45	0.40	0.41	0.53	0.53	0.64	0.51
Oosterweel (-5.8 m TAW)	Neap tide	0.42	0.67	0.24	0.21	0.74	0.81	0.90	0.27
	Avg tide	0.47	0.62	0.26	0.23	0.70	0.71	0.71	0.28
	Spring tide	0.43	0.61	0.25	0.25	0.63	0.71	0.70	0.30
Oosterweel (-2.3 m TAW)	Neap tide	0.36	0.53	0.27	0.28	0.51	0.58	0.62	0.24
	Avg tide	0.40	0.51	0.26	0.25	-	0.54	0.54	0.24
	Spring tide	0.38	0.50	0.33	0.24	0.46	0.52	0.55	0.23

Table 5-7: Monthly average value of the ebb phase averaged horizontal salinity gradient [ppt/km] and flow regime for each measurement station.

Location	Tidal phase	Apr '10	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan '11	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan '12	Feb	Mar	Total period
Buoy 84 (-8.1 m TAW)	Neap tide	0.55	-	-	0.51	0.67	0.66	0.59	0.72	0.54	0.48	0.47	0.61	0.70	0.60	0.73	0.56	0.81	0.76	0.75	0.79	0.89	0.95	0.59	-	0.66
	Avg tide	0.58	-	0.48	0.54	0.66	0.75	0.62	0.57	0.68	0.53	0.56	0.62	0.71	0.66	0.64	0.53	0.71	0.75	0.94	0.87	0.98	0.80	0.60	-	0.69
	Spring tide	0.58	-	0.51	0.58	0.68	0.82	0.62	0.62	0.65	0.38	0.72	0.69	0.77	0.86	0.65	0.65	0.75	0.86	0.80	0.94	1.01	0.69	0.56	-	0.70
Buoy 84 (-5.6 m TAW)	Neap tide	-	-	-	0.37	0.47	0.42	0.41	0.63	0.37	0.32	0.35	0.44	0.50	0.43	0.53	0.36	0.61	0.68	0.65	0.55	0.72	0.60	0.59	0.57	0.50
	Avg tide	-	-	0.40	0.43	0.53	0.48	0.52	0.38	0.40	0.39	0.40	0.47	0.50	0.50	0.57	0.39	0.55	0.62	0.77	0.63	0.72	0.55	0.62	0.64	0.51
	Spring tide	-	-	0.43	0.48	0.53	0.50	0.45	0.49	0.40	0.29	0.48	0.51	0.56	0.58	0.62	0.53	0.62	0.66	0.74	-	0.77	0.55	0.61	0.61	0.55
Oosterweel (-5.8 m TAW)	Neap tide	0.36	0.40	0.52	0.62	0.71	0.63	-	-	0.23	0.12	0.26	0.34	0.64	0.69	0.85	0.82	0.82	0.79	0.82	0.88	0.94	0.25	0.26	0.35	0.58
	Avg tide	0.36	0.43	0.55	0.64	0.64	0.55	-	-	0.25	0.19	0.24	0.31	0.56	0.70	0.75	0.71	0.72	0.70	0.80	0.83	0.55	0.25	0.34	-	0.54
	Spring tide	0.35	0.42	0.52	0.60	0.61	0.56	-	-	0.25	0.15	0.25	0.32	0.52	0.63	0.71	0.71	0.69	0.69	0.79	0.81	0.40	0.23	0.36	-	0.51
Oosterweel (-2.3 m TAW)	Neap tide	0.28	0.33	0.41	0.48	0.49	0.44	0.38	0.18	0.20	-	0.22	0.28	0.43	0.50	0.48	0.55	0.55	0.52	0.57	0.58	0.55	0.20	0.19	0.29	0.40
	Avg tide	0.28	0.35	0.42	0.47	0.48	0.42	0.37	0.20	0.18	-	0.21	0.23	0.37	-	0.52	0.48	0.50	0.48	0.54	0.57	0.40	0.19	0.26	0.24	0.35
	Spring tide	0.29	0.35	0.41	0.48	0.47	0.43	0.40	0.28	0.19	-	0.20	0.24	0.38	0.44	0.46	0.46	0.48	0.49	0.54	0.55	0.27	0.17	0.27	0.23	0.37

Table 5-8: Monthly average value of the flood phase averaged horizontal salinity gradient [ppt/km] and flow regime for each measurement station

Location	Tidal phase	Apr '10	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan '11	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan '12	Feb	Mar	Total period
Buoy 84 (-8.1 m TAW)	**Neap tide**	0.37	-	-	0.31	0.48	0.45	0.39	0.51	0.32	0.32	0.31	0.43	0.41	0.44	0.42	0.33	0.51	0.61	0.55	0.53	0.52	0.69	0.39	-	0.44
	Avg tide	0.36	-	0.29	0.34	0.43	0.42	0.44	0.38	0.43	0.31	0.37	0.43	0.46	0.42	0.40	0.36	0.48	0.54	0.60	0.65	0.68	0.51	0.37	-	0.46
	Spring tide	0.44	-	0.32	0.41	0.48	0.52	0.46	0.41	0.41	0.26	0.54	0.49	0.54	0.55	0.43	0.43	0.50	0.68	0.67	0.75	0.67	0.58	0.43	-	0.50
Buoy 84 (-5.6 m TAW)	**Neap tide**	-	-	-	0.24	0.33	0.34	0.31	0.51	0.26	0.27	0.30	0.35	0.30	0.33	0.32	0.28	0.52	0.46	0.43	0.50	0.50	0.47	0.37	0.37	0.37
	Avg tide	-	-	0.28	0.31	0.35	0.37	0.41	0.29	0.29	0.24	0.27	0.36	0.36	0.35	0.38	0.28	0.40	0.44	0.50	0.55	0.54	0.40	0.37	0.44	0.37
	Spring tide	-	-	0.31	0.35	0.38	0.43	0.36	0.40	0.31	0.23	0.39	0.41	0.50	0.48	0.41	0.38	0.46	0.54	0.55		0.49	0.40	0.41	0.48	0.42
Oosterweel (-5.8 m TAW)	**Neap tide**	0.32	0.42	0.55	0.65	0.74	0.66	-	-	0.24	0.10	0.25	0.37	0.66	0.71	0.95	0.76	0.78	0.89	0.91	0.92	0.93	0.24	0.25	0.39	0.60
	Avg tide	0.33	0.47	0.58	0.66	0.66	0.59	-	-	0.26	0.18	0.22	0.30	0.56	0.73	0.81	0.72	0.71	0.72	0.80	0.87	0.54	0.23	0.35	-	0.55
	Spring tide	0.34	0.46	0.58	0.65	0.68	0.58	-	-	0.26	0.13	0.24	0.34	0.54	0.68	0.78	0.73	0.71	0.71	0.80	0.85	0.39	0.22	0.37	-	0.53
Oosterweel (-2.3 m TAW)	**Neap tide**	0.30	0.41	0.53	0.60	0.62	0.54	0.48	0.22	0.20	-	0.24	0.33	0.50	0.58	0.59	0.58	0.62	0.64	0.65	0.76	0.64	0.20	0.20	0.31	0.47
	Avg tide	0.32	0.43	0.52	0.57	0.58	0.51	0.49	0.23	0.21	-	0.27	0.27	0.44	0.53	0.60	0.60	0.66	0.58	0.63	0.68	0.47	0.20	0.31	0.30	0.47
	Spring tide	0.32	0.44	0.51	0.59	0.59	0.50	0.50	0.34	0.21	-	0.22	0.29	0.44	0.50	0.57	0.55	0.57	0.57	0.66	0.66	0.30	0.18	0.30	0.26	0.44

5.5 LONG-TERM VARIATIONS

By using a monthly running-average filter (a low pass filter) the salinity data will be smoothed out and prolonged variations will be more visible. In the long-term, the average salinity in Annex-Figure D-38 to Annex-Figure D-41 shows a seasonal cycle. During the spring season the salinity is at its lowest due to a higher fresh water discharge and more runoff due to the increased saturation levels of soil at the end of winter. These seasonal variations can be seen in the data of all measurement stations taken into consideration: Prosperpolder, Buoy 84, Liefkenshoek and Oosterweel, and in the data from both bottom and top sensors. As a result of a lower influence of the fresh water inflow the measurement stations located in more downstream positions register the highest salinity levels during the summer period (more than 15 psu). In the measurement stations situated at a more upstream location, the peak salinities are lower, at around 10 psu. Annex-Figure D-42 shows that the summer salinities recorded for 2007 and 2008 are low in comparison with the summer salinity rates recorded in 2006, 2009, 2010 and 2011. This is possibly caused by a higher summer discharge during these years. In comparison with the previous survey years, the salinity of 2010 reaches their seasonal maximum 2 month earlier and their minimum 1 month (Annex-Figure D-38 to Annex-Figure D-41).

6. TEMPERATURE

The aim of this chapter is to determine whether the seasonal cycle has an influence on the sediment transport. Indeed, the quantities of available sediments might be influenced by temperature and light-related processes (biological activity, increase of flocculation, etc.). The temperature course has been taken in this sense. First we will present the monthly minimum, maximum and average values. Then we will study the evolution of the temperature amplitude. Finally, we will present the tidal-averaged temperature curves.

6.1 MINIMUM, MAXIMUM AND AVERAGE VALUES

Table 6-1 and Table 6-2 display the monthly minimum & maximum temperatures for the various measurement locations, see also Annex-Figure E-1a, Annex-Figure E-6a and Annex-Figure E-8. Table 6-3 shows the monthly average temperature.

The warmest month during the measurement period was July 2010 (24.27°C in Prosperpolder). The lowest water temperatures were measured in February 2012 in all the stations (0.25°C in Oosterweel) and the second in December 2010. Both periods are very cold compared to the previous survey years (Annex-Figure E-15 to Annex-Figure E-18). The maximum water temperature is almost the same as the one from the previous measurement period (April 2008 to March 2010, 24.22°C).

6.2 TEMPERATURE AMPLITUDE

Annex-Figure E-1b to Annex-Figure E-8b display the average difference between minimum & maximum temperatures per tide (temperature amplitude) and per measurement location for an average neap tide, an average tide and an average spring tide and for various other periods. The table shows that the temperature amplitude is influenced to a certain extent both by seasons (absolute water temperature) and by the tidal amplitude. Furthermore, the location of the measurement point is of importance.

The most important factor determining the size of the temperature amplitude is the seasonal variation at Buoy 84. Here, the greater temperature differences per tide occur during winter; during summer these differences are smaller. No seasonal variation in the temperature amplitude is present at the other locations. The influence of the tidal amplitude is of minor importance. In general, the temperature amplitude is larger in the upstream measurement locations; it is approximately 0.8°C upstream and about 0.4°C downstream. In the downstream location (Buoy 84) there is very little mixing of fresh and salt water, resulting in a small temperature amplitude. However, at Prosperpolder, large temperature amplitudes exist, probably as a result of local effects. An analogous phenomena probably occurs at the upstream end, where there is too little salt water to create a temperature difference. The brackish regions, such as in Oosterweel, where there is an important interaction between the upstream and downstream processes, present larger differences than those observed at Buoy 84.

Table 6-1: Monthly maximal temperature [°C] for each measurement station. April 2010 – March 2012.

	Apr '10	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan '11	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan '12	Feb	Mar	Total period
Buoy 84 (-8.1 m TAW)	12	-	21	24	23	20	18	13	8	7	8	11	17	18	20	21	21	20	19	14	10	8	6	-	24
Buoy 84 (-5.6 m TAW)	-	-	21	23	23	19	18	13	8	7	7	11	16	18	20	21	21	20	19	15	11	8	6	11	23
Oosterweel (-5.8 m TAW)	14	17	21	24	22	19	-	-	4	8	7	9	16	17	19	20	20	19	19	14	10	7	5	6	24
Oosterweel (-2.3 m TAW)	14	17	21	24	22	19	17	13	7	-	7	10	16	18	20	21	20	20	19	14	11	8	5	11	24
Prosperpolder (- 1.5 m TAW)	15	17	22	24	23	22	18	14	8	7	9	11	18	18	21	21	21	20	20	-	8	8	6	112	24
Liefkenshoek	15	16	22	24	23	20	18	13	8	7	8	11	17	18	20	21	21	20	19	15.0 9	11	8	6	12	24

Table 6-2: Monthly minimal temperature [°C] for each measurement station. April 2010 – March 2012.

	Apr '10	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan '11	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan '12	Feb	Mar	Total Period
Prosperpolder (- 1.5 m TAW)	9	11	15	20	18	16	12	7	2	3	5	6	10	15	17	18	19	17	13	-	7	7	2	5	1
Buoy 84 (-8.1 m TAW)	9	-	18	20	19	17	12	7	3	3	5	6	10	15	17	18	19	18	13	10	6.	7	2	-	2
Buoy 84 (-5.6 m TAW)	-		17	21	19	17	12	7	3	3	5	6	10	15	17	18	19	18	13	10	6	7	2	5.8	2
Liefkenshoek (-1.5 m TAW)	9	12	15	21	20	16	12	7	2	3	5	6	11	15	17	19	19	18	13	10	6	7	2	6	2.2
Oosterweel (-5.8 m TAW)	9	12	15	21	18	16	-	-	2	2	4	6	10	15	17	18	18	17	12	9	4	5	1	5.4	1
Oosterweel (-2.3 m TAW)	9	12	15	21	18	16	10	5	2	2	6	6	11	16	17	18	19	17	12	9	5	6	1	6	1

Table 6-3: Monthly averaged temperature [°C] for each measurement station. April 2010 – March 2012.

	Apr '10	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan '11	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan '12	Feb	Mar	Total period
Prosperpolder (-1.5 m TAW)	12	14	18	23	21	18	15	11	4	5	7	8	13	17	19	20	20	19	17		7	8	4	9	13
Buoy 84 (-8.1 m TAW)	10	-	19	22	21	18	15	11	4	5	6	8	13	16	18	19	20	18	16	12	8	7	3	-	14
Buoy 84 (-5.6 m TAW)	-	-	18	22	21	18	15	11	4	5	6	8	13	16	18	19	20	18	16	14	8	7	4	8	13
Liefkenshoek (-1.5 m TAW)	12	14	19	23	22	19	15	11	4	6	7	8	14	17	19	20	20	19	16	13	8	8	4	9	14
Oosterweel (-5.8 m TAW)	12	14	18	23	21	18	-	-	3	5	6	7	13	16	18	19	20	18	16	12	7	6	3	6	13
Oosterweel (-2.3 m TAW)	12	14	18	23	21	18	14	10	4	-	7	8	14	17	19	20	20	19	16	12	7	7	4	9	13

6.3 AVERAGE TIDAL CYCLES OF TEMPERATURE

Hence, the tidal temperature difference is limited and will almost never be greater than 2°C. However, it is interesting to note the temperature course during a tide at the different measurement locations. This tidal course of the temperature is represented in the tidal-averaged temperature curves, which were drawn up for each of the measurement locations.

The course of these tidal averaged temperatures is measured as function of time in relation to high water and this for neap tide, average tide and spring tide, see Annex-Figure E-9 and Annex-Figure E-14.

Analysis of the heat exchange between seawater and fresh water in the estuary is not as simple as de analysis of the salt exchange, for which seawater (high salinity) and fresh water (low salinity) are easily tracked. To be able to analyze the effects of the interaction on both water masses with their own seasonal variation of temperature and to explain the shape of the tidal temperature curves in each measurement locations, one should first be able to determine the boundary conditions (temperature in the deep sea and far enough upstream) in order to separate the periods for which the sea is warmer than de Upper Scheldt from the periods for which the sea is colder.

6.4 LONG-TERM VARIATIONS

Figures of the monthly average temperatures (Annex-Figure E-15 to Annex-Figure E-18) as well as multi-year variations of temperature (Annex-Figure E-19) at the different measurement stations can be found in the appendix.

7. SEDIMENT CONCENTRATION

The fine fraction of suspended material (sediment) is of great importance in an estuary. Due to the estuarine processes (tidal movement, salinity, residual flow etc.) the concentration varies strongly in time and place and affects the deposition, erosion and transport processes of the sediment. In this sense, the present study aims at providing a better insight in the processes and their influencing factors (flow velocity, salinity, temperature). This knowledge forms the basis to determine the strategies for dredging and relocation, both in the framework of productive and cost-effective working methods, and of developing sustainable relocation options.

The measurements presented here aim at quantifying the variation of sediment in suspension in different time scales and in space. Due to the high variability of the sediment concentration in the water column and especially near the bottom, it is often very difficult to distinguish the effects of local erosion and sedimentation from the general sediment transport, hence it is also very difficult to see the correlations between the measured concentrations in the different measurement locations.

To provide a comparable dataset the raw turbidity data was calibrated using the calibration curves provided by Flanders Hydraulics Research as described in reports IMDC (2012c) and IMDC (2012p).

At Buoy 84 (top) and Oosterweel (bottom), Aanderaa RCM-9 were replaced by Aanderaa SeaGuard in 2009 and 2010, which has its influence on the turbidity data. Since installing the SeaGuard the maximum level of the turbidity sensor (of 500 FTU) was reached on several occasions and this at both locations (Annex-Figure F-37 and Annex-Figure F-38). Based on the calibration curves (IMDC, 2012o), the maximum sediment concentration that could be measured by Aanderaa SeaGuard is about 630 mg/l for Oosterweel and about 828 mg/l for Buoy 84. While the Aanderaa RCM-9 measures sediment concentration values of up to 1460 mg/l at Oosterweel and 2300mg/l at Buoy 84. If the maximal sediment concentrations turn out to be larger than these values the maximum will be unknown and the calculated average sediment concentration will be lower than it actually.

In the first part of this chapter, the different behavioral patterns of the sediment transport between the ebb and flood phases will be studied with regard to the maximum and average values for both phases. Attention will then be paid to the different time scales governing the variations in sediment concentration. Afterwards, the focus will be put on the general course of the concentration along the tide. In a third part, the variations along the neap and spring tide cycle, as well as the correlation between flow velocity and sediment concentration will be analyzed. Finally, a fourth part gives gives an introduction to the analysis of the long-term variations of the suspended sediment concentration.

7.1 EBB AND FLOOD VARIATIONS

Previous long-term ADCP flow measurements (TV Sam, 2006a-c), 13-hour measurements and the tidal velocity curves, show that the flow patterns differ between ebb and flood. This leads to asymmetric sediment transport and to the so-called tidal pumping effect.

The minimum, maximum and average sediment concentrations at ebb and flood have been shown Annex-Figure F-1 to Annex-Figure F-10. On several occasions the figures from Oosterweel (bottom) and Buoy 84 (top) show,a constant maximum, which is caused by saturation of the SeaGuard’s turbidity sensor. Table 7-1 and Table 7-2 provide the monthly maximum recorded values of the sediment concentration at ebb and flood for the measurement locations and for an average neap tide, average tide and average spring tide.

Table 7-3 and Table 7-4 give the monthly average ebb and flood sediment concentrations for an average neap tide, average tide and average spring tide, also mentioning each time the flow regimes as defined in Chapter 5. Annex-Table F-1 to Annex-Table F-6 provide the average sediment concentration per ebb, per flood and per tide, also per trimester, per summer, per winter and per year as well as for an average neap tide, average tide and average spring tide.

The average sediment concentrations at Buoy 84 are higher during ebb than during flood, with the largest peak recorded by the lowest instruments and during flood. At Oosterweel, the average sediment concentration is slightly larger at flood. The largest peaks occur during this period and once again, they are observed at the bottom station location. In contrast to what was found in IMDC (2013b) there is no clear correlation between the flow regime and the sediment concentrations.

The tables and figures mainly indicate that the variations in sediment concentration are governed by phenomena working in accordance with different time scales:

- When a consolidated layer is suddenly brought back to suspension, peaks occur in the course of the maximum values. Although this increase is almost instantaneous, it is also the result of lengthy sedimentation and consolidation processes.
- Within one tide, and due to the nature of the velocity course itself, the variations in suspended sediment concentration are very high.
- Flow velocity is a determining factor for the bringing and keeping of sediment in suspension. In Chapter 4, a clear relation has been indicated between average flow velocity and tidal amplitude, as a result of this variations in sediment concentration are expected along the neap tide and spring tide cycle.
- Variations on a more prolonged time scale may occur. The availability of the sediments may change through the seasonal cycles. In Chapter 4 we also noted that the interaction between tidal flow and discharge (and hence between precipitation, wet and dry seasons), and the relation between the force of these two mechanisms leads to the shifting of zones with high spatial salinity gradients (greatly brackish) and zones with important mixing processes (saline front, slightly brackish), which are able to exert a strong influence on the suspension.

These factors cannot be separated from each other, making it therefore difficult to analyze them and to draw general conclusions. The high variability of the sediment concentration in the water column and especially near the bottom, and the turbulent variations in the flow, combined with the point character of the measurements as well as interventions in the sediment balance by dredging and relocation, place many obstacles in the way of a general understanding. Being able to make a distinction between a) the effects of local erosion & sedimentation and b) general sediment transport (advection) in the Scheldt, is a typical problem.

Nevertheless, this analysis will try to isolate the various phenomena and clarify them hereinafter.

Table 7-1: Maximal ebb phase suspended sediment concentration (mg/l) for an averaged neap, average and spring tide.

		Apr 2010	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan 2011	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan 2012	Feb	Mar	Total Period
Buoy 84 (-8.1 m TAW)	**Neap tide**	1048	-	-	476	489	639	443	649	561	724	713	1098	1172	910	880	442	389	539	520	572	429	349	-	-	655
	Avg tide	1265	-	405	607	678	689	545	741	711	703	918	1205	1137	947	1117	862	543	798	1036	706	829	672	-	-	824
	Spring tide	1278	-	451	742	822	841	567	758	817	1070	1089	1310	1198	1042	1187	988	692	865	1183	765	1036	1078	-	-	948
Buoy 84 (-5.6 m TAW)	**Neap tide**	-	-		289	249	363	247	313	346	389	466	785	668	563	639	267	198	326	283	303	330	206	271	209	372
	Avg tide	-	-	176	399	422	492	305	487	487	428	664	816	738	580	684	586	325	469	534	407	549	544	417	299	509
	Spring tide	-	-	200	476	507	601	412	459	626	677	775	817	817	718	740	695	428	573	645	-	705	767	698	504	614
Oosterweel (-5.8 m TAW)	**Neap tide**	830	395	178	303	320	434	-	-	442	429	482	619	619	443	616	518	305	614	574	485	321	305	424	319	463
	Avg tide	873	413	280	368	433	425	-	-	451	333	502	619	619	610	614	595	350	557	617	444	529	542	505	-	502
	Spring tide	868	393	322	325	434	476	-	-	537	434	545	619	619	619	618	611	454	558	619	439	465	532	574	-	539
Oosterweel (-2.3 m TAW)	**Neap tide**	617	357	148	230	204	298	244	340	354	-	495	500	514	343	428	334	212	448	496	421	356	341	728	300	376
	Avg tide	718	350	206	262	309	371	221	357	355	-	690	610	600	525	429	416	255	433	602	416	465	674	830	300	437
	Spring tide	783	369	208	270	303	358	252	330	365	-	717	592	592	625	453	462	314	512	716	351	434	844	942	328	502

Table 7-2: Maximal flood phase suspended sediment concentration (mg/l) for an averaged neap, average and spring tide.

		Apr 2010	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan 2011	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan 2012	Feb	Mar	Total period
Buoy 84 (-8.1 m TAW)	Neap tide	749	-	-	326	331	376	352	350	455	619	740	1091	862	636	518	381	255	437	358	375	419	306	-	-	502
	Avg tide	1257	-	335	453	496	649	447	631	738	717	939	1215	1046	995	660	769	583	798	787	637	801	769	-	-	748
	Spring tide	1371	-	346	639	685	711	570	650	869	1001	1216	1408	1071	1308	722	904	676	995	897	714	953	1008	-	-	899
Buoy 84 (-5.6 m TAW)	Neap tide	-	-	-	118	115	113	121	138	164	248	267	355	209	191	204	125	92	173	209	216	255	170	163	165	185
	Avg tide	-	-	108	205	201	183	191	266	252	271	449	507	313	268	309	199	185	253	403	418	438	536	372	336	295
	Spring tide	-	-	120	193	231	231	223	263	394	449	676	719	506	457	332	329	237	473	556	-	489	792	552	479	418
Oosterweel (-5.8 m TAW)	Neap tide	779	356	244	310	373	462	-	-	329	311	354	579	615	491	619	500	349	618	578	577	387	280	299	345	455
	Avg tide	790	393	361	372	462	485	-	-	421	273	450	577	619	605	619	582	393	578	619	527	491	461	470	-	497
	Spring tide	859	408	391	373	448	567	-	-	505	307	515	603	619	619	619	613	503	598	619	478	387	465	562	-	540
Oosterweel (-2.3 m TAW)	Neap tide	692	386	219	283	295	365	300	279	293	-	401	527	539	506	630	381	291	638	542	543	381	278	542	326	419
	Avg tide	726	377	315	347	406	467	277	346	342	-	644	604	644	710	614	527	334	539	715	545	453	516	838	269	505
	Spring tide	790	406	359	368	366	507	366	378	353	-	704	609	680	873	656	616	457	642	853	439	379	712	1025	282	581

Table 7-3: Average ebb phase suspended sediment concentration (mg/l) for an averaged neap, average and spring tide.

		Apr 2010	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan 2011	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan 2012	Feb	Mar	Total Period
Buoy 84 (-8.1 m TAW)	**Neap tide**	477	-	-	179	178	243	189	267	269	323	356	529	512	332	353	207	146	215	211	230	210	127	-	-	279
	Avg tide	723	-	161	259	284	324	277	395	384	332	515	707	590	400	463	367	272	355	438	366	408	325	-	-	399
	Spring tide	910	-	204	384	375	407	331	423	489	552	736	890	776	528	546	470	382	427	546	418	519	572	-	-	519
Buoy 84 (-5.6 m TAW)	**Neap tide**	-	-	-	89	98	138	102	125	160	157	209	362	245	192	195	117	80	119	132	133	158	90	125	98	153
	Avg tide	-	-	77	141	158	183	139	223	231	183	324	448	356	211	245	200	144	190	245	191	262	245	223	147	221
	Spring tide	-	-	93	188	208	238	205	220	320	305	514	584	518	301	274	267	201	259	314	-	312	381	372	238	307
Oosterweel (-5.8 m TAW)	**Neap tide**	544	219	115	159	179	257	-	-	249	281	258	440	427	240	428	291	177	399	382	352	244	187	211	190	293
	Avg tide	600	225	158	208	265	281	-	-	277	217	346	470	453	461	385	332	202	361	496	336	350	375	306	-	335
	Spring tide	615	223	163	210	249	291	-	-	352	286	439	441	471	453	401	406	261	434	563	310	270	385	378	-	374
Oosterweel (-2.3 m TAW)	**Neap tide**	408	183	94	127	129	185	160	222	220	-	273	310	317	234	288	213	132	278	304	296	243	188	347	170	232
	Avg tide	482	191	126	160	204	243	152	256	247	-	446	412	369	346	289	257	163	282	415	308	301	396	501	182	285
	Spring tide	532	209	125	165	188	251	181	245	254	-	505	389	395	439	303	308	213	359	512	277	271	499	619	215	337

Table 7-4: Average flood phase suspended sediment concentration (mg/l) for an averaged neap, average and spring tide.

		Apr 2010	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan 2011	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan 2012	Feb	Mar	Total Period
Buoy 84 (-8.1 m TAW)	**Neap tide**	330	-	-	108	110	110	119	136	161	223	234	321	233	175	165	114	87	117	125	133	157	106	-	-	163
	Avg tide	573	-	118	168	173	198	185	285	276	279	409	477	312	237	241	211	181	208	256	218	295	205	-	-	262
	Spring tide	774	-	136	242	242	246	222	286	393	458	614	634	403	392	299	306	255	260	331	264	341	366	-	-	357
Buoy 84 (-5.6 m TAW)	**Neap tide**	-	-	-	54	57	60	64	71	90	125	133	176	108	91	91	56	46	69	91	94	121	81	87	75	89
	Avg tide	-	-	55	88	89	100	101	158	156	156	253	280	170	132	141	99	91	108	177	164	189	223	173	118	146
	Spring tide	-	-	61	101	117	121	125	157	224	249	387	414	278	208	173	163	127	165	235	-	229	383	278	187	211
Oosterweel (-5.8 m TAW)	**Neap tide**	531	216	148	209	221	306	-	-	216	196	212	406	447	296	485	300	215	456	398	395	248	158	185	202	303
	Avg tide	561	225	214	258	314	309	-	-	250	171	306	410	459	488	479	361	235	401	525	377	321	322	296	-	346
	Spring tide	584	226	228	259	288	347	-	-	317	217	400	412	479	527	499	455	302	449	570	330	252	341	370	-	386
Oosterweel (-2.3 m TAW)	**Neap tide**	447	207	126	181	180	242	183	180	188	-	266	336	362	315	394	242	177	377	351	342	246	157	284	184	262
	Avg tide	487	218	179	222	258	292	169	235	234	-	442	394	414	461	398	321	201	339	492	355	297	322	507	168	323
	Spring tide	526	247	198	232	236	311	215	247	232	-	480	395	450	599	422	395	278	417	598	300	254	432	628	187	377

7.2 TIDAL VARIATIONS

The data reports of the measurement campaign show the 10 minute evolution on week plots for all variables, among which sediment concentration. Several peaks can be found per tide. The variations between the tides in relation to the tidal difference are clearly visible too.

The course of the flow velocity along one tide, put in parallel with erosion and sedimentation processes may explain the occurrence of some of the peaks in the concentration course. The flow pattern and the erosion and sedimentation processes could explain three different peaks during an episode (ebb or flood):

- The sediment layer formed during slack will have a lower density and will easily erode when the flow velocity increases just after the slack, resulting in a first possible concentration peak.
- In previous research studies we saw that the average velocity values followed the neap tide and spring tide cycle, with high amplitude tides showing higher velocities. Along this cycle, during the periods with the smallest amplitudes (neap tides), sedimentation would prevail, allowing the consolidation of layers of settled sediments. During the phases of the cycle with higher velocity (spring tides and, to a lesser degree, average tides), (part of) those consolidated layers can be eroded and brought back into suspension. Consolidation and erosion cycles of this type can also be imagined in relation to longer time scales (for instance, seasonal, dry-humid periods and years). The resistance against erosion of those layers, consolidated on various time scales, is higher than the settled layers during slack. Erosion of those layers only occurs when the flow velocity (and thus when the bed shear stress) is higher than a certain threshold. During the phase of increasing flow velocity, and during the erosion phase of the consolidation-erosion cycle (i.e. during spring tide, and to a lesser degree during average tide for the tidal amplitude cycle), this threshold can be exceeded, causing the erosion of all or a part of a consolidated layer, which can be brought into suspension, leading to the appearance of a second peak.
- A third peak in the concentration during the increasing velocity phase will coincide with the maximum flood velocity, which is in general more distinct during a spring tide than during a neap tide. During ebb, the velocity course shows a more uniformed pattern than during flood, for which more peaks are recorded. Hence, the appearance of a maximum velocity concentration peak should be less frequent during ebb than during flood.
- Since the ebb and ebb currents follow different paths in the Scheldt estuary, the position of the measurement station has a big influence on the sediment concentration data registered.
- The settlement of the suspended sediment during slack leads to a higher suspended sediment concentration near the bottom of the riverbed. The bottom station will register higher sediment concentrations during this period.

7.3 TIDAL AVERAGED SEDIMENT CONCENTRATION CURVES

A tidal-averaged sediment concentration curve has been drawn for each of the measurement locations. The course of this sediment concentration curve is determined as a function of the time in relation to high water and this for neap tide, average tide and spring tide; see Annex-Figure F-11 to Annex-Figure F-22. These curves allow us to determine the average time tags of the peaks in sediment concentration as a function of the tidal amplitude; see also Table 7-5. Because the data have been measured with a frequency of 10 minutes, there is an inaccuracy in the time tags calculated which amounts to 10 minutes at most. In general, the time tags in this table are reasonably in agreement with the time tags found in the data from March 2008 to March 2010 (IMDC, 2013b), which indicates that the tidally-averaged sediment concentration curves are qualitatively similar to those from April 2008 to March 2010. This is confirmed by a visual comparison of the graphs.

- **Buoy 84**: During flood (considered here as going from low water slack to high water slack), a first small concentration peak can be observed at the bottom station about 5h30 to HW. This peak is the reflection of a small velocity peak that is also only observed at the bottom location. Another concentration peak occurs together with the velocity peak about 1h30 to HW. At that moment the flood velocity is fully decreases towards slack, which means that the concentration peak cannot be explained by the velocity course or local erosion processes. During ebb (from HWS to LWS), a first concentration peak occurs about 2h30 after HW, an hour and an half before the first ebb velocity peak, which is very weak during neap tide conditions. This first ebb peak can thus only be explained by the erosion of the layer that settled during high water slack. The velocity peak at about 2h30 after HW, which is also the maximal ebb velocity, does not find any reflected image in the concentration course. The second velocity peak, about 4h00, is well reflected in the concentration. The peak here in the concentrations at the upper measurement instrument is the most pronounced of all. As can be observed by comparing both curves, the velocity course is far from being perfectly reflected in the concentration course. Some of the velocity peaks (even the biggest ones) do not create any concentration peak. Furthermore, in a more global way, it can be observed that while the velocity pattern is clearly flood-oriented, the biggest concentrations values are recorded during ebb (especially at the upper measurement instrument). This shows that the concentration at one point in the estuary is not the consequence of local erosion and sedimentation processes but rather the result of the global sediment transport in the river, which is itself the consequence of multiple local processes. In this way, the higher concentrations during ebb can be explained by the fact that in this location, the ebb flow is loaded with more sediment than the flood flow “coming” from the sandy environment at the location called Plaat van Doel).

- **Oosterweel**: The velocity curve shows a double peak pattern (-3h30 and -1h00, the second one dominant) during flood and a quite continuous pattern during ebb with peaking values between +2h00 and +4h00. During flood, the first velocity peak generates a small bump in the concentration (HW-4h), most visible for the bottom station during average or spring tide. The biggest flood concentration peaks occur between the two velocity peaks and this is probably due to the erosion of the settled layers. During ebb, a first concentration peak occurs during the increase of the velocity after slack by erosion of the settled layers, a second, peak is synchronous with the velocity maximum. In this location, there is a better correspondence between the ebb and flood proportions of the velocity and the concentration course.

Table 7-5: Average tidal curves of the sediment concentration, time to HW of the minimal (around slack waters) and maximal (during the ebb and flood phase, max value of both in bold characters) concentration for an average neap, average and spring tide.

Location	Depth (m TAW)	Tidal phase	*Min around LSW 1*	*Max during flood*	*Min around HSW*	*Max during ebb*	*Min around LSW 2*	*Tide duration*
Buoy 84	-8.1	Neap	-05:40	-03:50	01:10	03:50	07:00	12:40
		Average	-05:10	-03:50	01:20	03:50	07:10	12:20
		Spring	-05:10	-03:50	01:30	03:50	07:10	12:20
Buoy 84	-5.8	Neap	-04:40	-01:30	01:20	03:50	07:50	12:30
		Average	-04:30	-01:40	01:30	03:50	08:00	12:30
		Spring	-04:30	-03:20	01:40	03:50	08:00	12:30
Oosterweel	-5.7	Neap	-05:30	-02:10	00:50	02:20	07:10	12:40
		Average	-05:10	-02:10	00:50	02:10	07:00	12:10
		Spring	-05:00	-02:10	00:50	02:20	07:20	12:20
Oosterweel	-2.1	Neap	-04:50	-02:00	01:20	02:20	07:40	12:30
		Average	-04:40	-02:00	01:20	02:10	07:40	12:20
		Spring	-04:40	-02:10	01:30	02:10	07:50	12:30

7.4 NEAP TIDE – SPRING TIDE VARIATIONS AND INFLUENCE OF FLOW VELOCITY

The velocity course during a neap tide is different from the one during a spring tide. The flow during flood is also qualitatively different for a spring tide and a neap tide. During a spring tide the flood velocities are more asymmetric and they display a distinct double peak. During a neap tide the flood course of the velocity occurs more gradually. This means that along neap tide and spring tide cycles the peak flood velocities undergo relative increases in a more pronounced way than the peak ebb velocities, resulting therefore in a relatively higher erosion of sediment during a spring tide flood than during a neap tide flood.

For instance, in Buoy 84 the average sediment concentration at the lower and upper measurement instruments respectively, during a spring tide (Annex-Tables F-1 to F-6) is 102% and 110% higher than during a neap tide, and the increase can be felt more during flood (111% and 122%) than during ebb (108% and 102% respectively).

In Oosterweel there is not a great degree of difference between the average sediment concentrations recorded at the lower and upper measurement instrument locations respectively, and during spring tides and neap tides. The following being the average difference for both: during ebb and during flood is 23%.

Also to be observed, is that the increase in sediment transport between neap tide and spring is felt in a more pronounced way at the bottom stations during the winter. In summer, the increase along the cycle is identical for the lower and higher stations.

In the upstream direction, the influence of the tidal amplitude on the flow velocity is less obvious and the flow is mainly ebb-oriented. Although it is difficult to draw any conclusions or to observe any trends for the sediment transport because configurations at each of the measurement locations differ (depth, distance to water channel, quay-walls, banks and other constructions that might influence the sediment transport).

One of the factors that determines transport is the flow velocity. The relation between tidal amplitude and flow velocity found in section §3.1 might provide an explanation for the variations in concentrations in the neap and spring tide cycle. In Annex-Figure F-23 to Annex-Figure F-26, the ebb-average, respectively, flood-average sediment concentration, has been determined on the basis of the ebb-average, respectively flood-average flow velocity. The figures clearly indicate that the average sediment concentration is in significant correlation with the average flow velocity at Buoy 84, where the correlation factor is fairly high (0.42-0.59) both for ebb and flood. In Oosterweel, it seems that the sediment concentration can only be correlated with the velocity during flood at the top sensor (0.4) and during ebb at the bottom sensor (-0.31; negative correlation). At the top sensor position during ebb, and at the bottom sensor position during flood on the instrument used for flood conditions, the readings that show correlation factors are fairly low, while the significance is fairly high, indicating that here there is no relationship between both variables. This might, among others things, be explained by the fact that in Oosterweel the flow is more ebb-oriented and is thus more concentrated in the navigation channel. Since the instrument is located outside the channel, it is normal that no relationship can be found between both variables.

As was also observed during the 2008–2010 period, the correlation found during the current period at Buoy 84 shows that the angle of the fitted lines is steeper for autumn and winter than it is for spring and summer. It is known that during summer, algae layers on top of intertidal areas increase the critical shear stress. It can therefore be the reason why certain flow velocities correlate with higher concentrations in winter compared to summer.

A correlation of velocity and sediment concentration was found here, but the flow velocity is far from being the sole factor that exerts influence on sediment concentration. The relationship with the tidal amplitude of section §3.1 only forms a partial explanation for the development in the neap and spring tide cycle, but also in the flow regime and hence in the interaction between tidal amplitude and discharge. The sediment availability also forms an important factor. This will be discussed below.

7.5 PROLONGED VARIATIONS

The variations on a long-term scale of the sediment concentrations may be caused by different, although not always independent, influential factors. For example:

- Fresh water discharge (shifting of zones with high salinity gradients and intense mixing processes of salt and fresh water, larger sediment input from the non-tidal related part of the basin)
- Temperature (biological activity, climate factors, organic material in suspension and aggregation/ flocculation of sediment particles),
- Storm surges,
- Land erosion (terrestrial input of fine sediments)
- Human activities

Hereinafter, we will first discuss the evolutions along the seasonal cycle (Annex-Figure F-35 and Annex-Figure F-36), then the influence of the interaction between discharge and tidal effects and last but not least the long-term evolution of the suspended sediment concentration.

7.5.1 Seasonal cycle

Temperature is a variable, which is clearly related to the seasons. That is why temperature may be used to show the season-related variation of the sediment concentration. Annex-Figure F-27 to Annex-Figure F-34 display the tidal-average sediment concentration based on the tidal-average water temperature for the measurement stations. The coefficients of Buoy 84 and Oosterweel are all negative and between -0.14 and -0.43, this means to say that the periods with a low water temperature (winter) correspond to periods with a higher sediment concentration rather than to periods with higher temperatures (summer) and that both variables are correlated in a comparable way, as the correlation with the velocity. This corroborates with the seasonal influences that are clearly visible in Annex-Table F-1 to Annex-Table F-6, showing that on average concentrations are 18.6 % higher during winter than they are in summer, with maximum differences of 56.4 %. Care must be taken in interpreting these results, because (as can be seen in § 6.1) the temperatures that occur are mostly around 8 to 20°C and hence the temperature data used in the correlation analysis is not homogeneously distributed. This explains the peaks in the sediment concentrations around these temperatures, because any extreme event leading to a high sediment concentration is more likely to occur at one of these temperatures, because they occur most frequently.

7.5.2 Interaction tide-discharge

Table 7-1 to Table 7-4 indicate the ebb and flood maximum and average sediment concentration of the different flow regimes discussed in Chapter 4.

According to the literature (see for example Dyer, 1995) in meso tidal and macro tidal estuaries, there is one zone that has higher sediment concentrations than those found elsewhere. The turbidity maximum is usually found at the upstream end of the salt penetration front, which is a zone with a salinity of 1 to 5 ppt. The intertidal saline regime contains this saline front for each tide and this explains the higher concentration values. In the present dataset the maximum sediment concentrations occur at Buoy 84 confirming that the turbidity maximum is indeed occurring in the area studied.

For example, in Annex-Figure F-3 it is clear that the minimal tidal sediment concentration correlates well over the long-term, with the fresh water discharge at Buoy 84. The same can be observed for Oosterweel in the following figures. The causality might be direct or indirect. High discharge occurs in winter, when sediments are also eroded more easily due to, among other factors, the absence of algae within intertidal areas and a higher frequency of storms.

7.5.3 Long-term Evolution

The long-term evolution of the suspended sediment concentration at Buoy 84 does not show any obvious trends. However, there is a seasonal cycle that shows higher sediment concentrations during summer periods and lower sediment concentrations during winter periods. Possibly a rise in the suspended sediment concentration is masked in the top instrument due to saturation of the SeaGuard’s turbidity sensor (Annex-Figure F-37 and Annex-Figure F-38). At the Oosterweel measurement location, there is a long-term trend of rising sediment concentrations in both bottom and top measurement locations. From 2005 onward the data shows increased sediment concentration (Annex-Figure F-39. In 2005 an average sediment concentration of about 150 mg/l is found, going up to 250 mg/l in 2008 and 350 mg/l in 2011. Up until 2008, monthly moving averages varied only slightly with the seasons: about 100 mg/l difference. In the spring of 2010 remarkable variations occurred with variations in the monthly moving averages amounting to more than 400 mg/l.

In IMDC (2013c) is proved that significant human influences had an impact on the sediment concentration values in the Lower Sea Scheldt: deepening of the fairway, the opening (2005) and maintenance of Deurganckdock. At the Oosterweel measurement station in particular, there is a clear increase of the sediment concentration between 2005 and 2012. Possible causes are dumping of dredging material from the Deurganckdok at the dumping location the Plaat van Boomke close to Oosterweel station.

On the other hand, it is known that the lunar nodal tide variations (18.6 year cycle) have an influence on tidal range and thus sediment concentration (E.g. Wang and Townend, 2011). The nodal factor was rising in the period 2007–2010 and could therefore be partially responsible for rising trends during that period.

8. CONCLUSION

The analysis of the measurements has clearly proven that the variables measured vary in a very complex way with the tide, along neap and spring tide cycles and with the seasons. The tide-related and the neap and spring tide variations may be explained by the hydrodynamics of the estuary. The seasonal-related variations are caused by climate, physical, chemical and biological processes.

Flow velocity, salinity, sediment concentration and temperature clearly vary with the tide. Furthermore, sediment concentration, salinity and temperature display prolonged variations (seasons). The influence of seasons stands in direct relationship to the climatological cycle. However, the influence on the sediment concentration and salinity is indirectly related due to variations in discharge and biological activity.

Nevertheless, the data in the current measurement period, which ranges from April 2010 to March 2012, compares well with the data measured between April 2008 and March 2010 (IMDC 2013b). For the flow velocity data this could be expected, as these are mainly determined by the astronomical tide, which does not show much variation across the years, and because the fresh water flow discharge in the River Scheldt showed very similar statistics for both periods.

The data for the suspended sediment concentration show a distinct long-term trend. At the Oosterweel measurement station in particular, there is a clear increase of the sediment concentration between 2005 and 2012. In IMDC (2013c) is proved that there is strong relation between the sediment concentration increase and the dredging activities on the Lower Sea Scheldt. There will be also impact of lunar nodal factor influences on tidal range.

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IMDC (2011b) Evaluatie externe effecten aanslibbing Deurganckdok. Deelrapport 1.2 Annual Sediment Balance year 2: 1/04/2009–31/03/2010 (I/RA/11354/10.100/MBO/ANF)

IMDC (2011c) Evaluatie externe effecten aanslibbing Deurganckdok. Deelrapport 1.4 Boundary Conditions year 1: 01/04/2009 – 31/03/2010 (I/RA/11354/10.102/MBO/ANF)

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IMDC (2012c) Evaluatie externe effecten aanslibbing Deurganckdok. Deelrapport 2.6 Through Tide measurement: eddy currents DGD Autumn 2011 (I/RA/11354/10.110/MBO/ANF)

IMDC (2012d) Evaluatie externe effecten aanslibbing Deurganckdok. Deelrapport 2.10 Salt-Silt & Current Distribution entrance Deurganckdok: Frame measurements and through tide measurements: Autumn 2011 (I/RA/11354/11.131/BQU)

IMDC (2012e) Evaluatie externe effecten aanslibbing Deurganckdok. Deelrapport 2.12 Calibration stationary & mobile equipment 16/03/2011 (I/RA/11354/11.113/MBO/ANF)

IMDC (2012f) Evaluatie externe effecten aanslibbing Deurganckdok. Deelrapport 1.5 Boundary conditions year 2: 01/04/2010–31/03/2011 (I/RA/11354/11.103/MBO/ANF)

IMDC (2012g) Evaluatie externe effecten aanslibbing Deurganckdok. Deelrapport 2.3 Through Tide Sediview measurement: entrance DGD during spring tide in Winter 2012 (I/RA/11354/10.108/MBO/ANF)

IMDC (2012h) Evaluatie externe effecten aanslibbing Deurganckdok. Deelrapport 2.4 Through Tide Sediview measurement: entrance DGD during neap tide in Winter 2012 (I/RA/11354/10.109/MBO/ANF)

IMDC (2012k) Evaluatie externe effecten aanslibbing Deurganckdok. Deelrapport 2.7 Through Tide measurement: eddy currents DGD Winter 2012 (I/RA/11354/10.111/MBO/ANF)

IMDC (2012l) Evaluatie externe effecten aanslibbing Deurganckdok Deelrapport 2.11 Salt-Silt & Current Distribution entrance Deurganckdok: Frame measurements and through tide measurements: Winter 2012 (I/RA/11354/11.114/MBO/ANF)

IMDC (2012m) Evaluatie externe effecten aanslibbing Deurganckdok. Deelrapport 1.3 Annual Sediment Balance year 3: 1/04/2011–31/03/2012 (I/RA/11354/10.101/MBO/ANF)

IMDC (2012n) Evaluatie externe effecten aanslibbing Deurganckdok. Deelrapport 2.9 Sal-Silt distribution Deurganckdok 01/04/2009–31/05/2010 (I/RA/11354/10.112/MBO/ANF)

IMDC (2012o) Evaluatie externe effecten aanslibbing Deurganckdok. Deelrapport 2.13 Calibration stationary & mobile equipment 01/06/2012 (I/RA/11354/12.011/JCA)

IMDC (2012p) Evaluatie externe effecten aanslibbing Deurganckdok. Deelrapport 1.6 Boundary conditions year 3: 01/04/2011–31/03/2012 (I/RA/11354/11.104/MBO/ANF)

IMDC (2013a) Evaluatie externe effecten aanslibbing Deurganckdok. Deelrapport 1.8 Analysis of external effects on siltation processes and factors (I/RA/11354/10.105/MBO/ANF)

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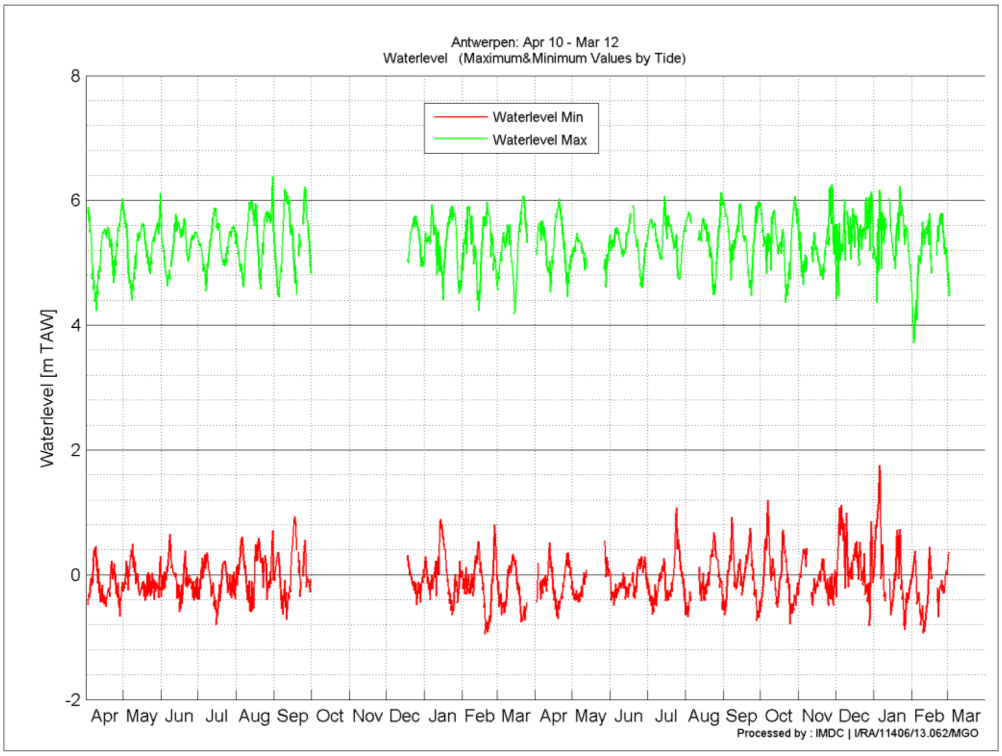
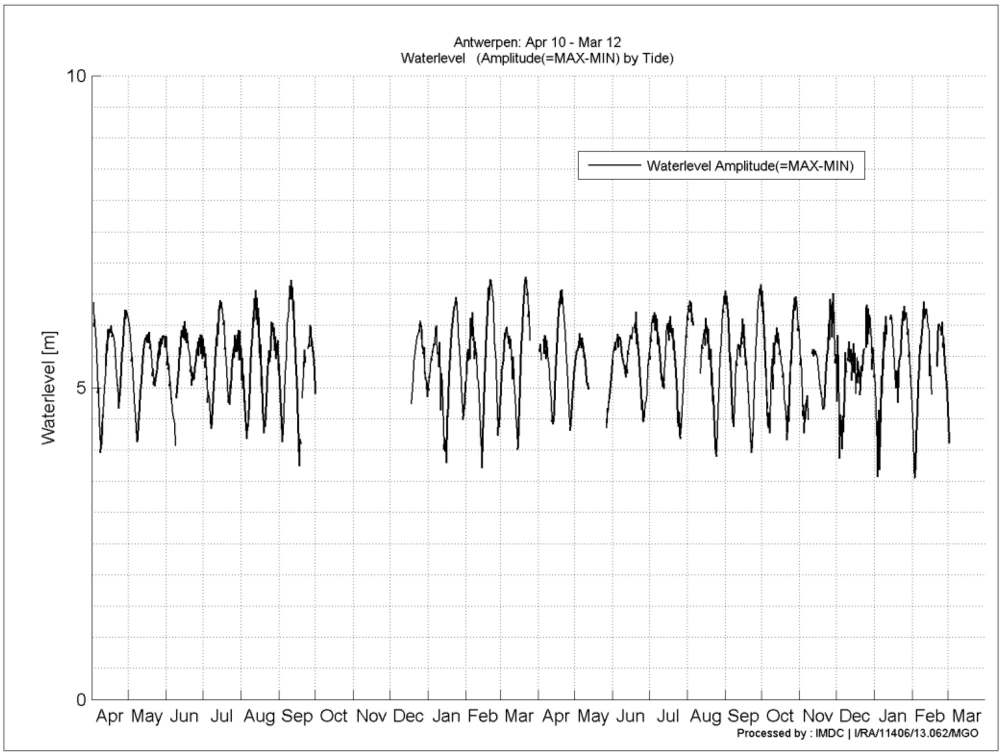
Annex A Overview of the reports from the previous project: External effects siltation Deurganckdok (2009–2012)

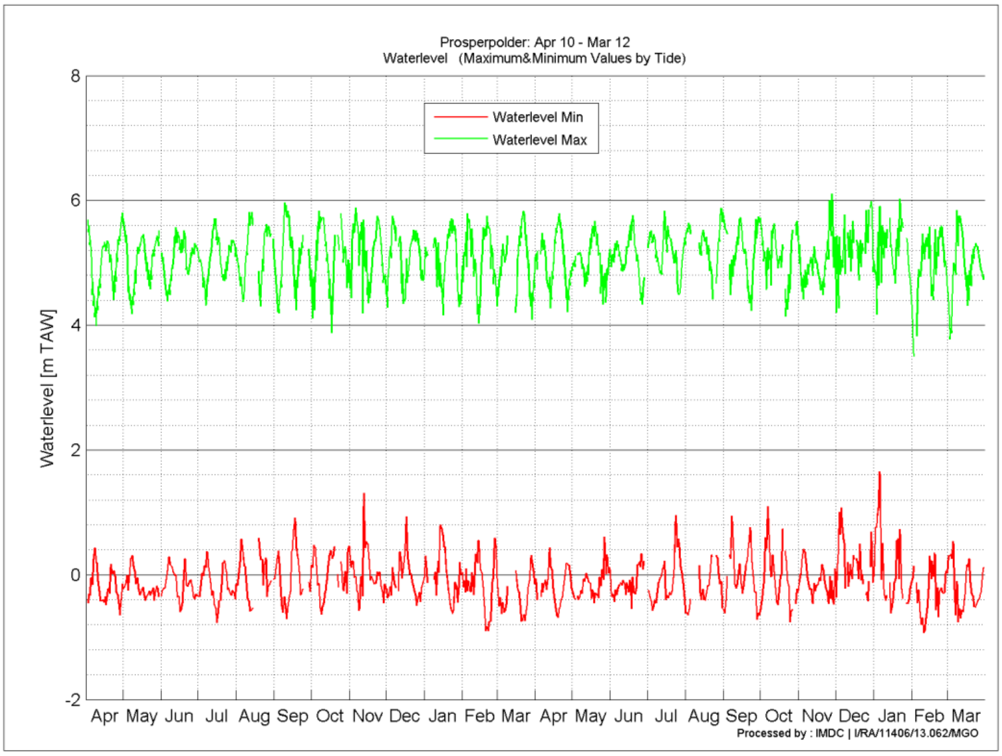
Report	Description
1.	**Reporting**
I.1 Annual Sediment Balance: Bathymetry surveys, Density measurements, Maintenance and construction dredging activities	
1.1	Annual Sediment Balance year 1: 1/4/2009–31/3/2010 (I/RA/11354/10.067/NZI)
1.2	Annual Sediment Balance year 2: 1/4/201031/3/2011 (I/RA/11354/10.100/MBO/ANF)
1.3	Annual Sediment Balance year 3: 1/4/2011–31/3/2012 (I/RA/11354/10.101/MBO/ANF)
I.2 Boundary Conditions: Upriver discharge, Salt concentration Scheldt, Bathymetric evolution in access channels, Dredging activities in Lower Sea Scheldt and access channels	
1.4	Boundary Conditions year 1: 01/04/2009–31/3/2010 (I/RA/11354/10.102/MBO/ANF)
1.5	Boundary Conditions year 2: 01/04/2010–31/3/2011 (I/RA/11354/10.103/MBO/ANF)
1.6	Boundary Conditions year 3: 01/04/2011–31/3/2012 (I/RA/11354/10.104/MBO/ANF)
I.3 Synthesis of CDW research	
1.7	Synthesis report of research on Current Deflecting Wall (I/RA/11354/10.063/MBO)
I.4 Analysis: evaluation of external effects on siltation in Deurganckdok	
1.8	Analysis of external effects on siltation processes and factors (I/RA/11354/10.105/MBO/ANF)
2.	**Measurement campaigns: Factors contributing to salt and sediment distribution in Deurganckdok: Salt-Silt (OBS3A) & Frame measurements, Through-tide measurements (Silt Profiling & ADCP) & Calibrations**
II.1 Through-tide measurements fixed transects	
2.1	Through-tide Sediview measurement: Entrance DGD during spring tide Autumn 2011 (I/RA/11354/10.106/MBO/ANF)
2.2	Through-tide Sediview measurement: Entrance DGD during neap tide Autumn 2011 (I/RA/11354/10.107/MBO/ANF)
2.3	Through-tide Sediview measurement: Entrance DGD during spring tide Winter 2012 (I/RA/11354/10.108/MBO/ANF)
2.4	Through-tide Sediview measurement: Entrance DGD during neap tide Winter 2012 (I/RA/11354/10.109/MBO/ANF)
II.2 Through tide measurements eddy currents	
2.5[2]	Through-tide measurements: Eddy Currents DGD 02/03/2010 (I/RA/11283/10.051/MSA)
2.6	Through-tide measurements: Eddy Currents DGD Autumn I/RA/11354/10.110/MBO/ANF)
2.7	Through-tide measurements: Eddy Currents DGD Spring 2012 (I/RA/11354/10.111/MBO/ANF)
II.3 Salt-Silt Distribution entrance Deurganckdok	
2.8[3]	Salt-Silt distribution Deurganckdok 1/4/2009–31/3/2010 (I/RA/11354/10.068/NZI)
2.9	Sal-Silt distribution Deurganckdok 1/6/2011–30/05/2012 (I/RA/11354/10.112/MBO/ANF)
II.4 Current Salt-Silt Distribution CDW Deurganckdok	
2.10	Salt-Silt & Current Distribution entrance Deurganckdok: frame measurements and through-tide measurements: Autumn 2011 (I/RA/11354/11.131/BQU)
2.11	Salt-Silt & Current Distribution entrance Deurganckdok: frame measurements and through-tide measurements: Winter 2012 (I/RA/11354/10.114/MBO/ANF)
II.5 Quality Control instruments	
2.12	Calibration stationary & mobile equipment 16/03/2011 (I/RA/11354/10.113/MBO/ANF)
2.13	Calibration stationary equipment 2012 (I/RA/11354/12.011/JCA)

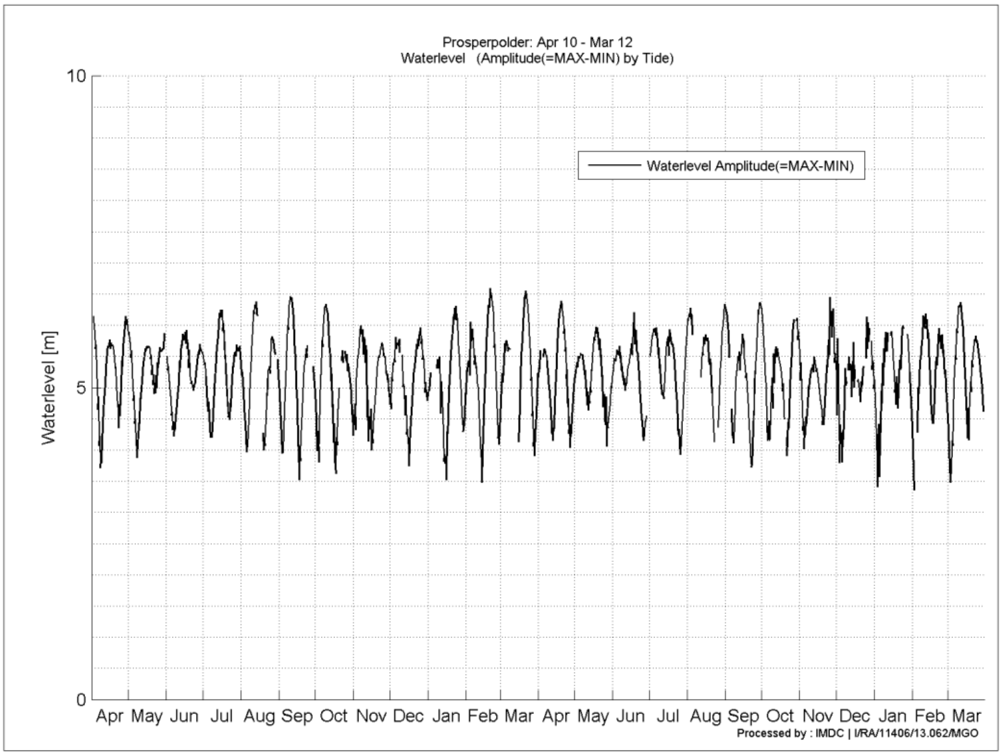
Annex B Figures for tide and discharge



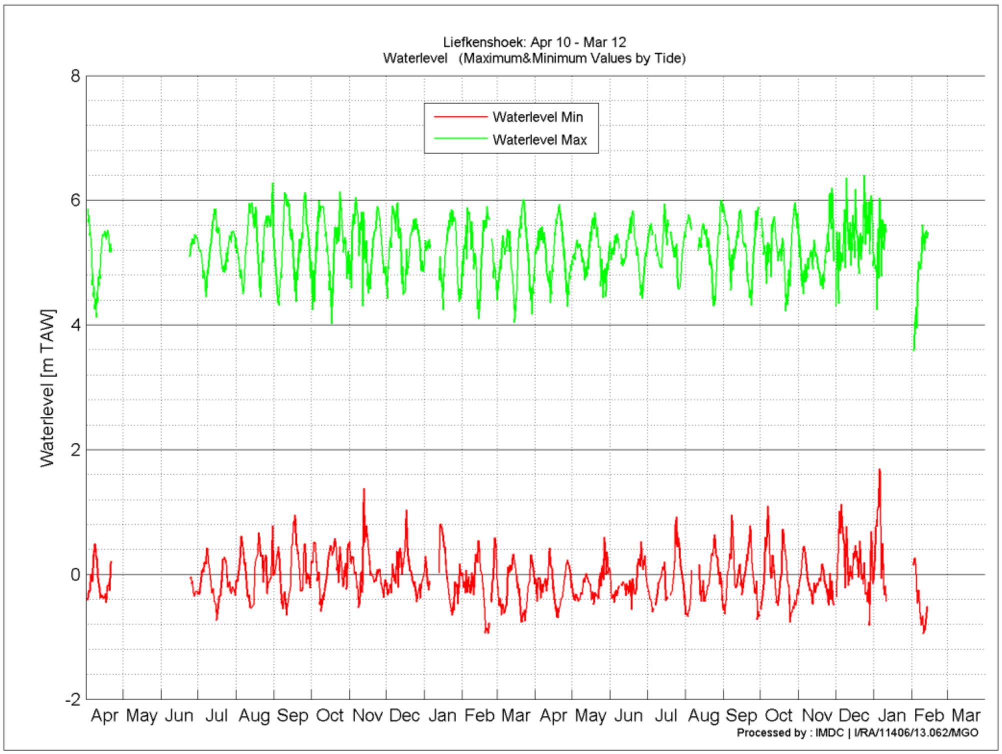


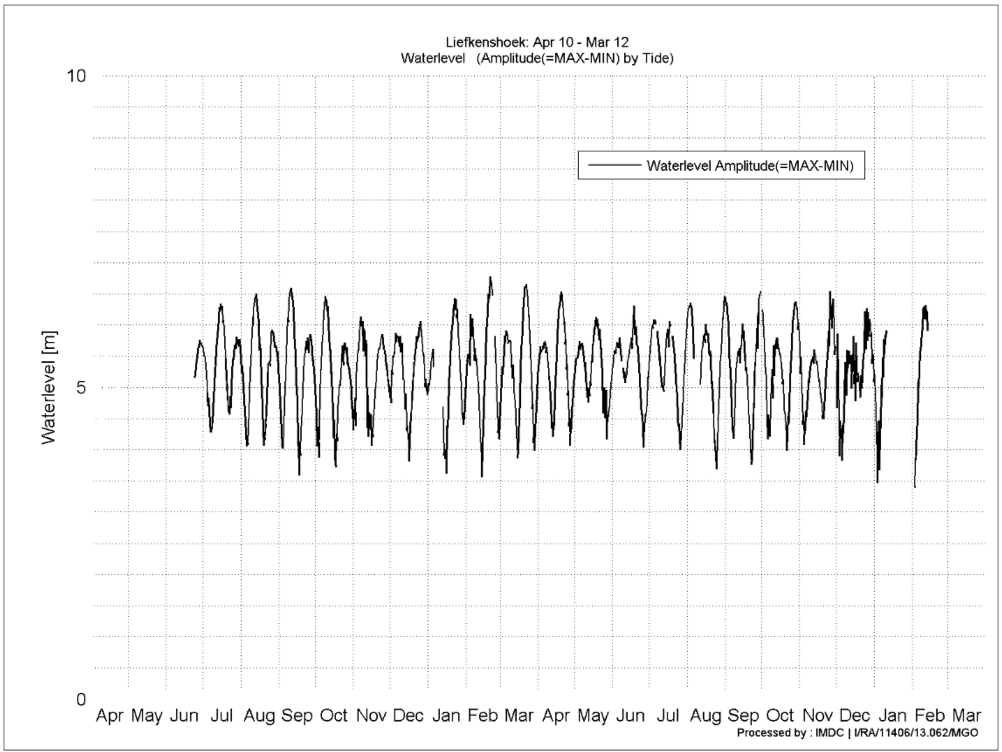
Annex-Figure B-1: Antwerp April 2010 – March 2012 (a) HW and LW (b) Tidal Amplitude.



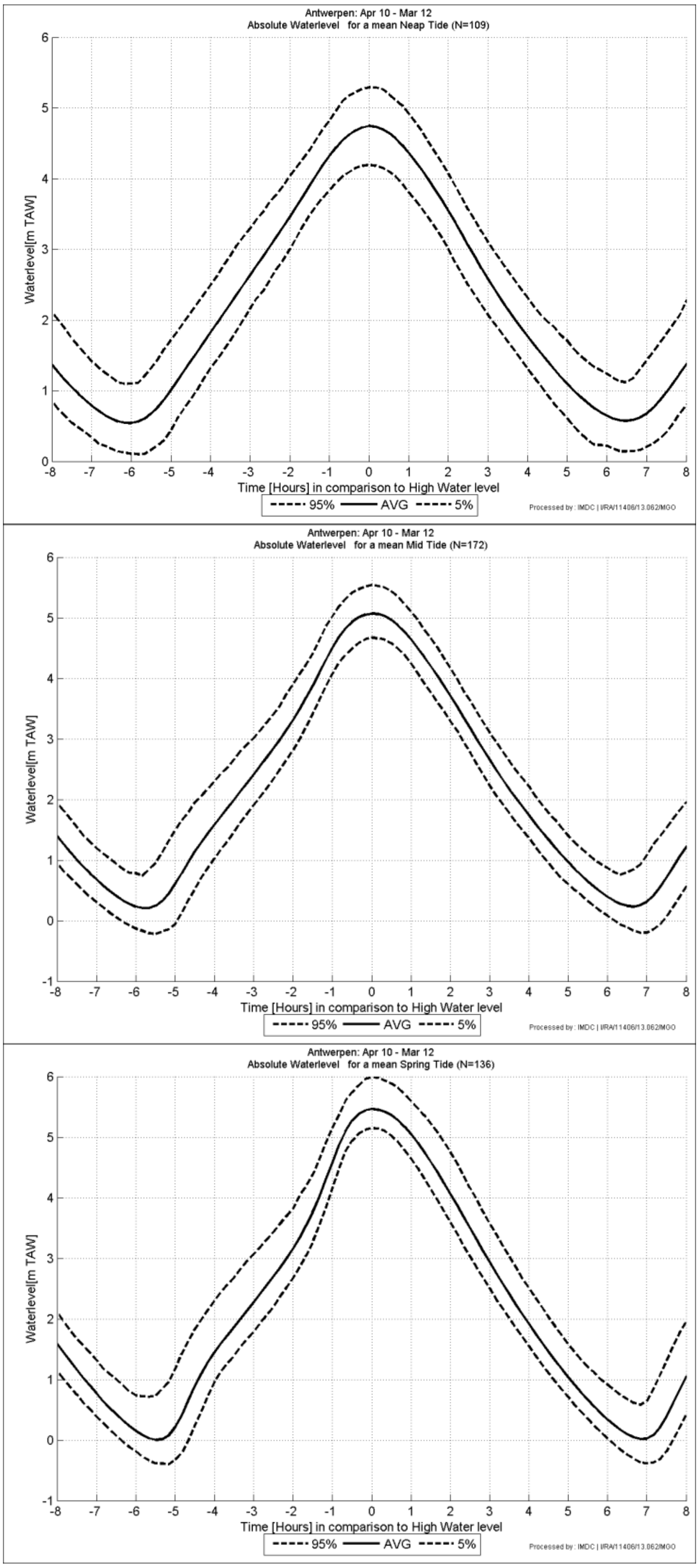


Annex-Figure B-2: Prosperpolder April 2010 – March 2012 (a) HW and LW (b) Tidal Amplitude.

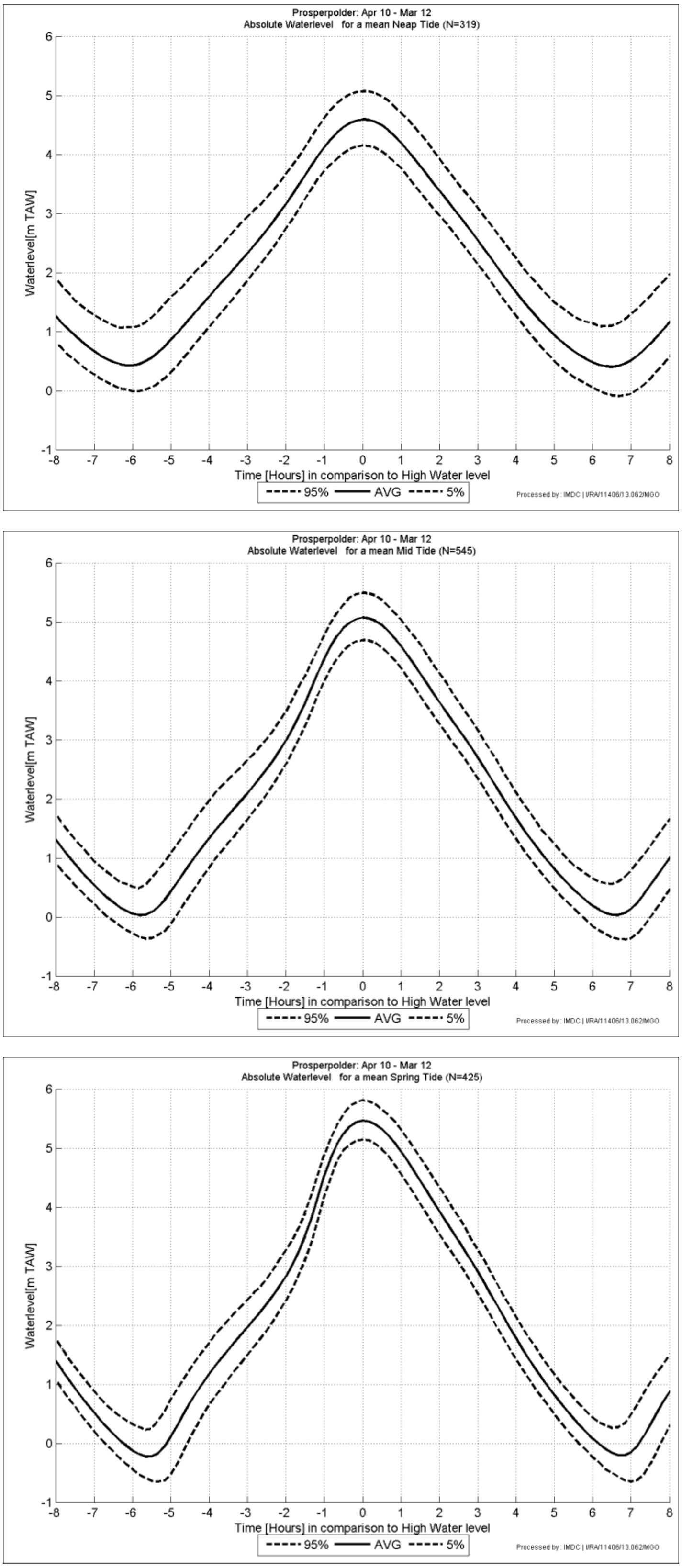




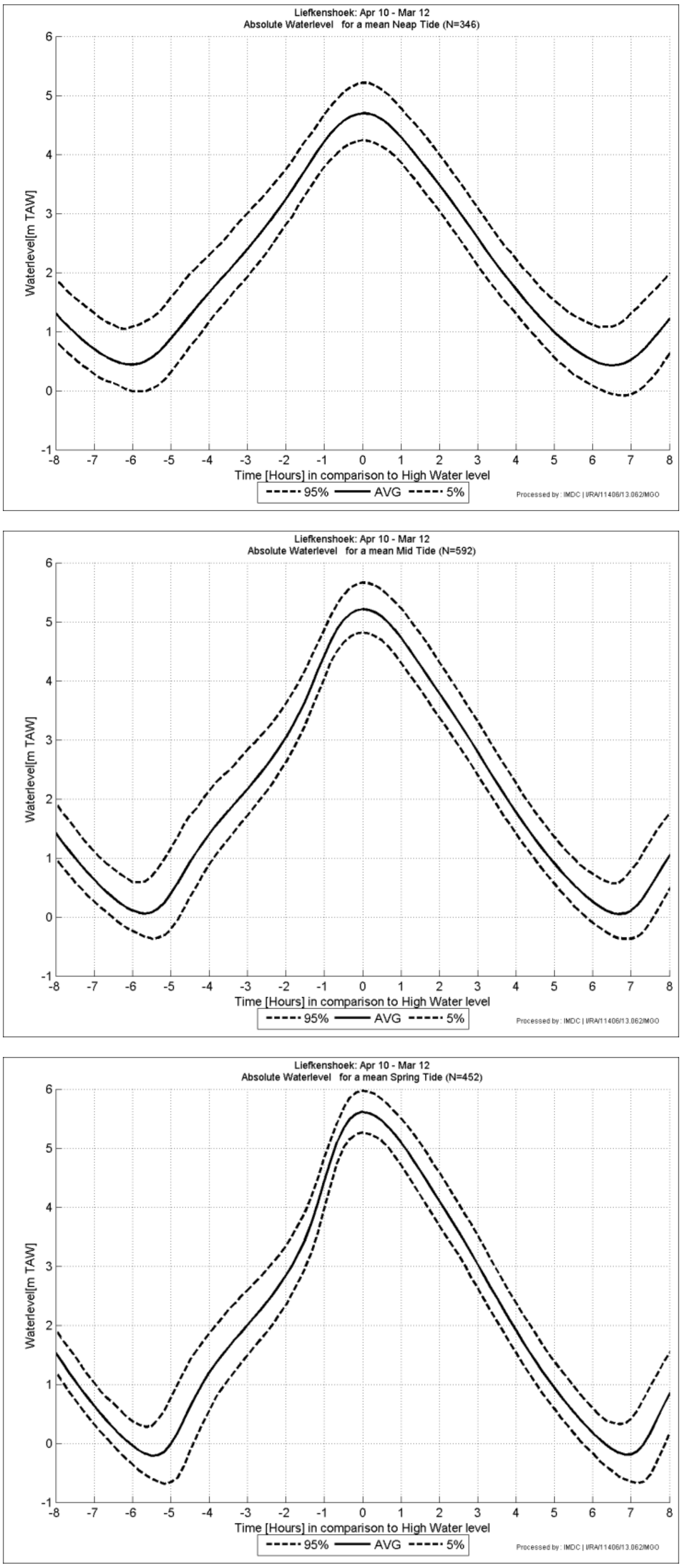
Annex-Figure B-3: Liefkenshoek April 2010 – March 2012 (a) HW and LW (b) Tidal Amplitude.



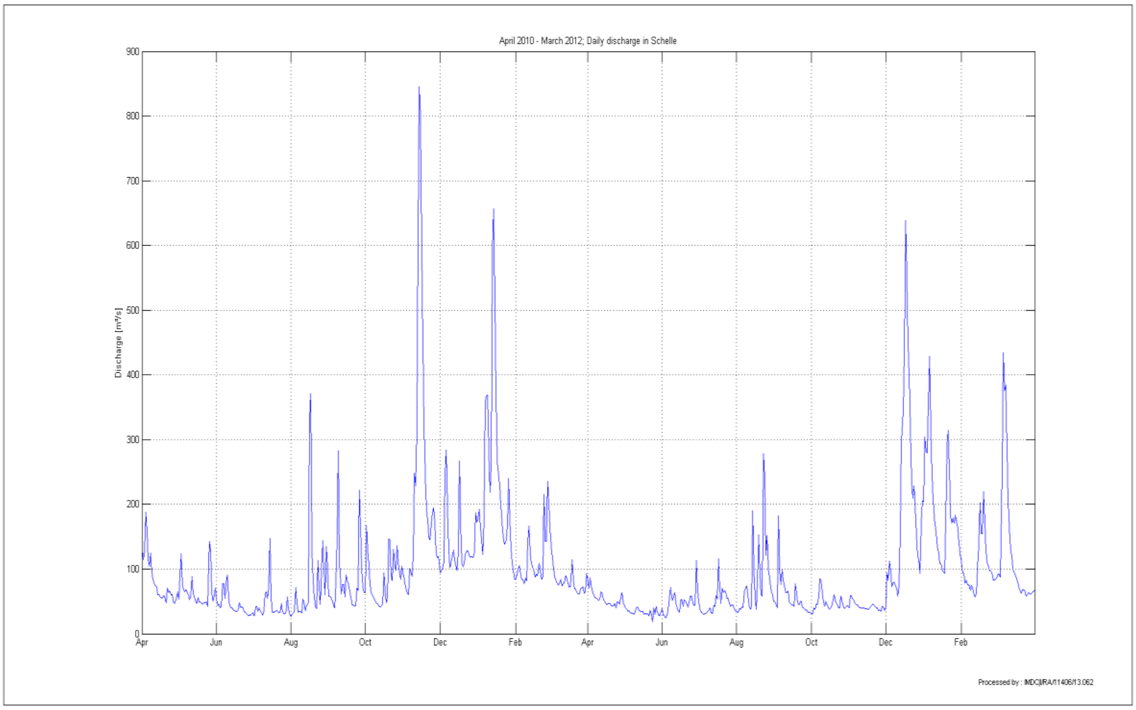
Annex-Figure B-4: Antwerp Averaged (a) neap tide, (b) average tide and (c) spring tide curve, April 2010 – March 2012.

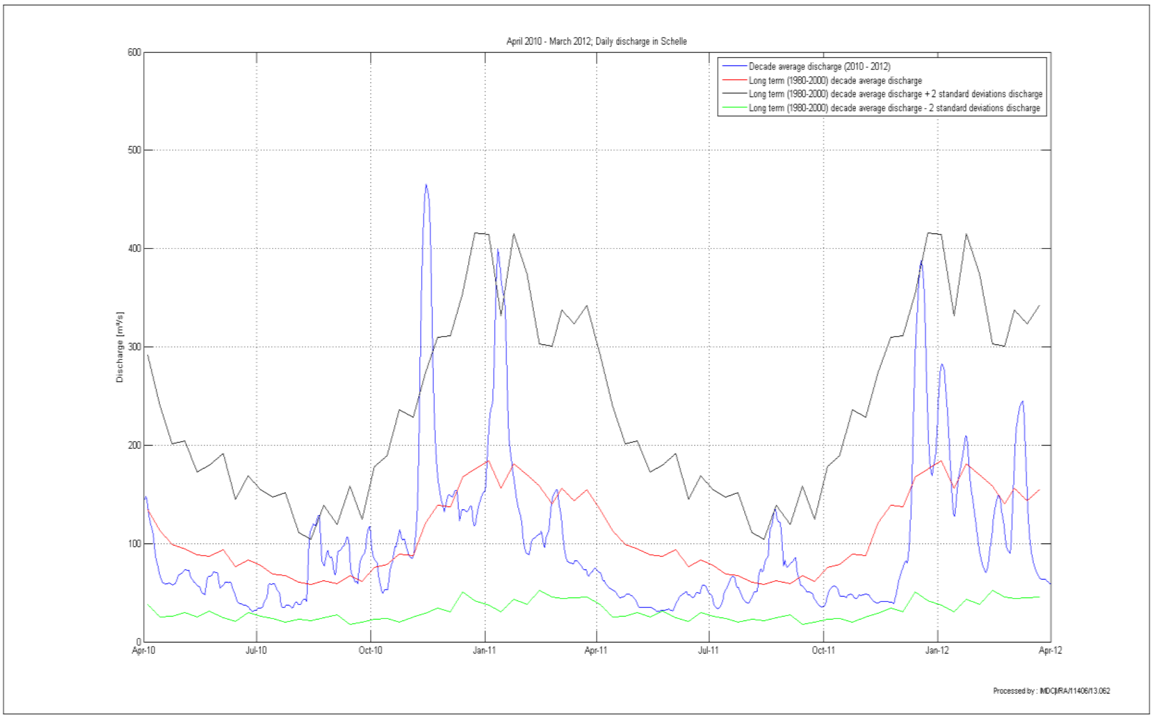


Annex-Figure B-5: Prosperpolder Averaged (a) neap tide, (b) average tide and (c) spring tide curve, April 2010 – March 2012.



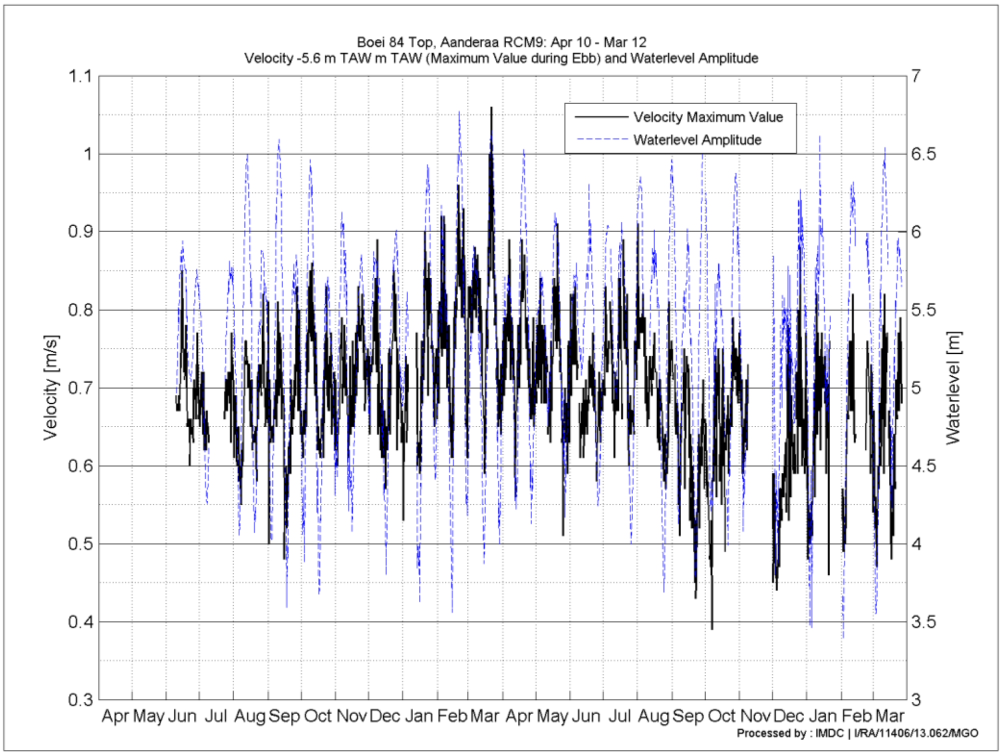
Annex-Figure B-6: Liefkenshoek Averaged (a) neap tide, (b) average tide and (c) spring tide curve, April 2010 – March 2012.

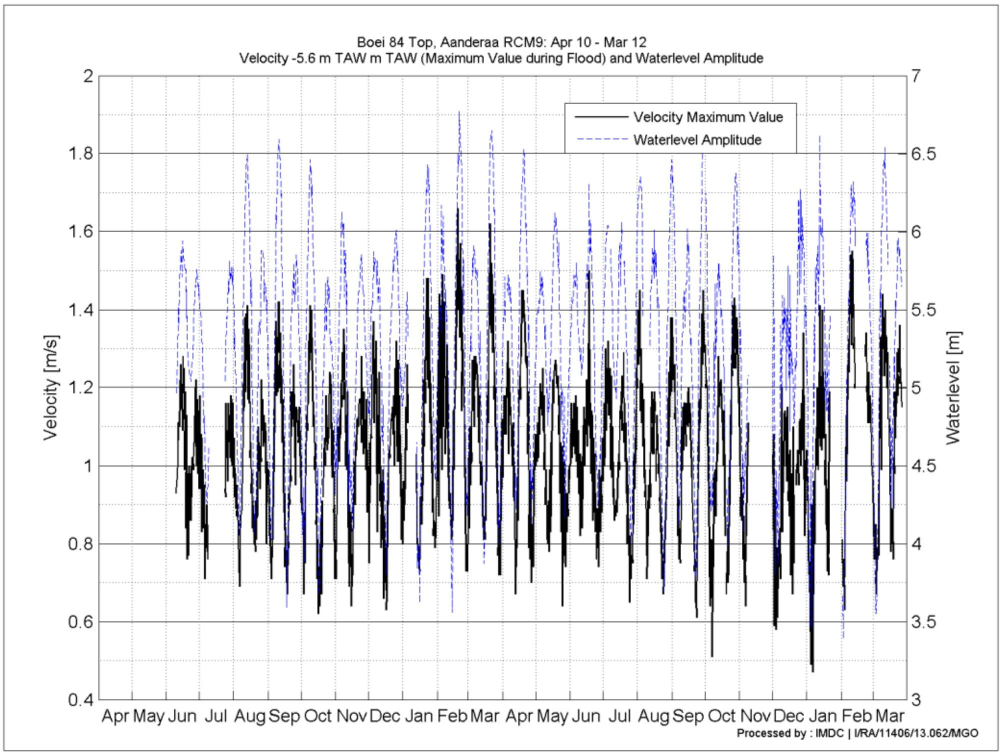




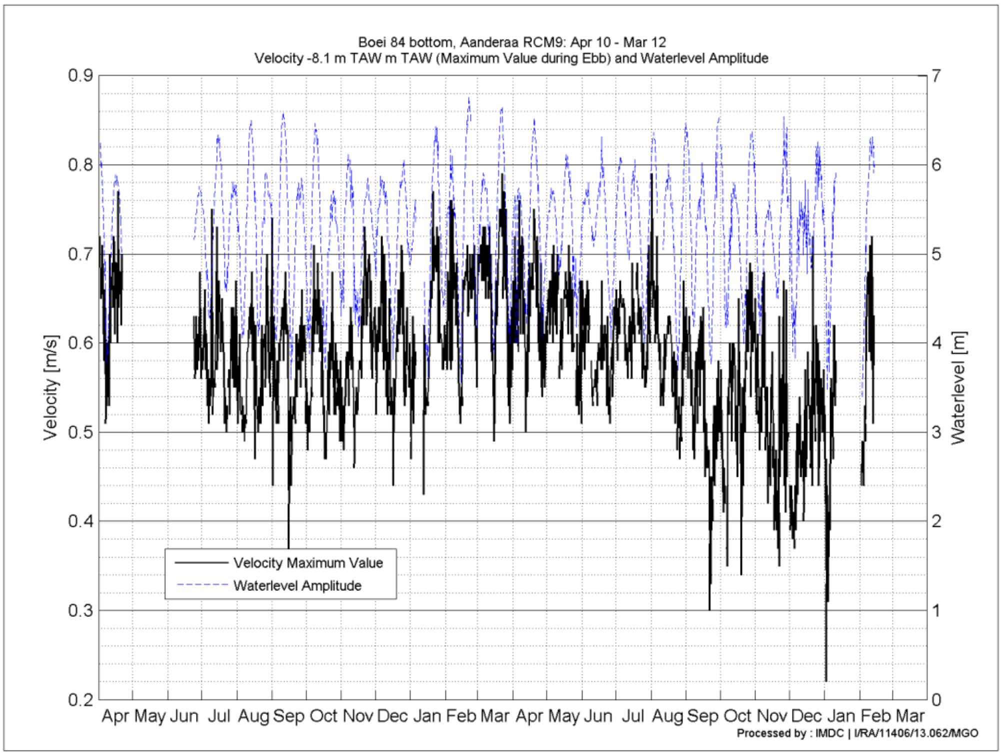
Annex-Figure B-7: (a) Day averaged and (b) decade averaged Scheldt discharge at Schelle.

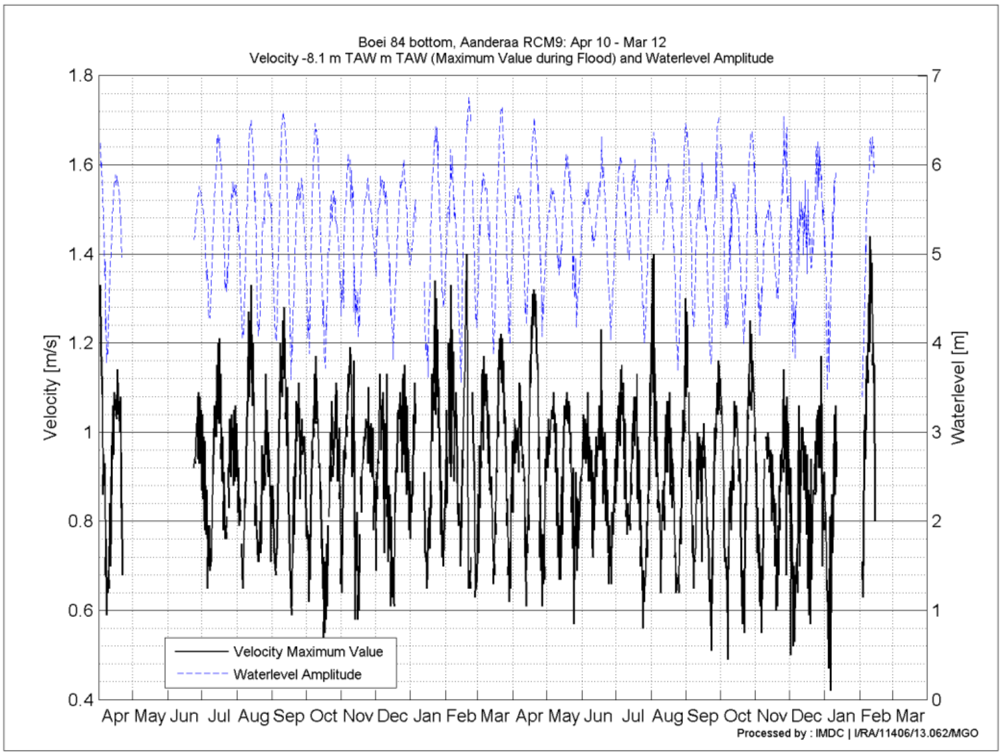
Annex C Figures for flow velocity and direction



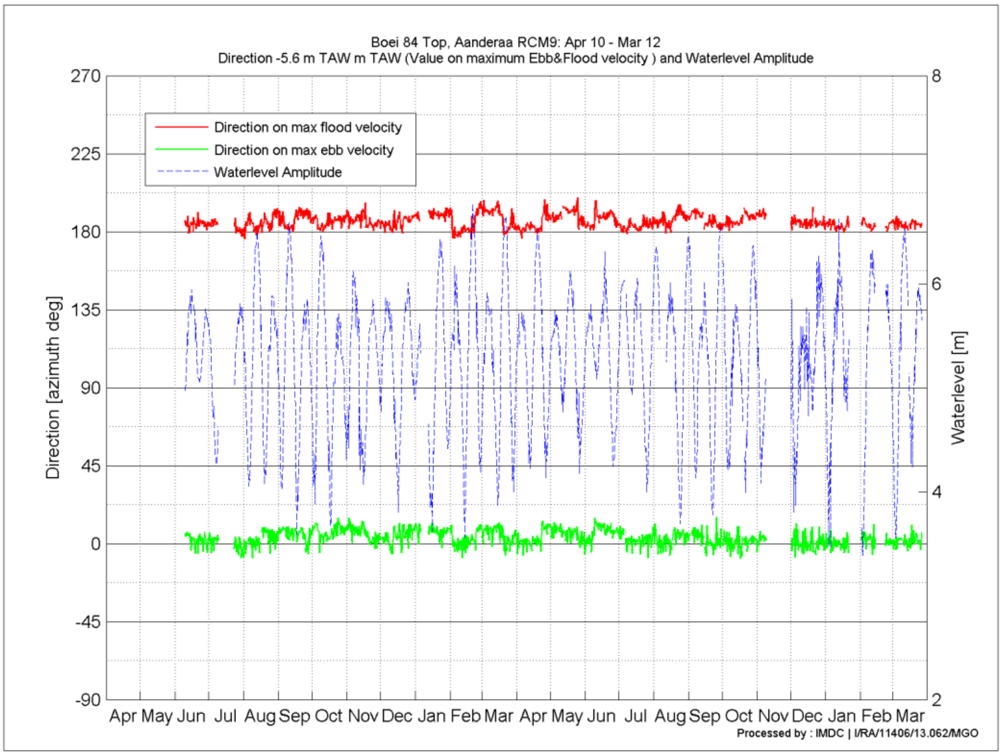


Annex-Figure C-1: Buoy 84 Top (-5.6 m TAW). Maximum (a) ebb & (b) flood phase velocity and tidal amplitude at Liefkenshoek, April 2010 – March 2012.

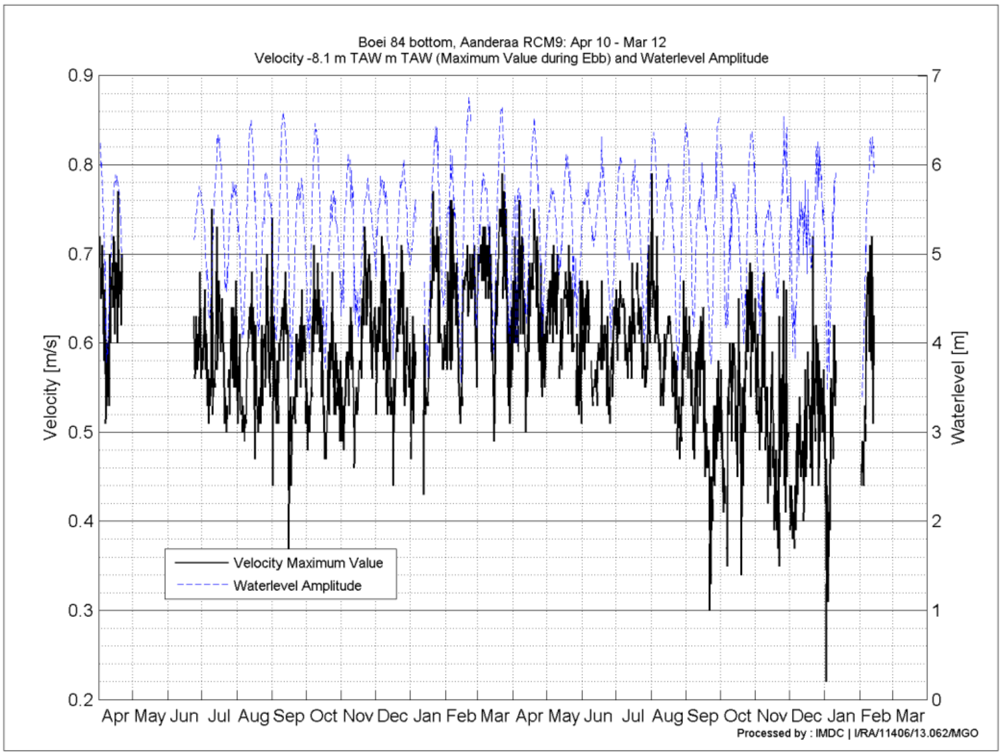


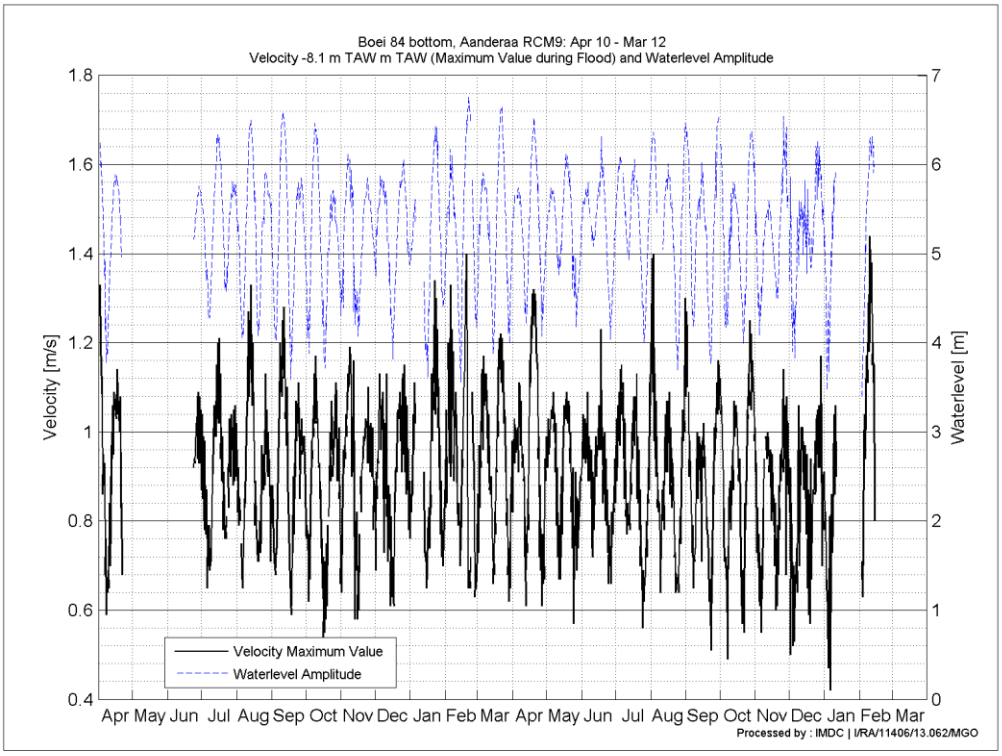


Annex-Figure C-2: Buoy 84 Bottom (-8.1 m TAW). Maximum (a) ebb & (b) flood phase velocity and tidal amplitude at Liefkenshoek, April 2010 – March 2012.

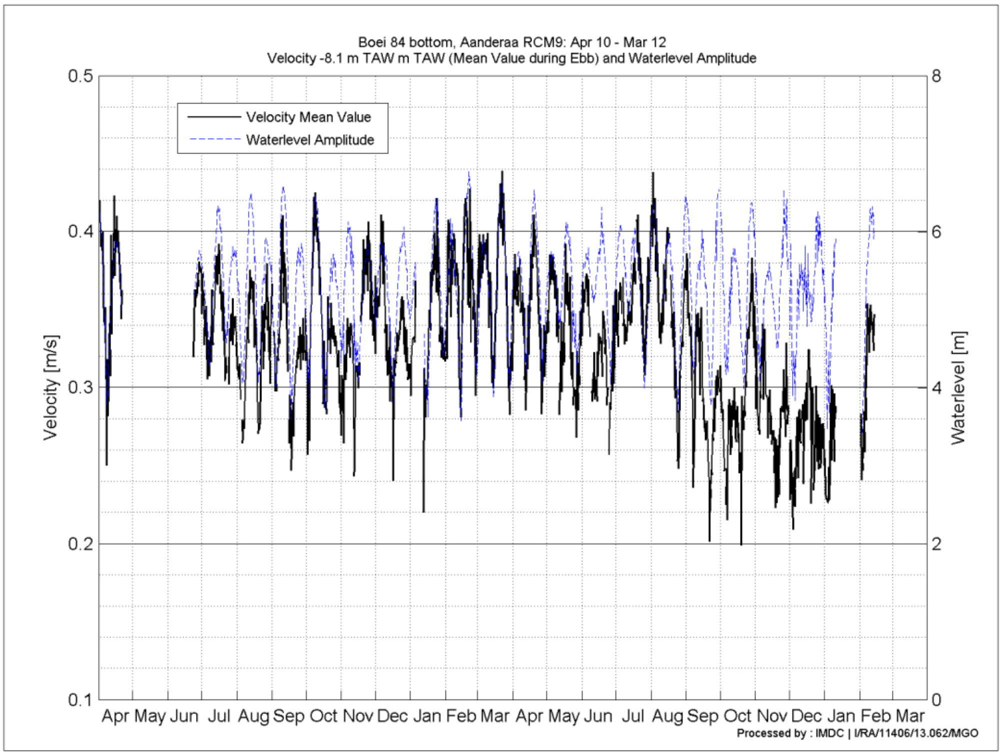


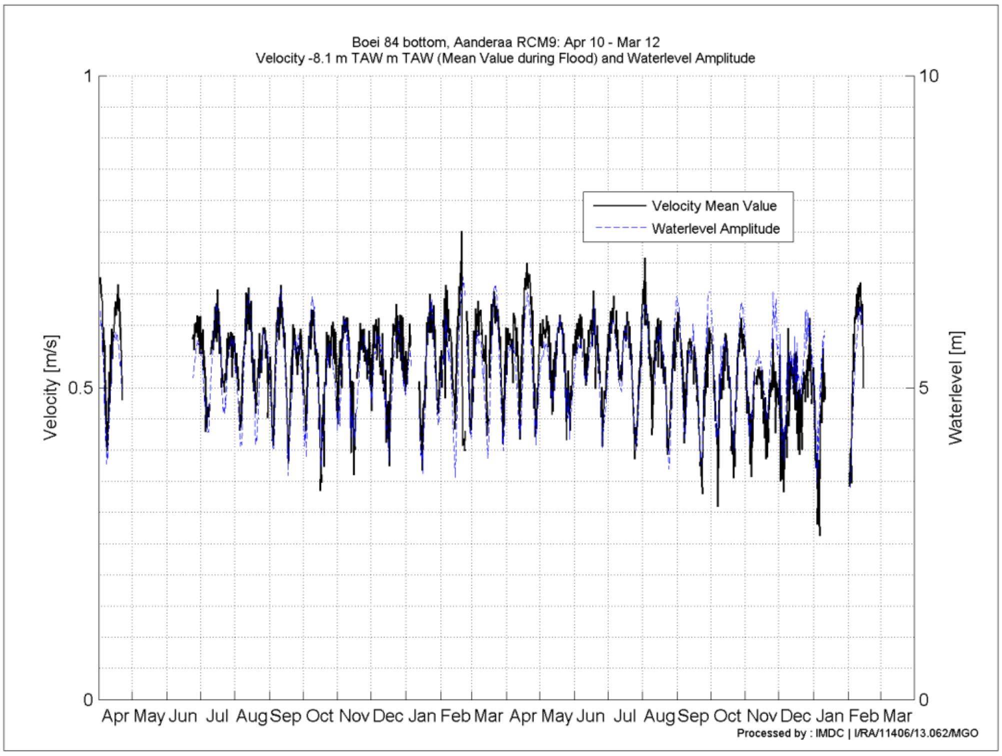
Annex-Figure C-3: Buoy 84 (-5.6 m TAW). Flow direction on maximal ebb phase and flood phase velocity and water level amplitude, April 2010 – March 2012.



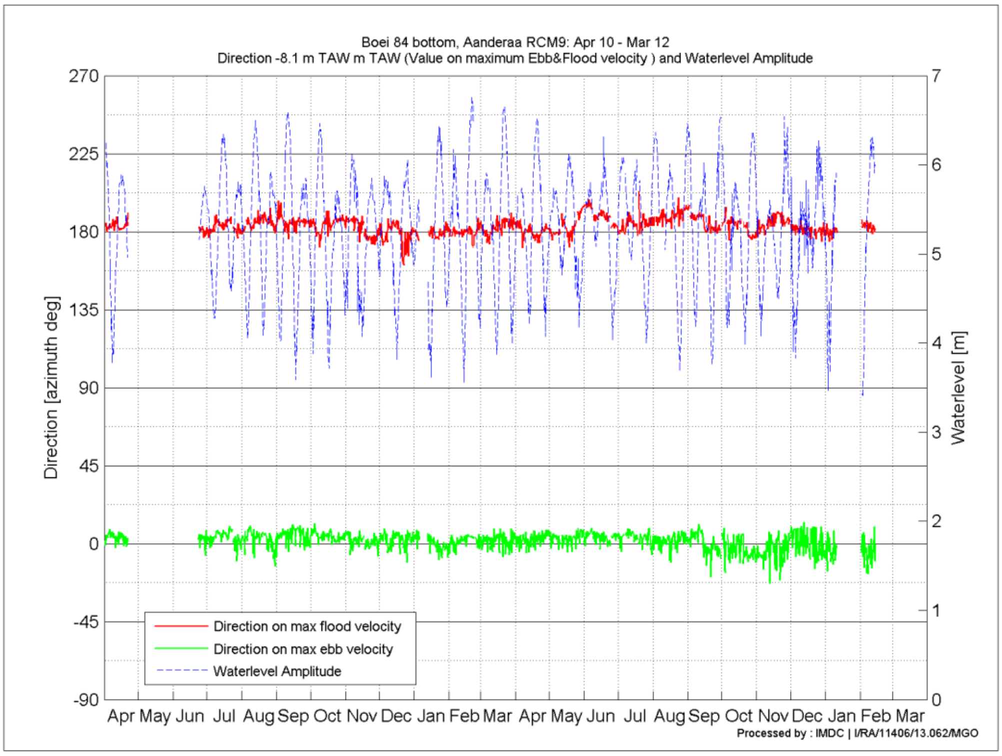


Annex-Figure C-4: Buoy 84 (-8.1 m TAW). Maximal (a) ebb & (b) flood phase velocity and tidal amplitude at Liefkenshoek, April 2010 – March 2012.

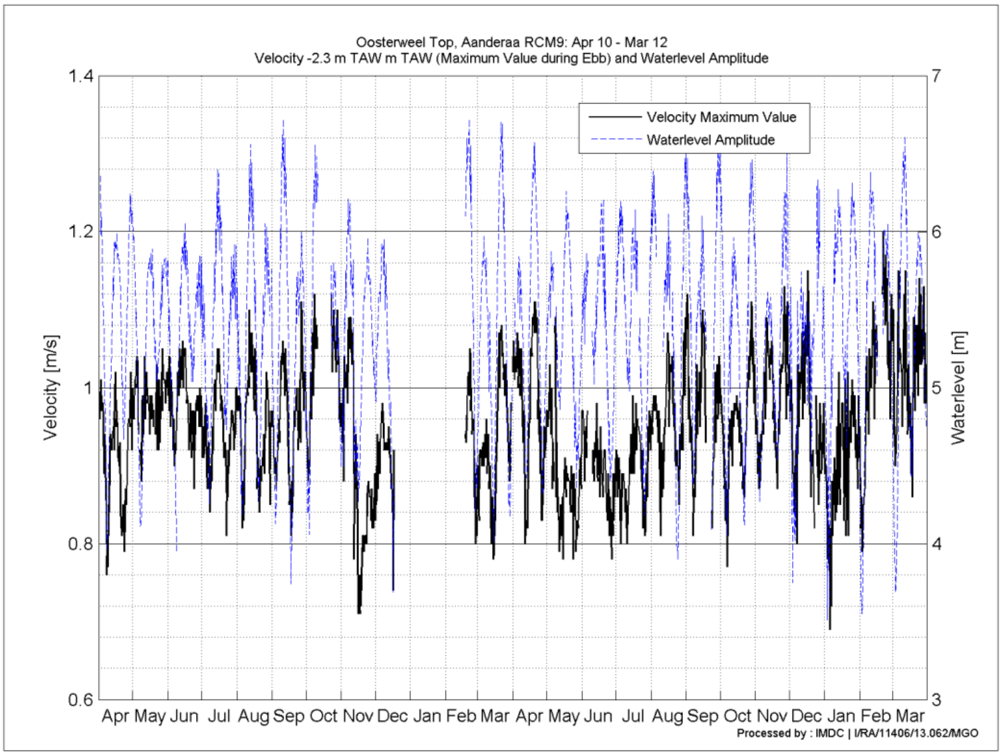


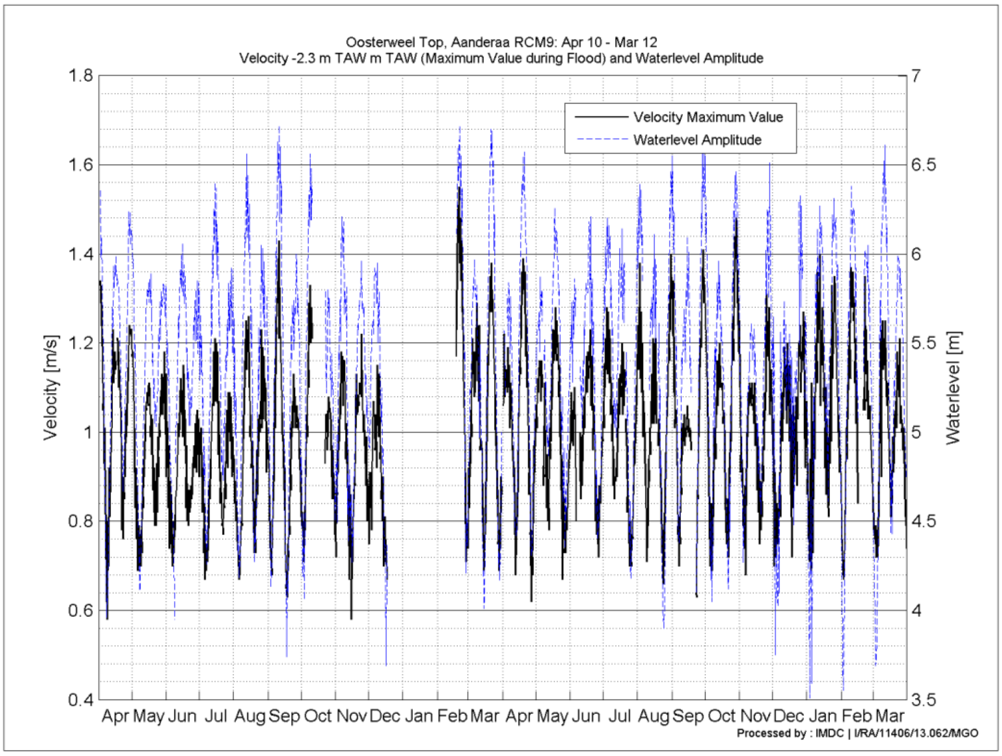


Annex-Figure C-5: Buoy 84 Bottom (-8.1 m TAW). Averaged (a) ebb & (b) flood phase velocity and tidal amplitude at Liefkenshoek, April 2010 – March 2012.

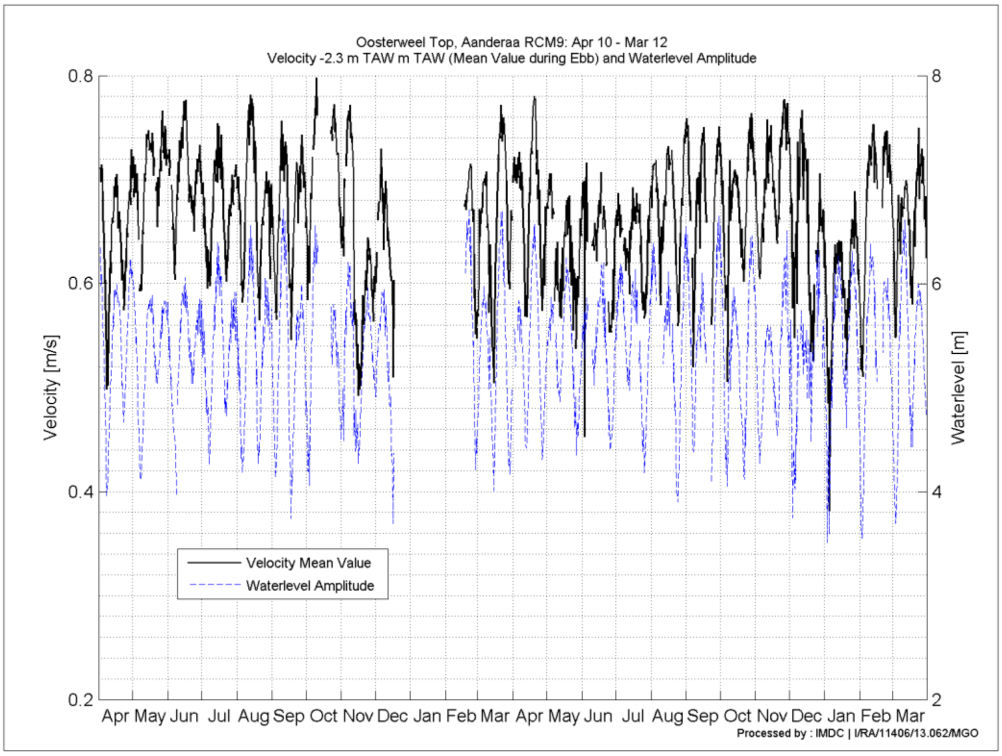


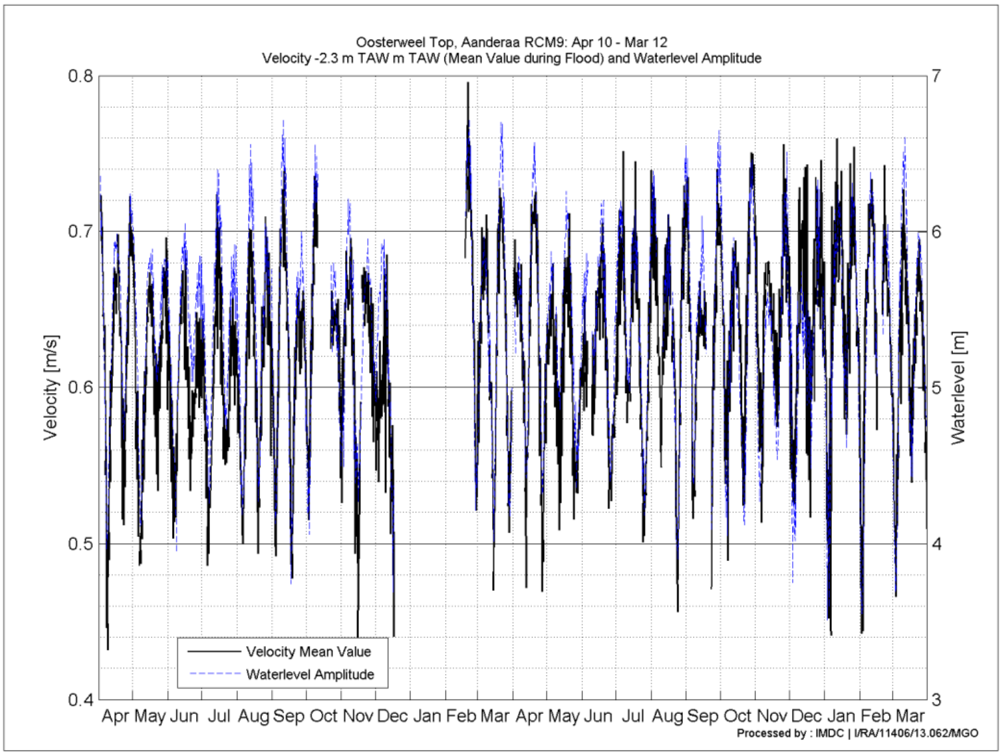
Annex-Figure C-6: phase velocity and water level amplitude, April 2010 – March 2012.



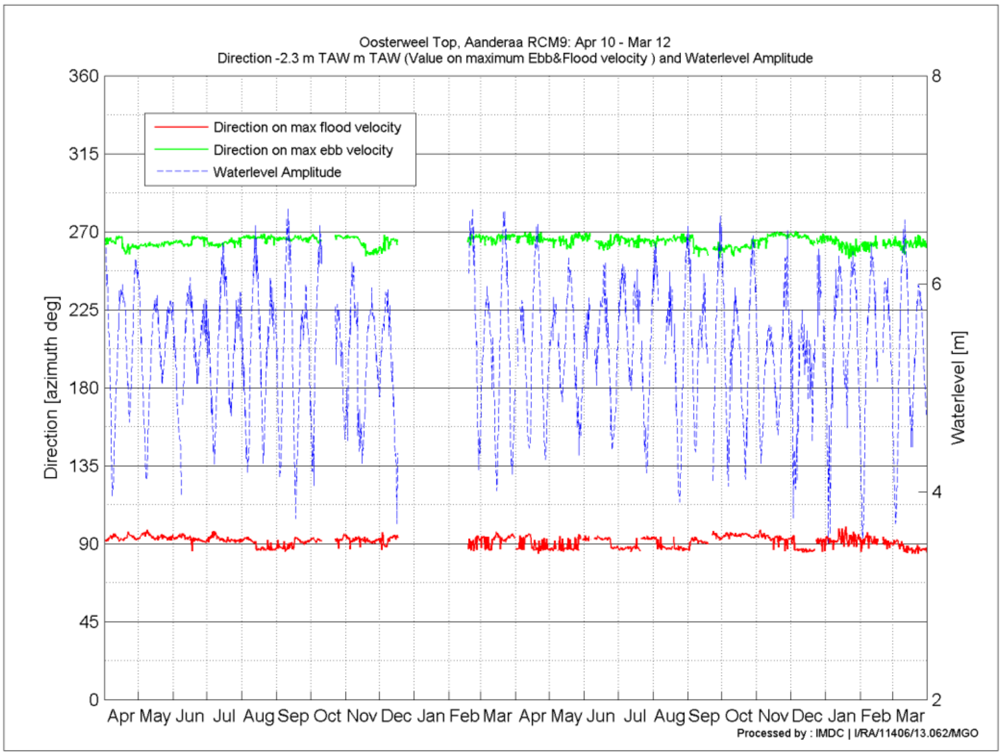


Annex-Figure C-7: Oosterweel (-5.3 m TAW). Maximal (a) ebb & (b) flood phase velocity and tidal amplitude at Liefkenshoek, April 2010-March 2012.

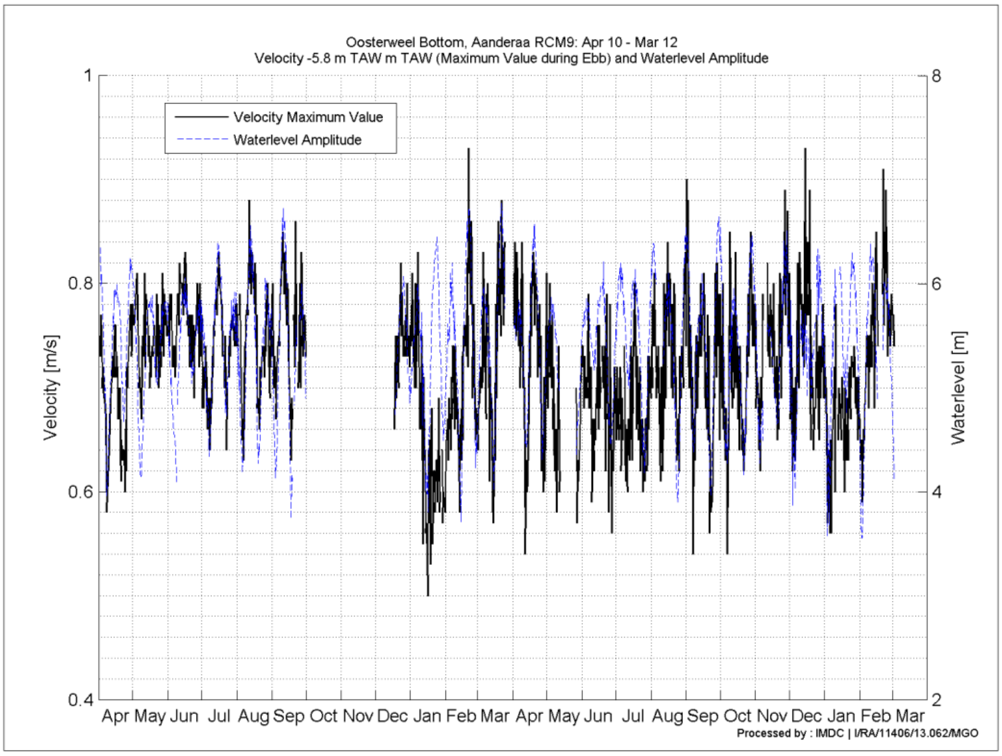


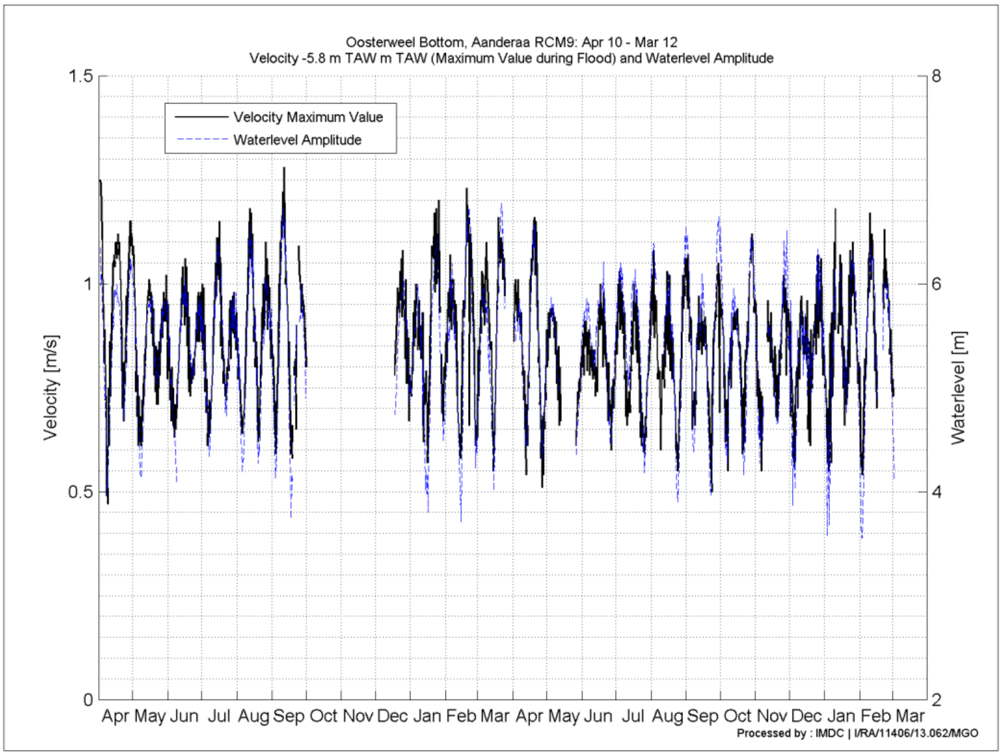


Annex-Figure C-8: Oosterweel (-5.3 m TAW). Mean (a) ebb & (b) flood phase velocity and tidal amplitude at Liefkenshoek, April 2010 – March 2012.

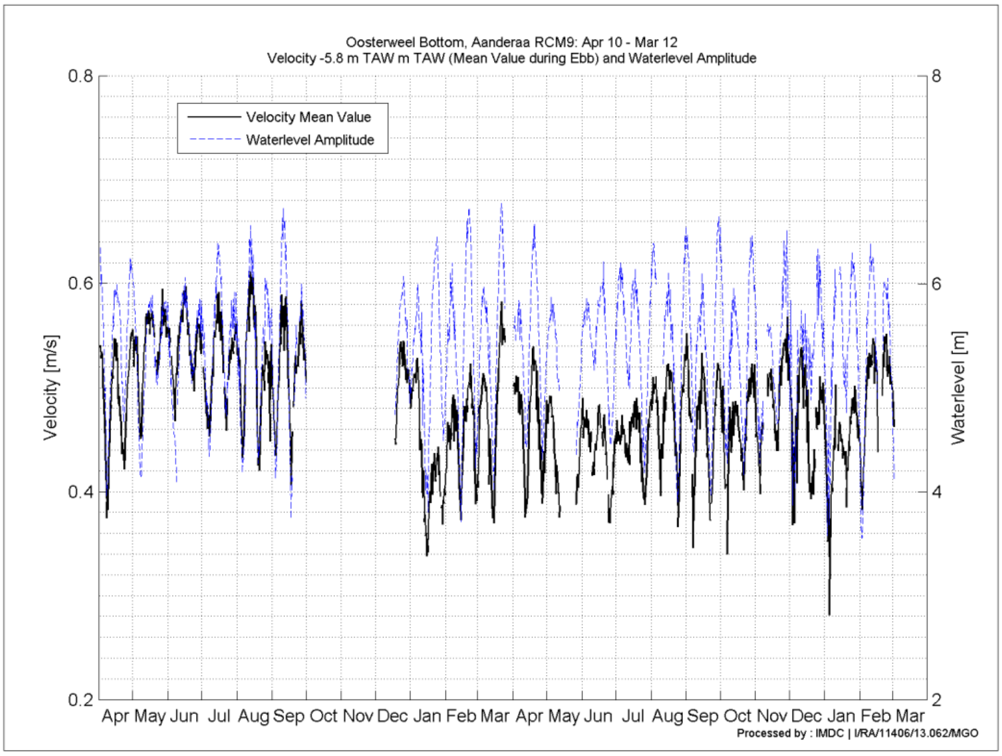


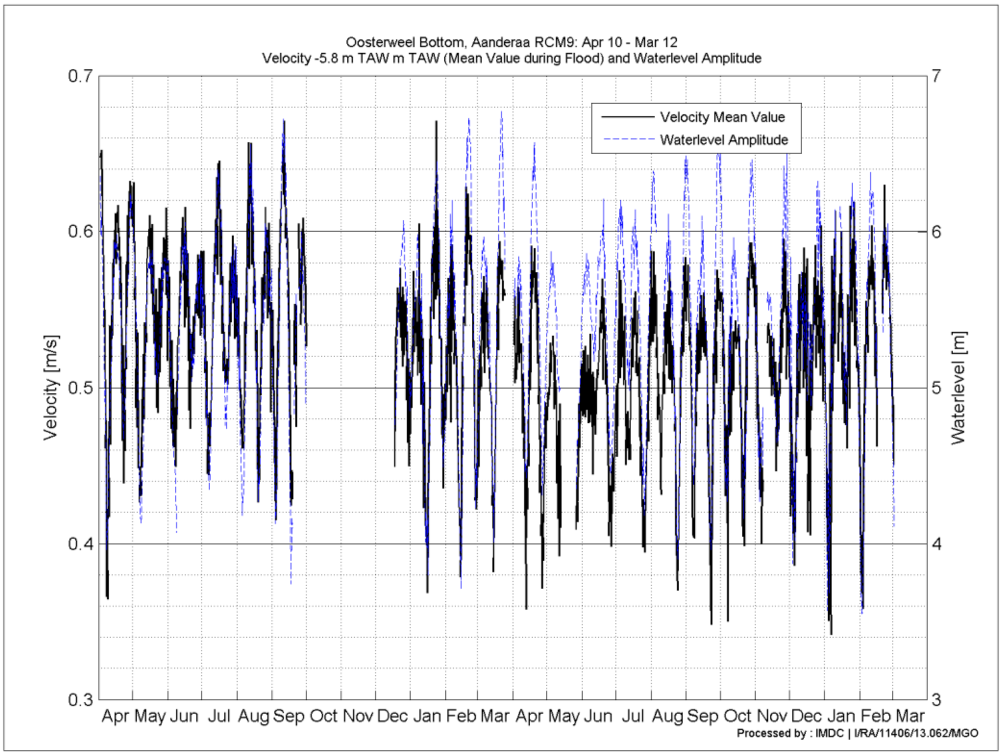
Annex-Figure C-9: Oosterweel (-5.3 m TAW). Flow direction on maximal ebb phase and flood phase velocity and water level amplitude, April 2010 – March 2012.



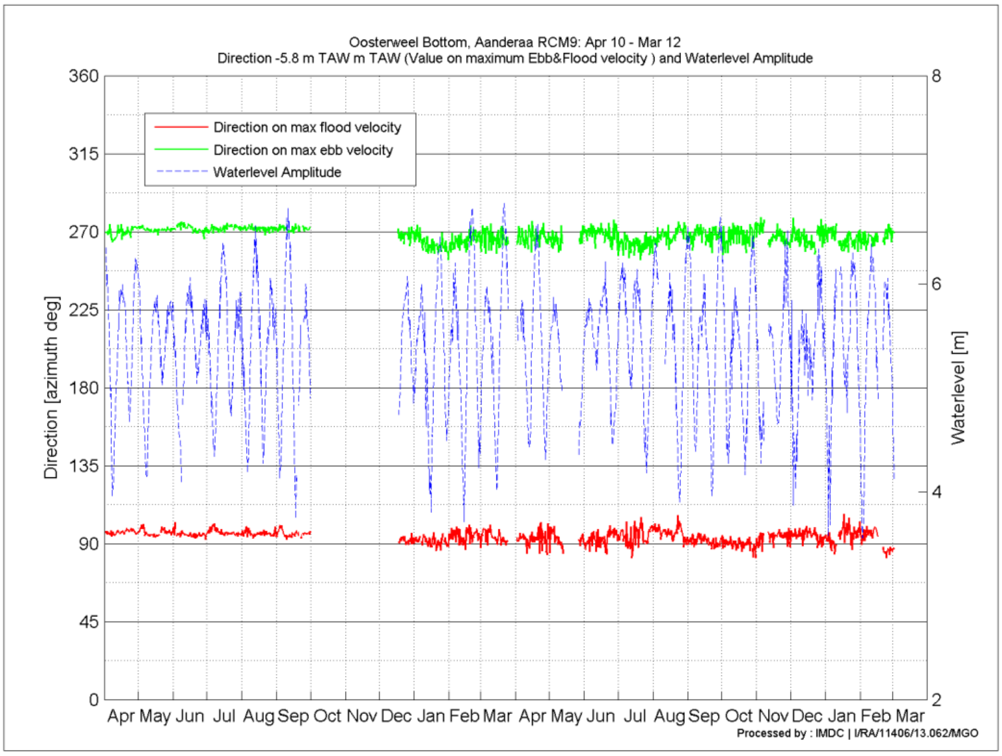


Annex-Figure C-10: Oosterweel (-5.8 m TAW). Maximal (a) ebb & (b) flood phase velocity and tidal amplitude at Liefkenshoek, April 2010 – March 2012.

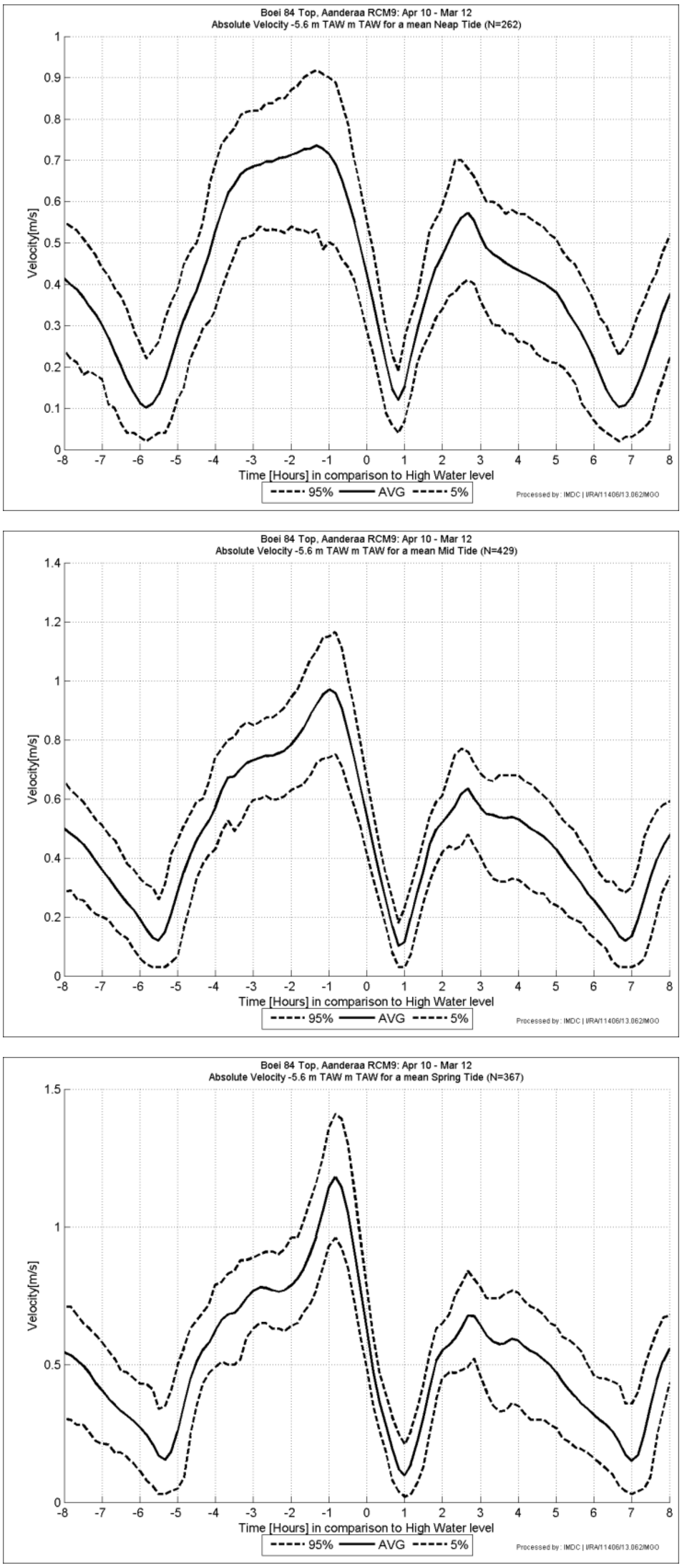




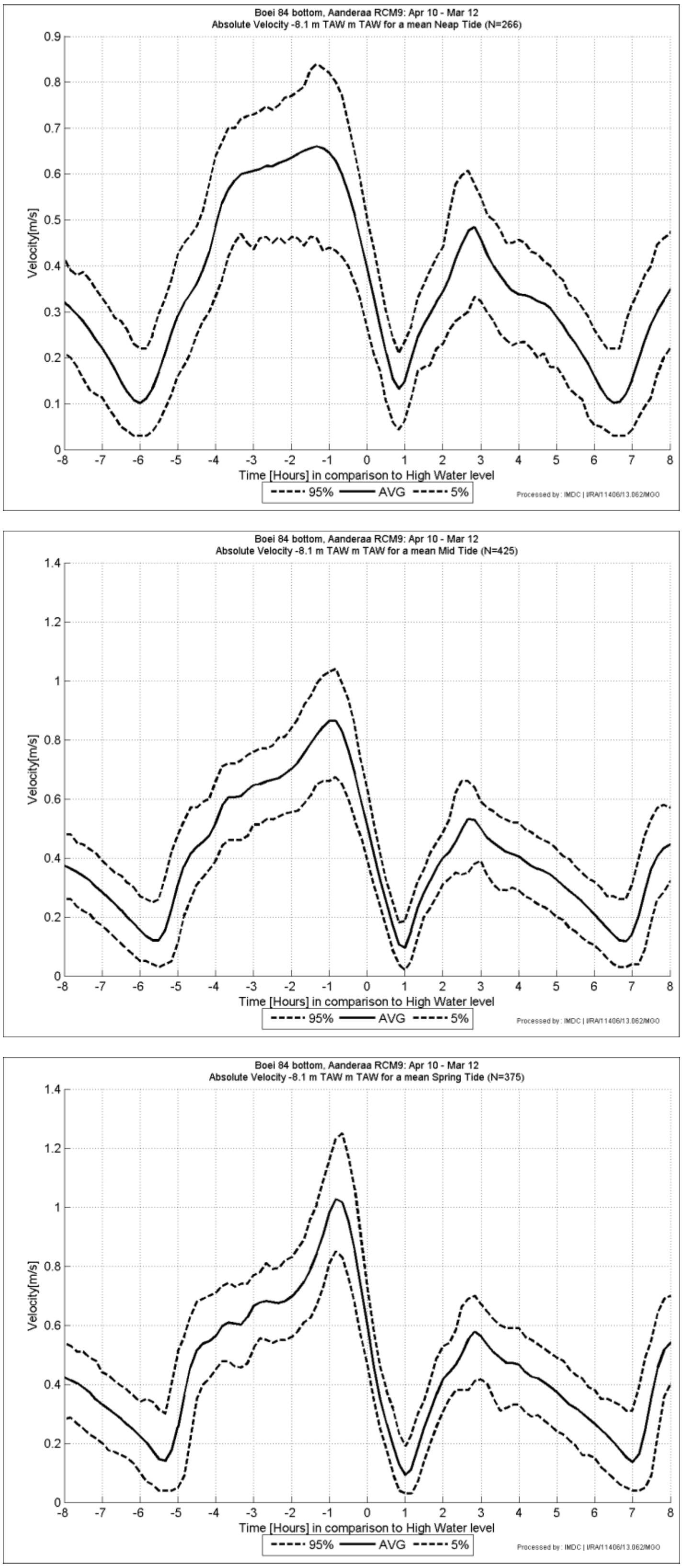
Annex-Figure C-11: Oosterweel (-5.8 m TAW). Mean (a) ebb & (b) flood phase velocity and tidal amplitude at Liefkenshoek, April 2010 – March 2012.



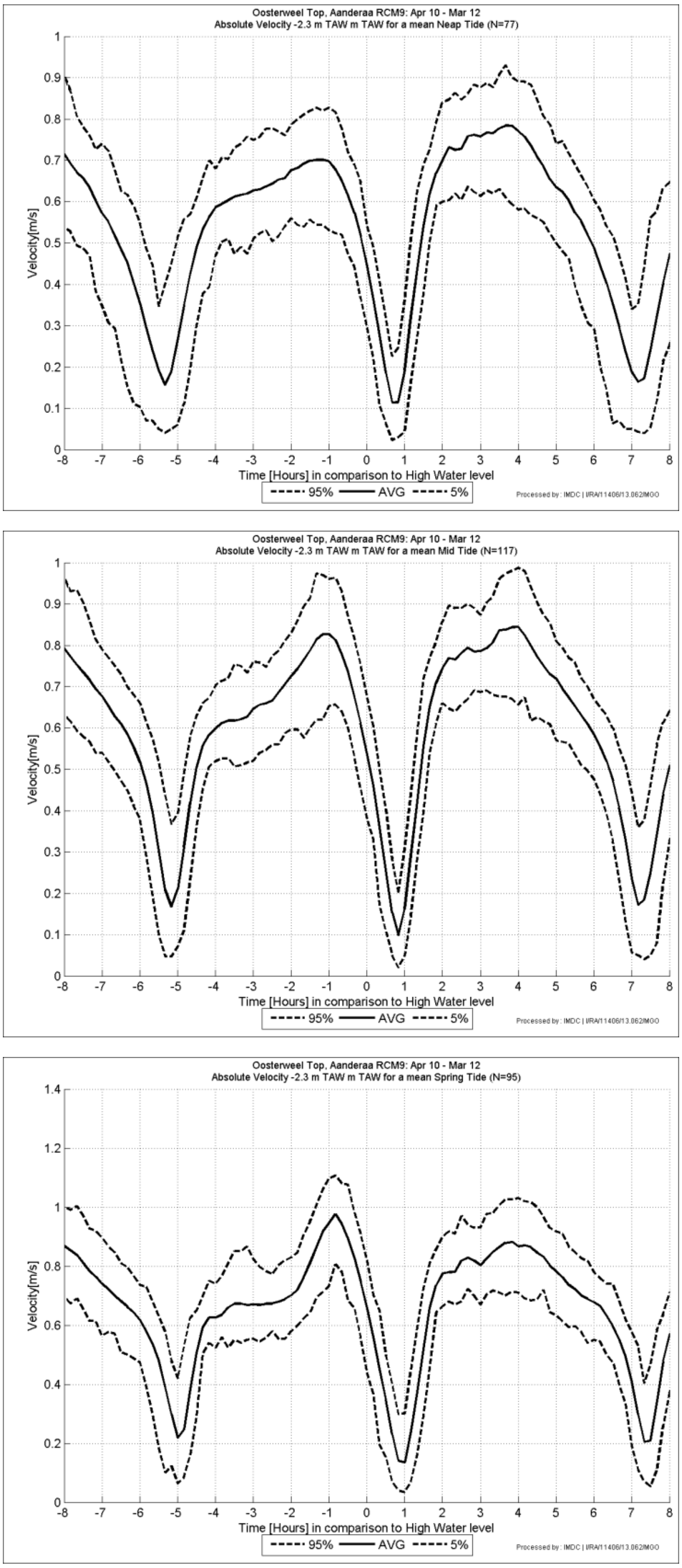
Annex-Figure C-12: Oosterweel (-5.8 m TAW). Flow direction on maximal ebb phase and flood phase velocity and water level amplitude, April 2010 – March 2012.



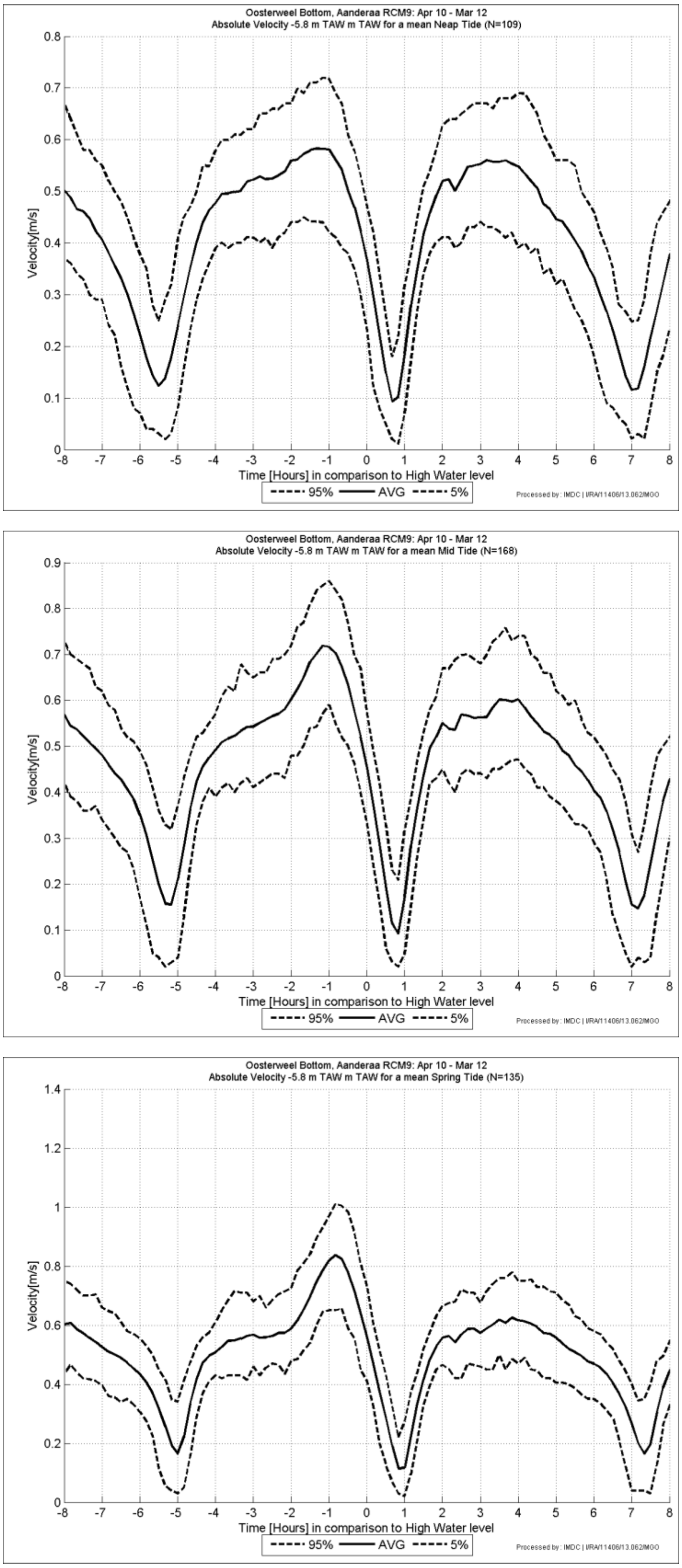
Annex-Figure C-13: Buoy 84 (-5.6 m TAW). Averaged tidal curve of the flow velocity for (a) a neap (b) an average and (c) a spring tide, April 2010 – March 2012.



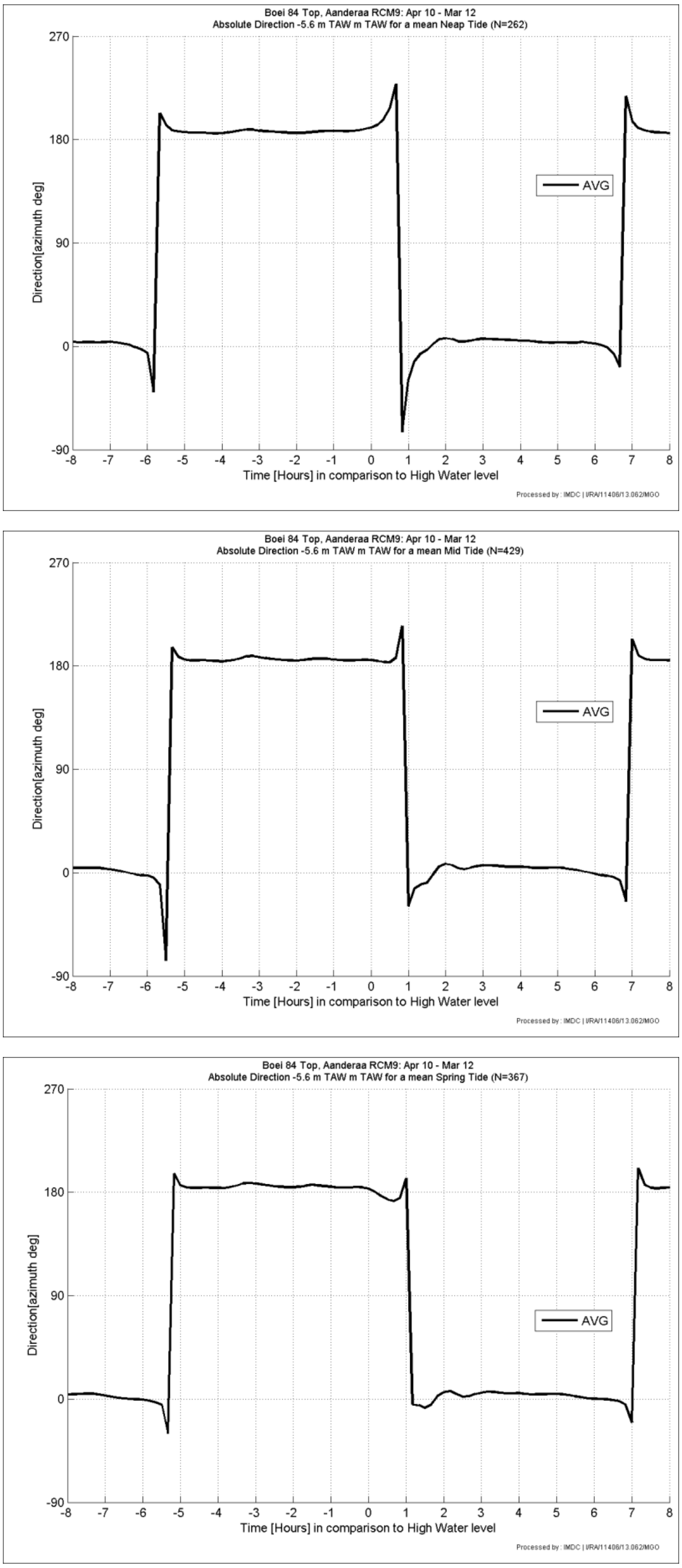
Annex-Figure C-14: Buoy 84 (-8.1m TAW). Averaged tidal curve of the flow velocity for (a) a neap (b) an average and (c) a spring tide, April 2010 – March 2012.



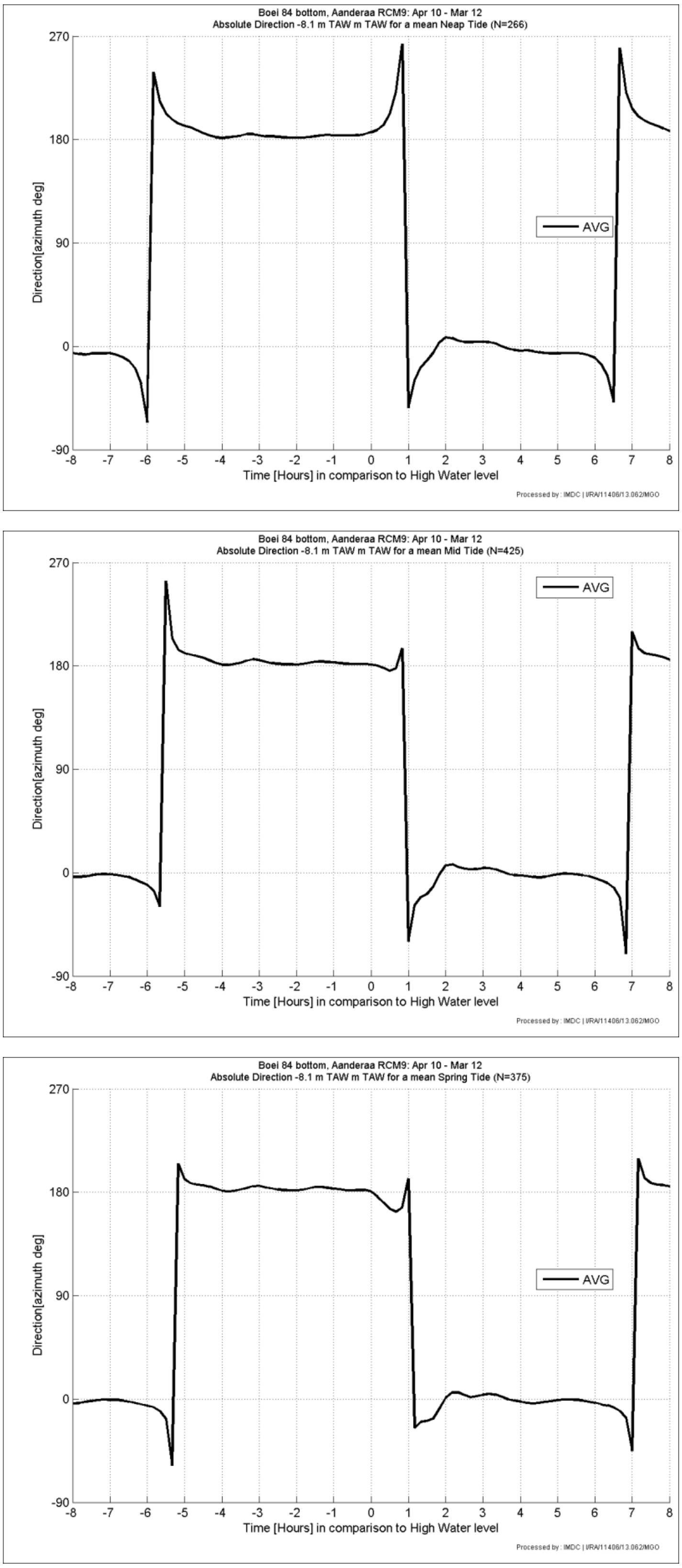
Annex-Figure C-15: Oosterweel (-2.3 m TAW). Averaged tidal curve of the flow velocity for (a) a neap (b) an average and (c) a spring tide, April 2010 – March 2012.



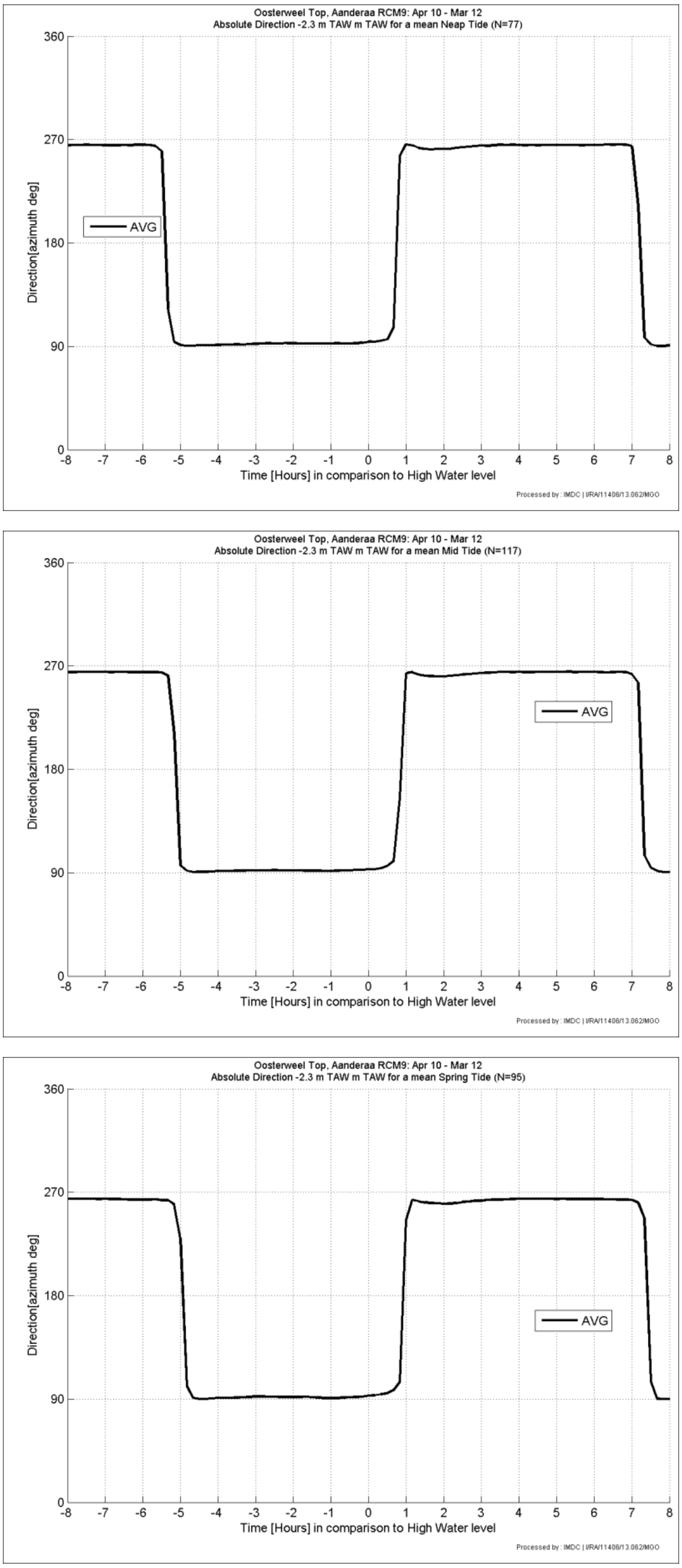
Annex-Figure C-16: Oosterweel (-5.8 m TAW). Averaged tidal curve of the flow velocity for (a) a neap (b) an average and (c) a spring tide, April 2010 – March 2012.



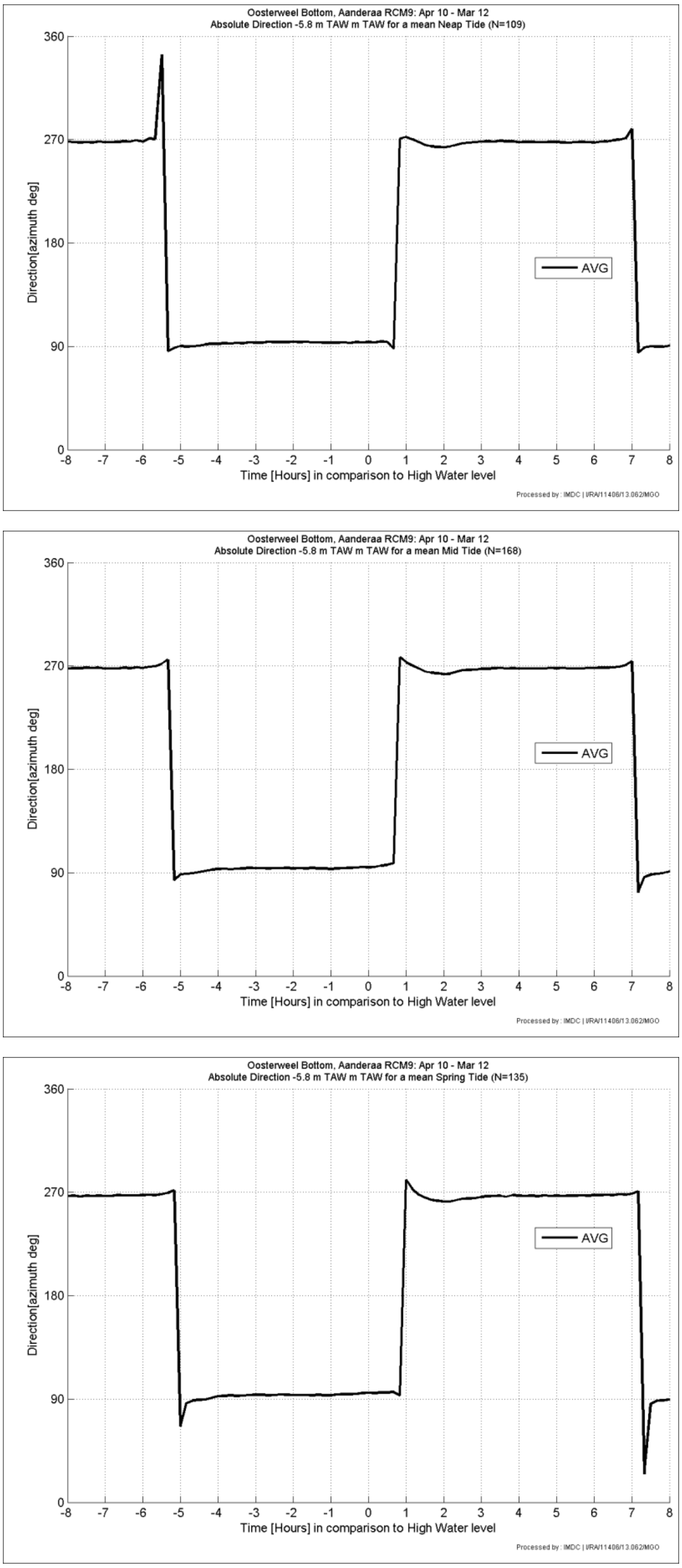
Annex-Figure C-17: Buoy 84 (-5.6m TAW), averaged tidal curve of the flow direction for (a) a neap (b) an average and (c) a spring tide, April 2010 – March 2012.



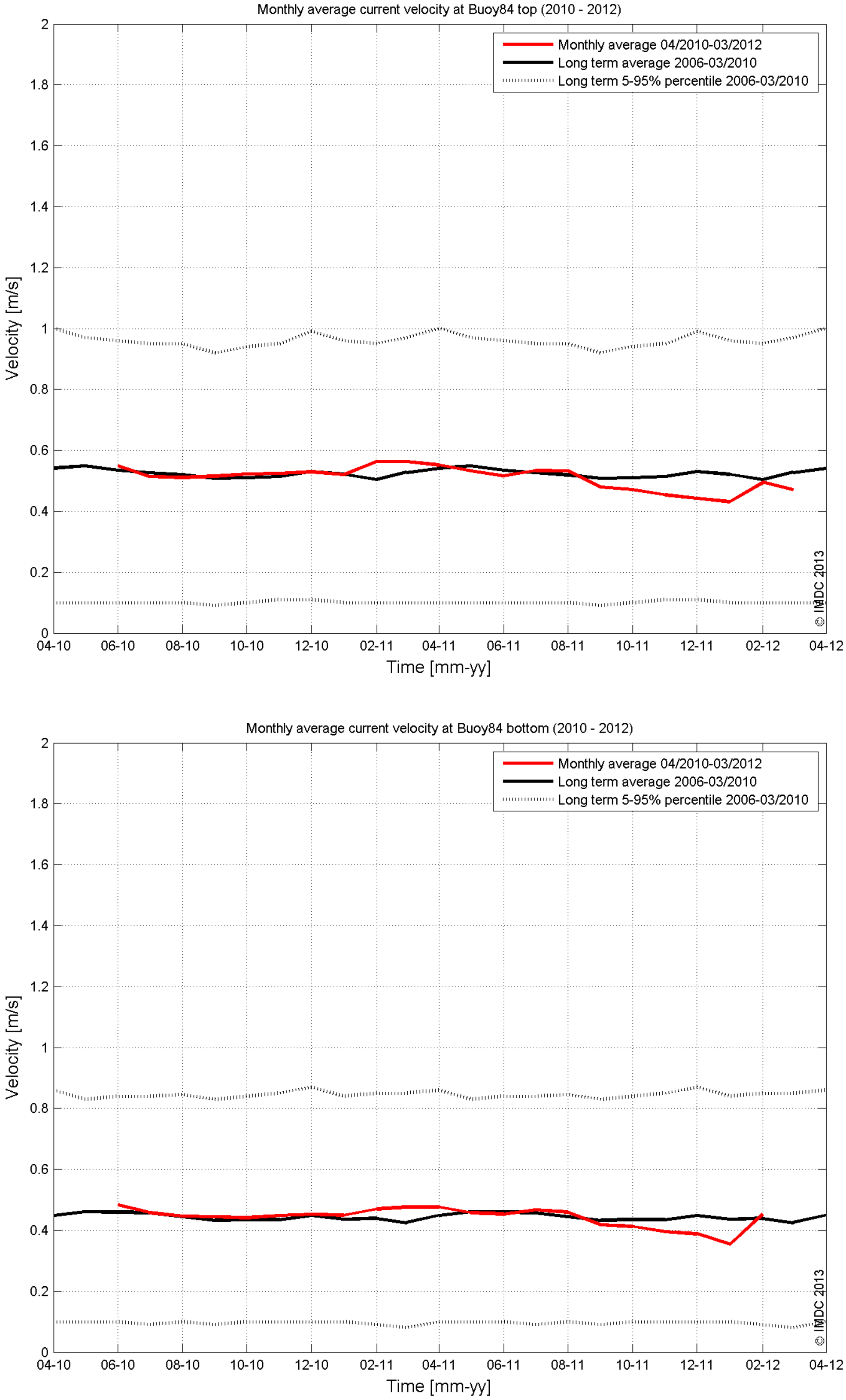
Annex-Figure C-18: Buoy 84 (-8.1m TAW). Averaged tidal curve of the flow direction for (a) a neap (b) an average and (c) a spring tide, April 2010 – March 2012.



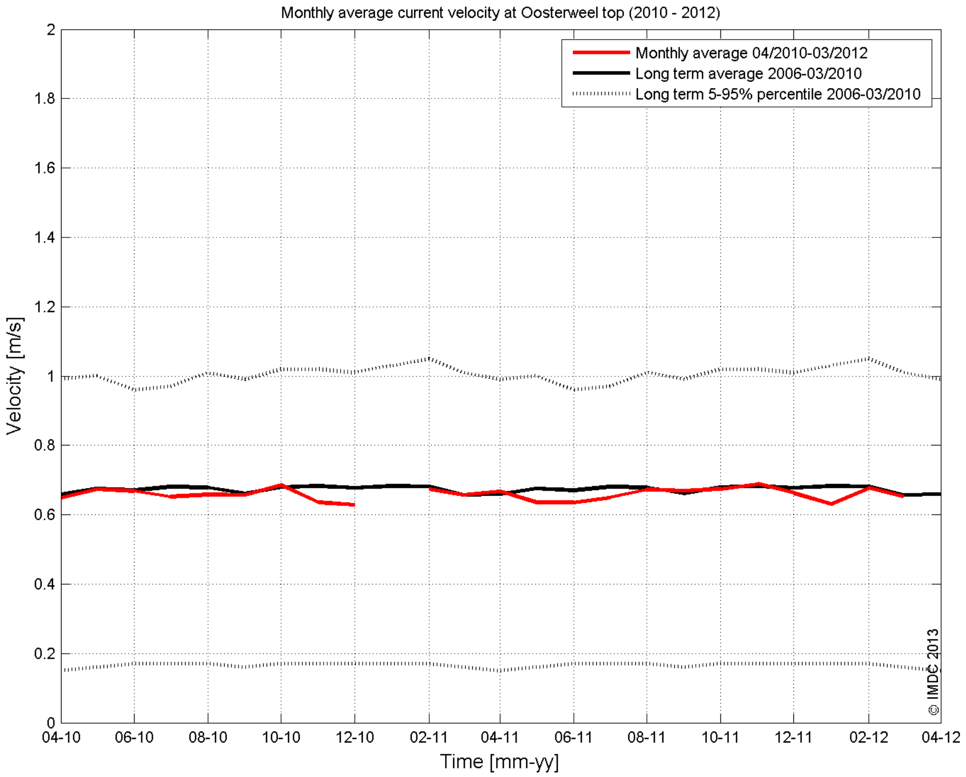
Annex-Figure C-19: Oosterweel (-2.3m TAW). Averaged tidal curve of the flow direction for (a) a neap (b) an average and (c) a spring tide, April 2010 – March 2012.

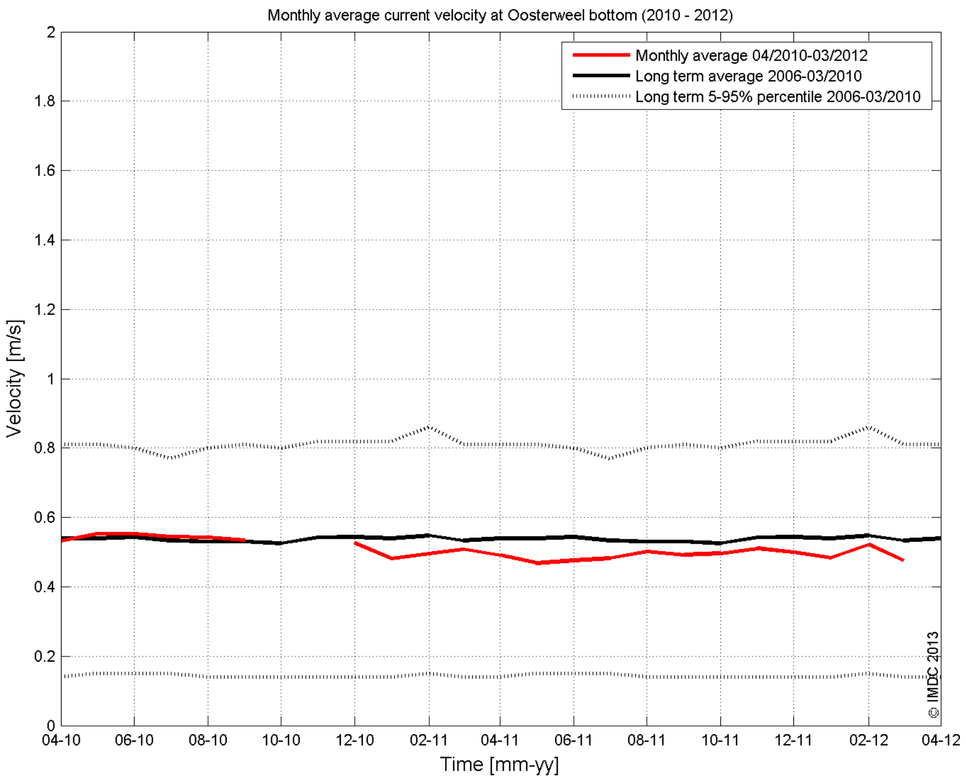


Annex-Figure C-20: Oosterweel (-5.8m TAW). Averaged tidal curve of the flow direction for (a) a neap (b) an average and (c) a spring tide, April 2010 – March 2012.



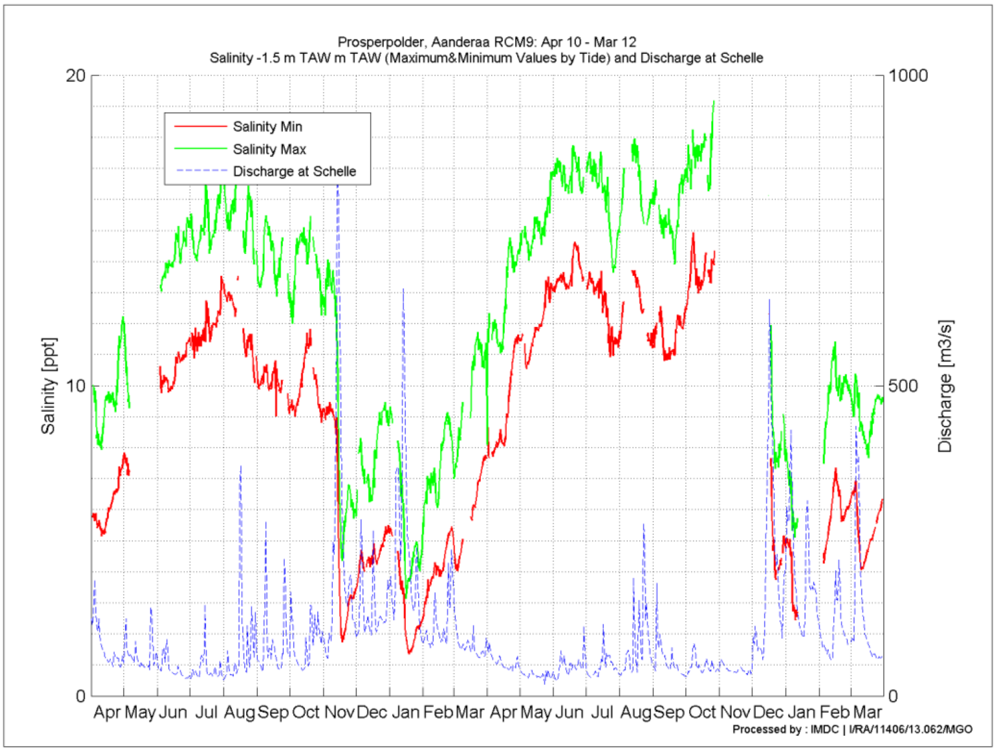
Annex-Figure C-21: The monthly average current velocity of Buoy84 (a) top and (b) bottom between April 2010 – March 2012 and 2006 – March 2010 including the monthly 5/95%-percentiles for period 2006 – March 2010.

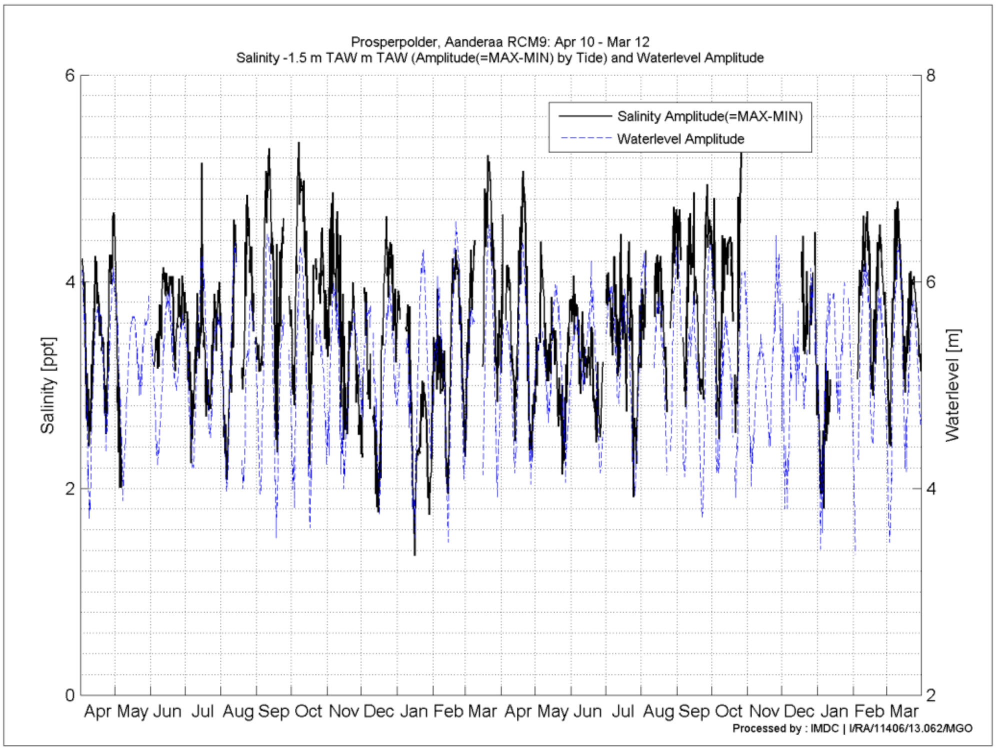




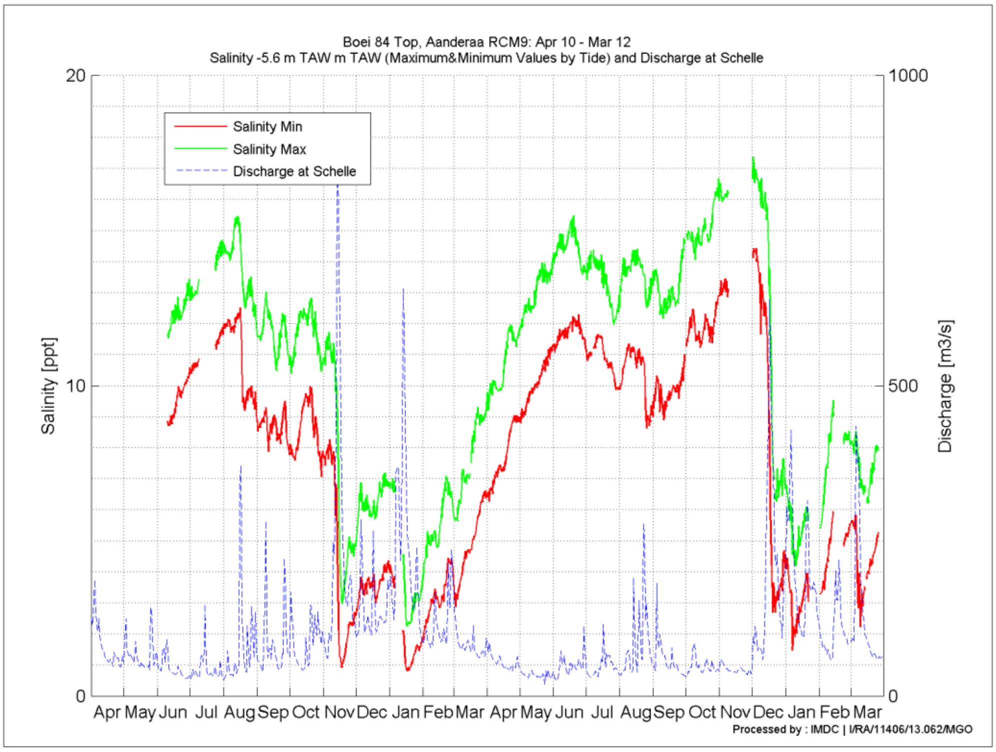
Annex-Figure C-22: The monthly average current velocity of Oosterweel (a) top and (b) bottom between April 2010 – March 2012 and 2006 – March 2010 including the monthly 5/95%-percentiles for period 2006 – March 2010.

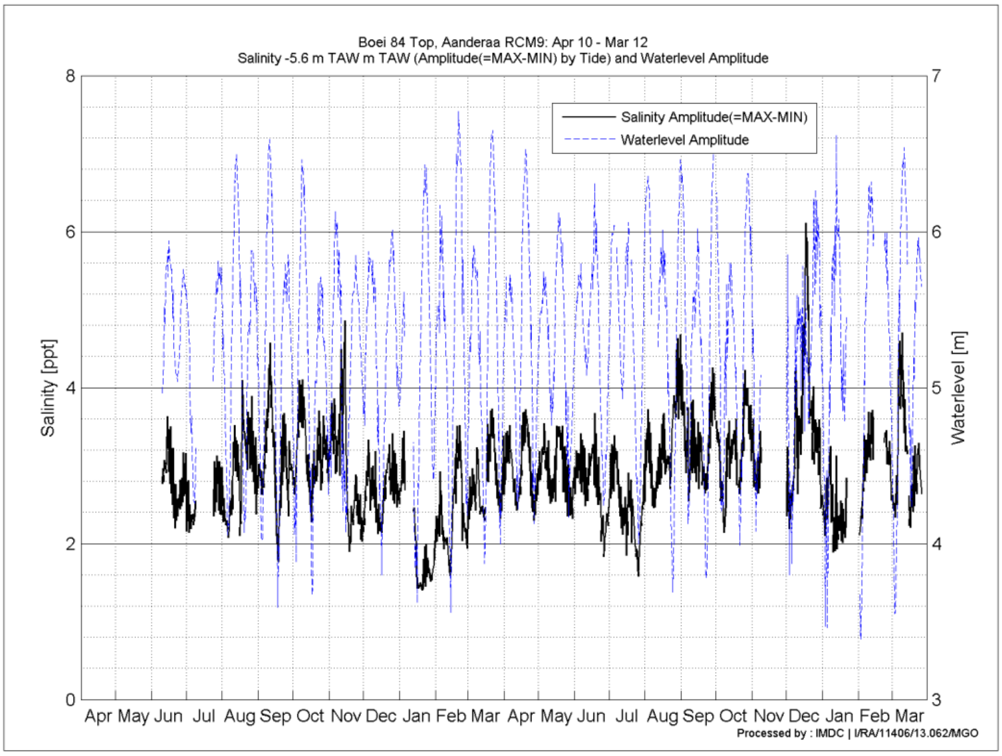
Annex D **Figures for salinity**



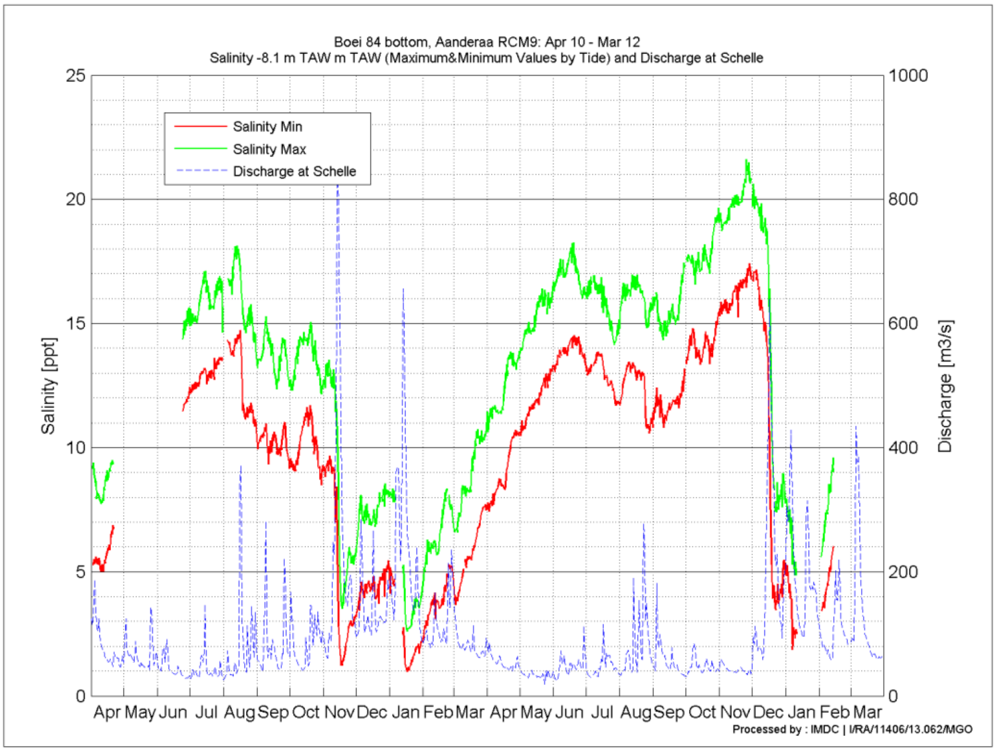


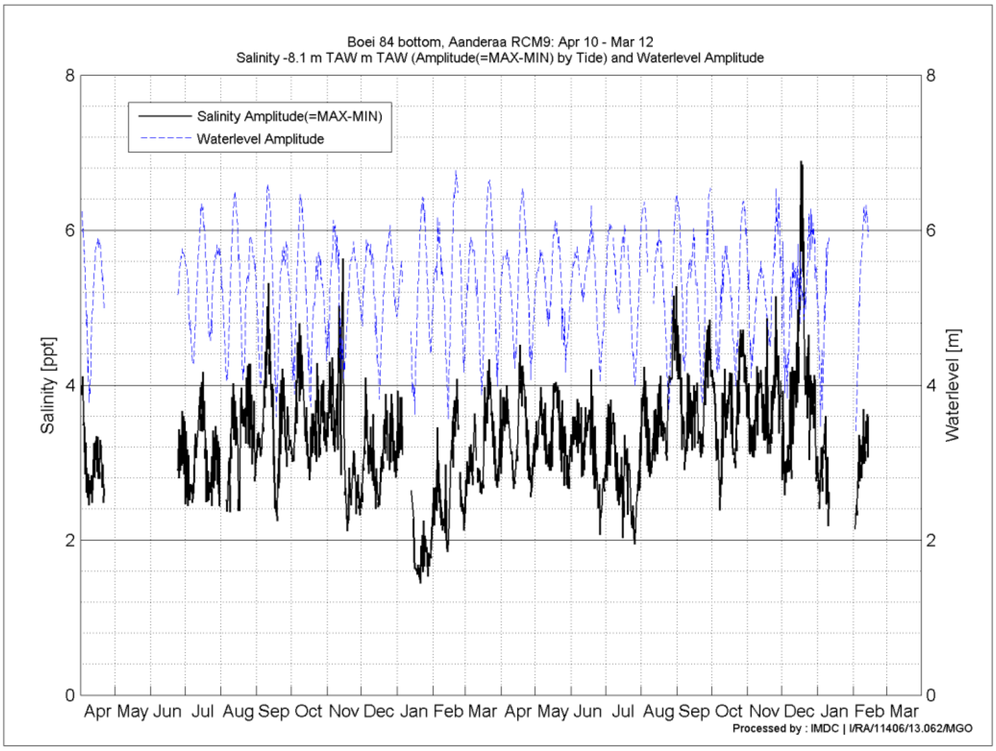
Annex-Figure D-1: Prosperpolder (-1.5m TAW), April 2010 – March 2012 (a) tidal min & max salinity and discharge at Schelle (b) tidal salinity and water level amplitude.



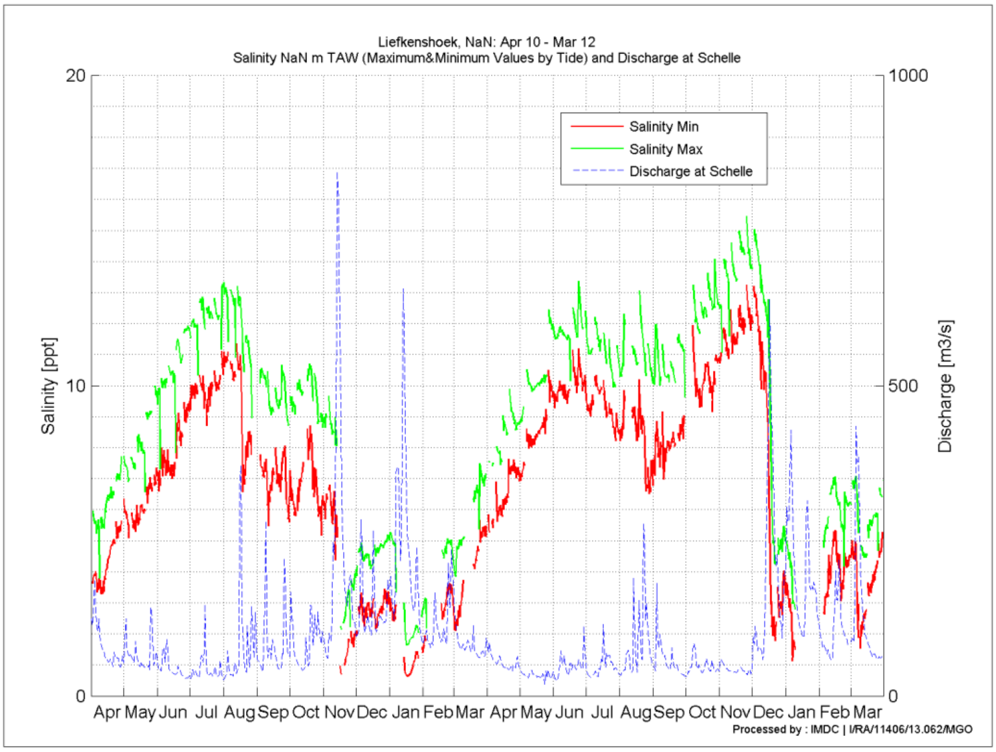


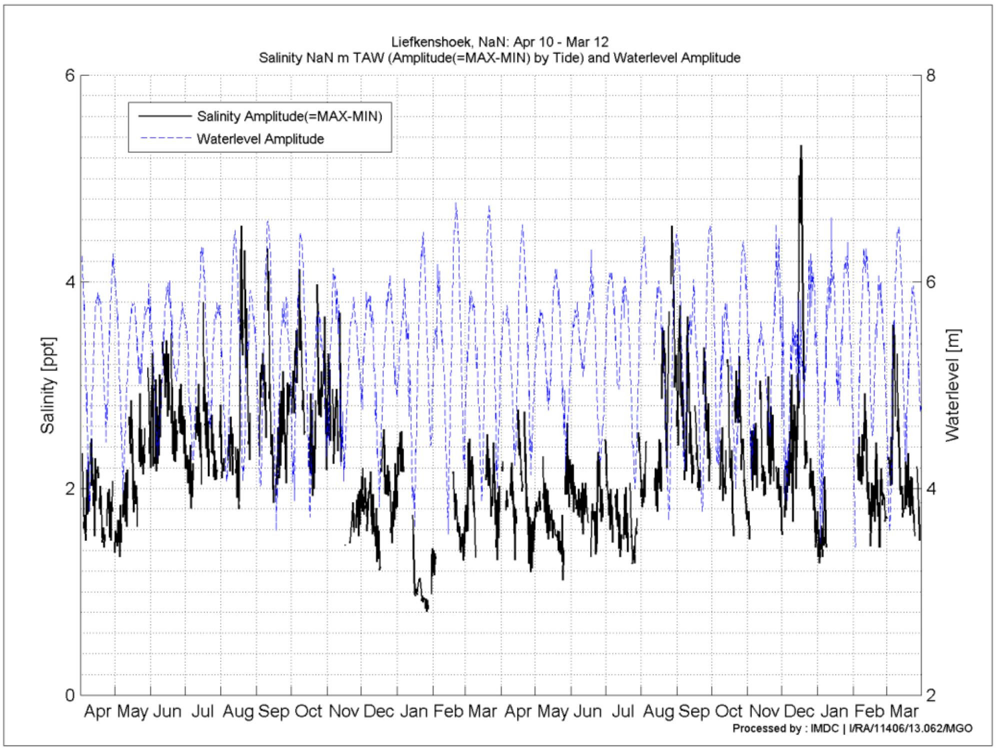
Annex-Figure D-2: Buoy 84 (-5.6m TAW), April 2010 – March 2012 (a) tidal min & max salinity and discharge at Schelle (b) tidal salinity and water level amplitude.



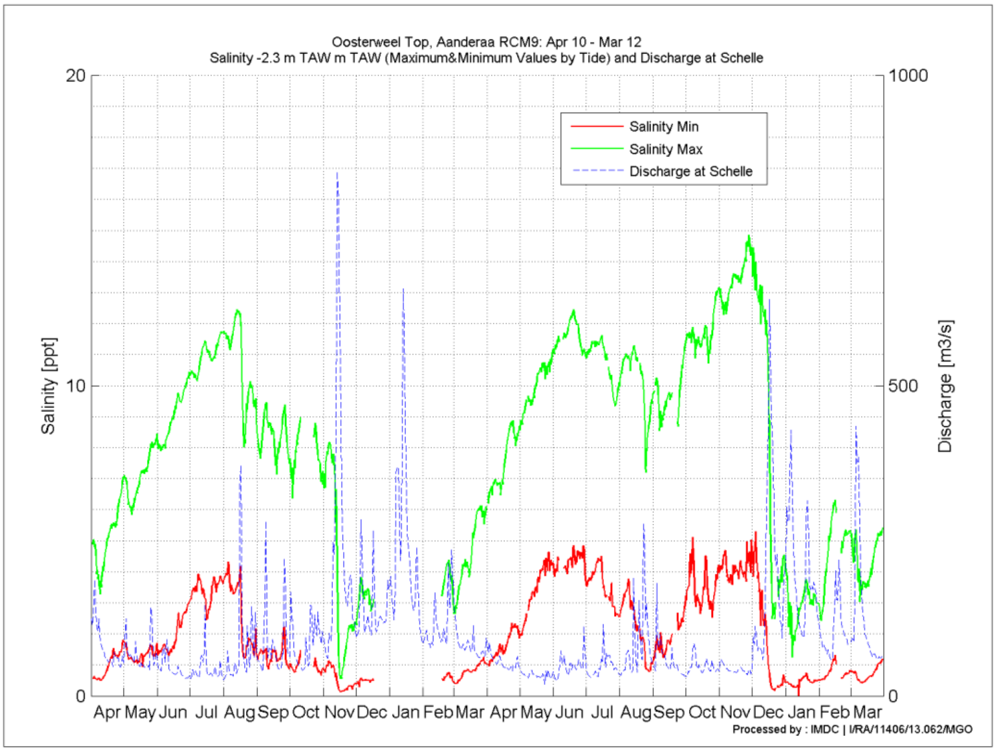


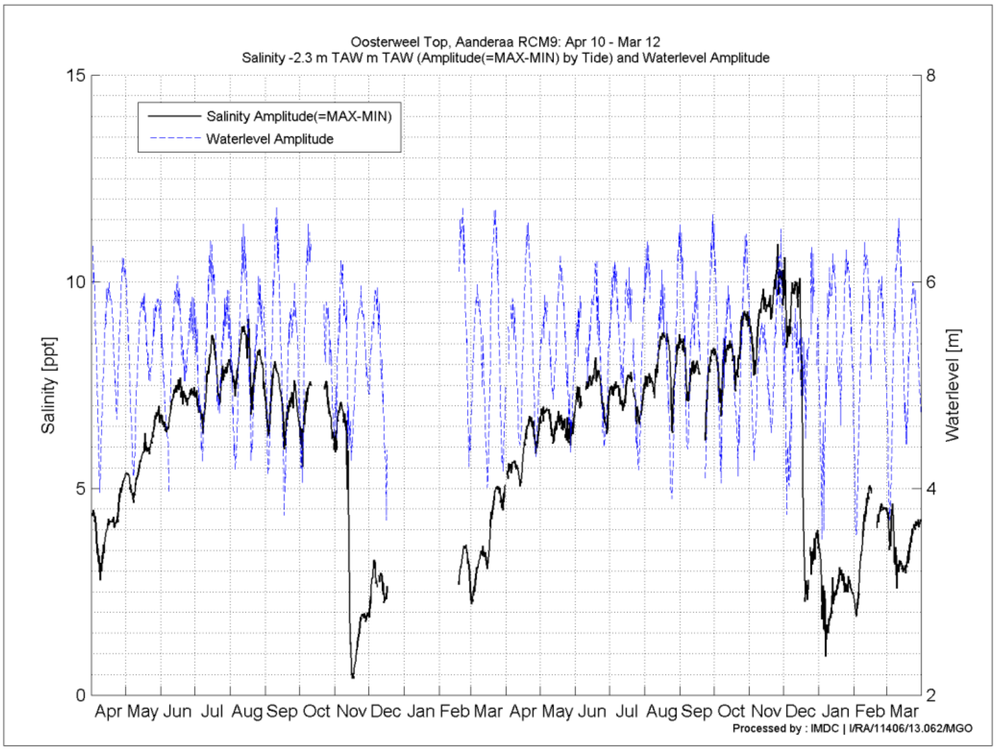
Annex-Figure D-3: Buoy 84 (-8.1m TAW), April 2010 – March 2012 (a) tidal min & max salinity and discharge at Schelle (b) tidal salinity and water level amplitude.



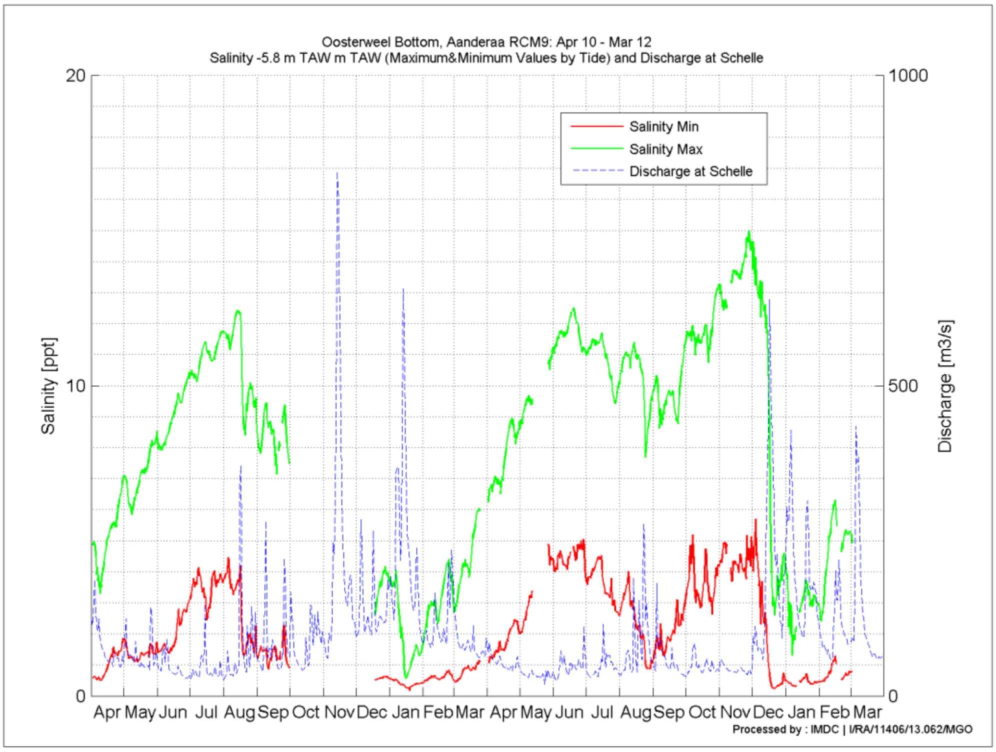


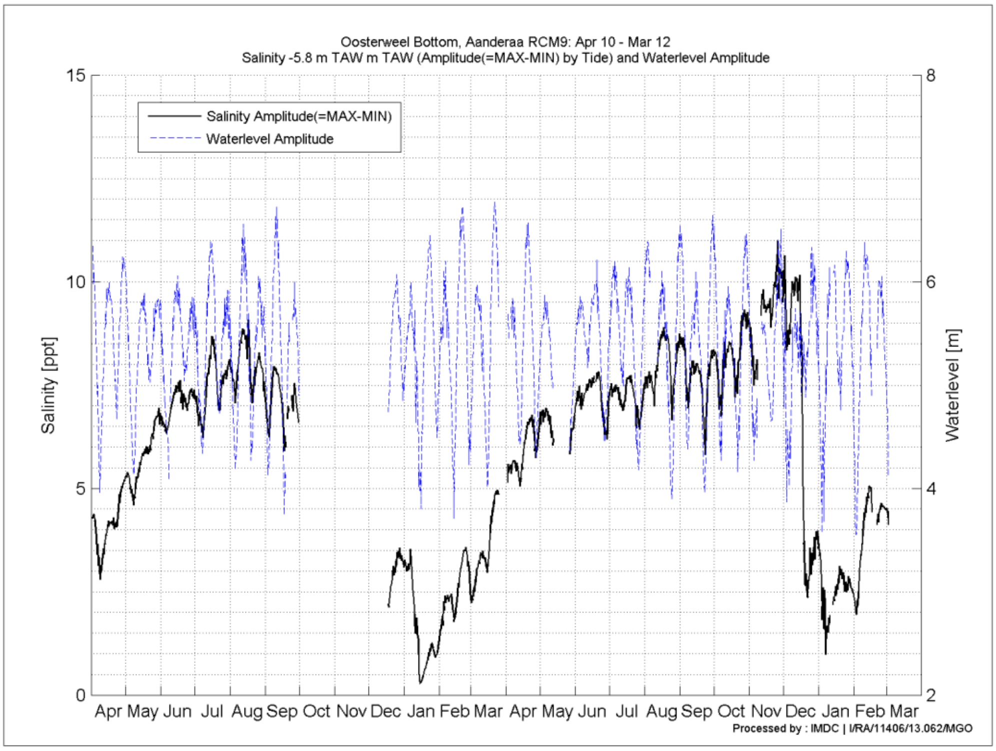
Annex-Figure D-4: Liefkenshoek, April 2010 – March 2012 (a) tidal min & max salinity and discharge at Schelle (b) tidal salinity and water level amplitude.



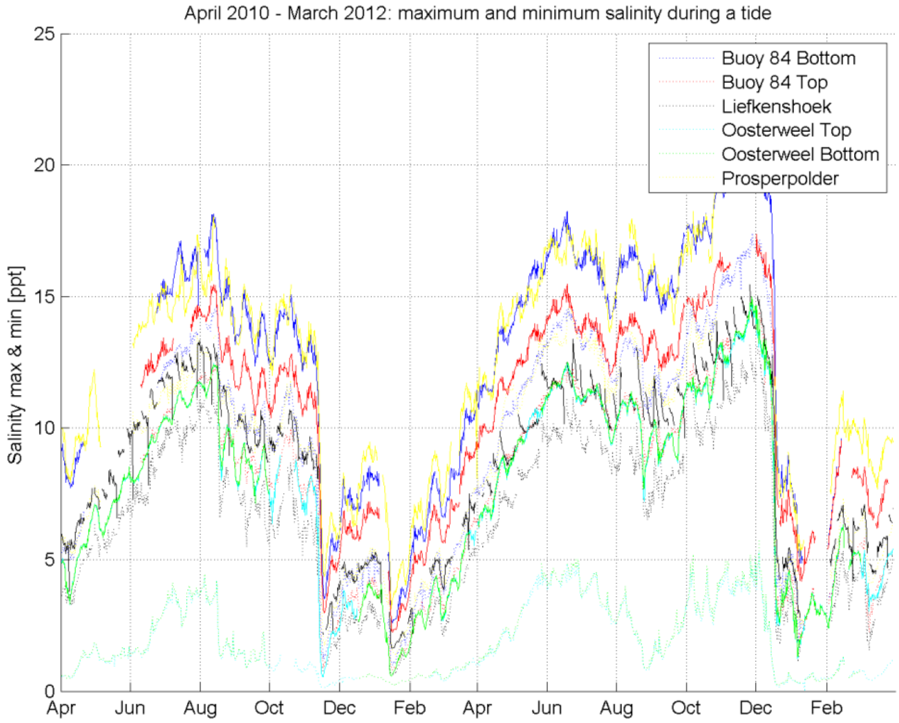


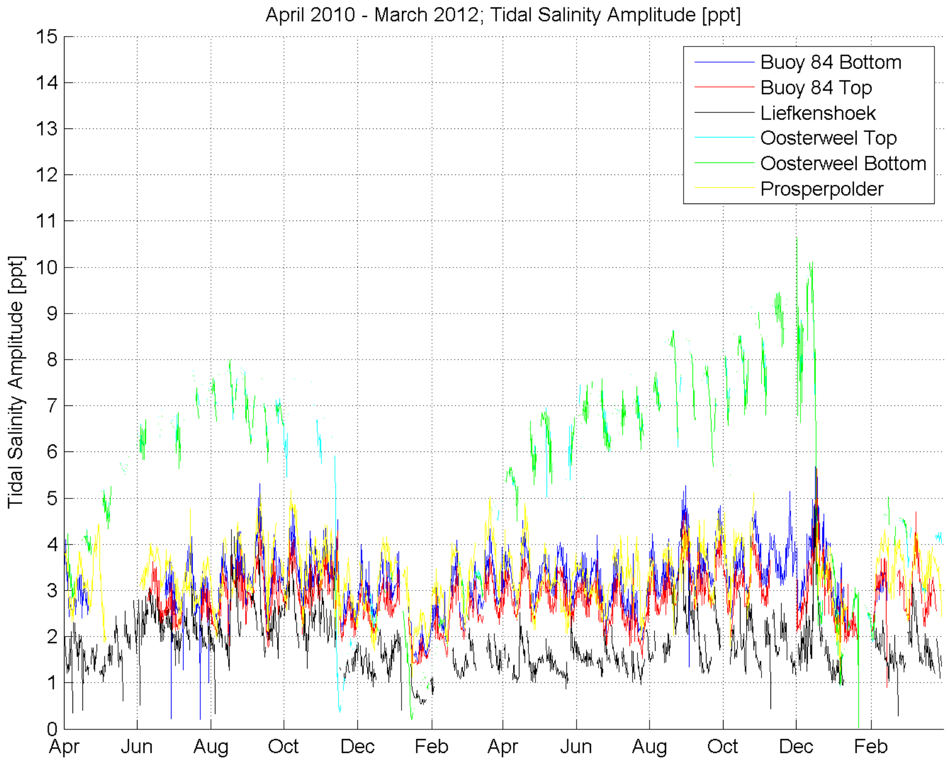
Annex-Figure D-5: Oosterweel (-2.3m TAW), April 2010 – March 2012 (a) tidal min & max salinity and discharge at Schelle (b) tidal salinity and water level amplitude.





Annex-Figure D-6: Oosterweel (-5.8m TAW), April 2010 – March 2012 (a) tidal min & max salinity and discharge at Schelle (b) tidal salinity and water level amplitude.





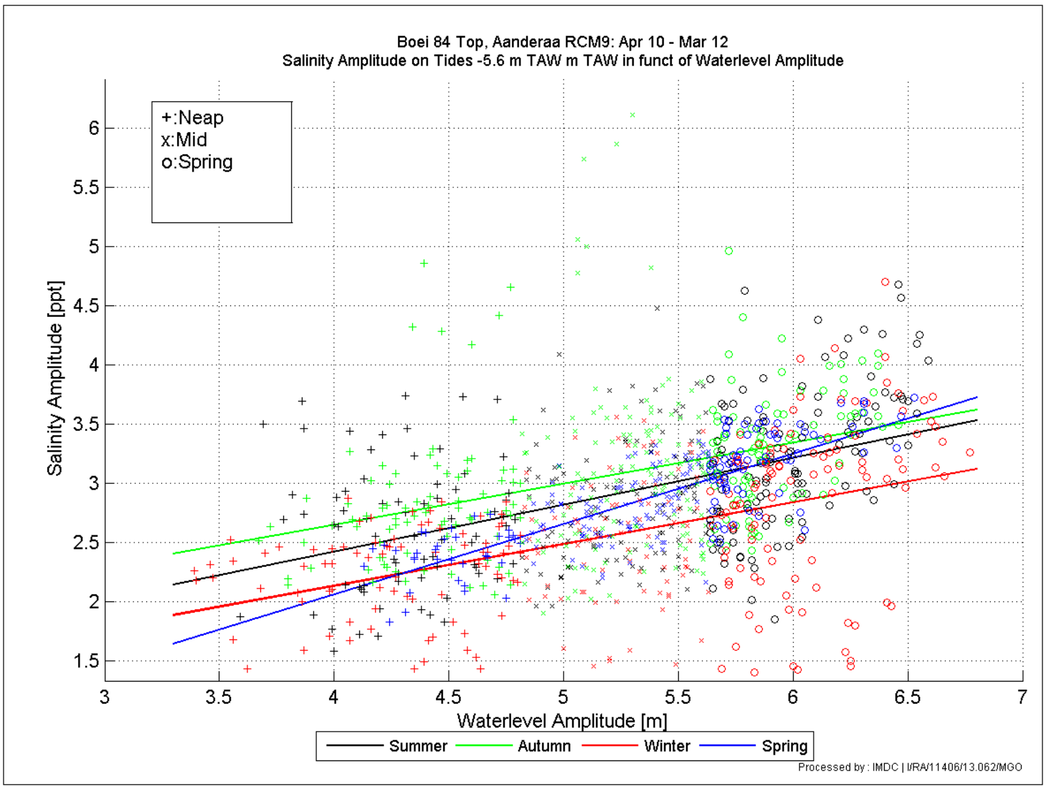
Annex-Figure D-7: Minimal and maximal tidal salinity for all measurement stations (a) Tidal amplitude of the salinity for all measurement stations (b).

Annex-Table D-1: Averaged-tidal salinity amplitude [ppt] (ΔS), standard deviation (σ), and amount of tide in the sample (N) for every measurement station during the period considered (April 2010 – March 2012) – year 1 (April 2010 – March 2011). Summer = April to September, Winter = October to March.

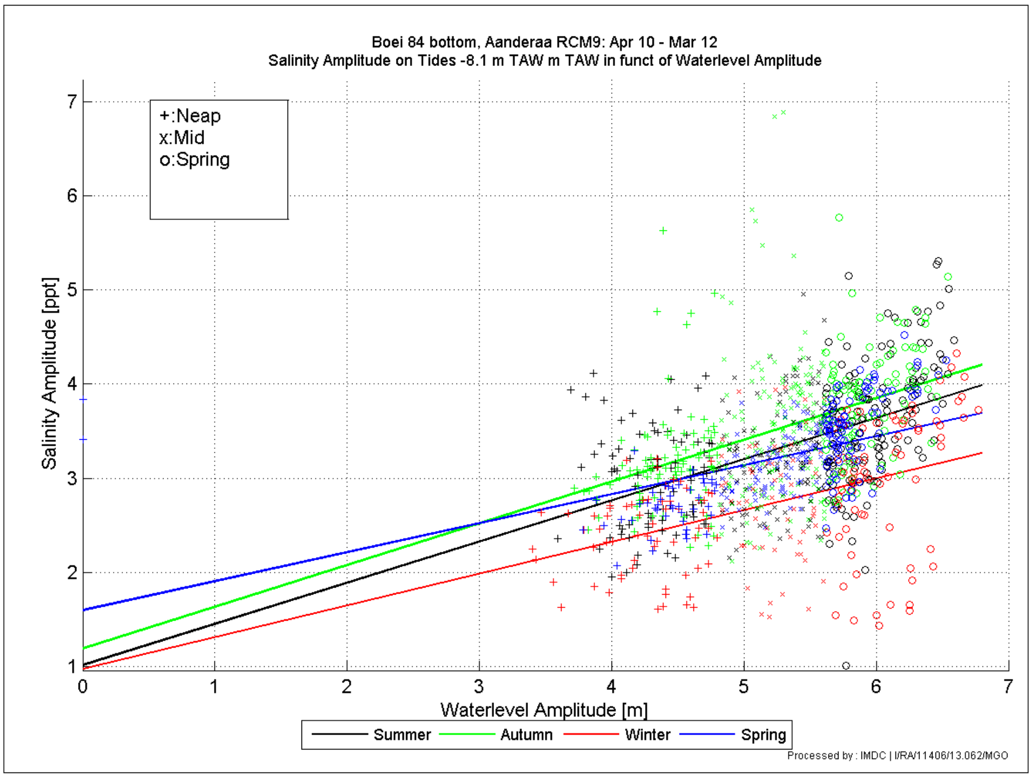
			Apr-Jun			Jul-Sep			Oct-Dec			Jan-Mar			Summer			Winter			Year 1			Total period		
			Δ	σ	N	Δ	σ	N	Δ	σ	N	Δ	σ	N	Δ	σ	N	Δ	σ	N	Δ	σ	N	Δ	σ	N
Buoy 84	-8.1 m TAW	Neap	2.63	0.14	8.00	2.90	0.44	43.00	3.16	0.70	47.00	2.33	0.43	48.00	2.86	0.41	53.00	2.74	0.71	95.00	2.78	0.63	146.00	2.88	0.58	275.00
		Avg	2.88	0.26	21.00	3.20	0.49	61.00	3.21	0.55	81.00	2.71	0.60	53.00	3.12	0.46	82.00	3.01	0.62	134.00	3.05	0.56	216.00	3.27	0.65	446.00
		Spring	3.28	0.35	23.00	3.59	0.63	65.00	3.59	0.58	48.00	3.00	0.81	56.00	3.51	0.58	88.00	3.27	0.77	104.00	3.38	0.70	192.00	3.55	0.67	380.00
		All	3.02	0.38	52.00	3.27	0.60	169.00	3.30	0.62	176.00	2.70	0.69	157.00	3.21	0.56	223.00	3.02	0.72	333.00	3.09	0.67	554.00	3.27	0.69	1101.00
	-5.6 m TAW	Neap	-	-	1.00	2.56	0.47	43.00	2.84	0.63	48.00	2.08	0.38	48.00	2.58	0.46	45.00	2.46	0.65	96.00	2.49	0.60	139.00	2.55	0.54	282.00
		Avg	2.64	0.30	23.00	2.87	0.44	60.00	2.82	0.46	79.00	2.39	0.50	55.00	2.81	0.42	83.00	2.64	0.52	134.00	2.71	0.49	217.00	2.87	0.59	454.00
		Spring	3.04	0.34	18.00	3.19	0.53	47.00	3.19	0.49	51.00	2.67	0.69	56.00	3.15	0.49	65.00	2.92	0.65	107.00	3.01	0.60	172.00	3.14	0.58	381.00
		All	2.82	0.37	41.00	2.88	0.53	150.00	2.93	0.54	178.00	2.40	0.59	159.00	2.87	0.50	193.00	2.68	0.63	337.00	2.75	0.59	528.00	2.88	0.62	1117.00
Oosterweel	- 5.8 m TAW	Neap	4.76	1.29	33.00	6.87	0.50	46.00	2.67	0.58	4.00	1.88	1.03	43.00	5.99	1.39	79.00	1.94	1.02	47.00	4.48	2.33	126.00	5.48	2.41	269.00
		Avg	5.90	1.22	86.00	7.52	0.53	73.00	3.03	0.40	16.00	2.41	0.92	63.00	6.64	1.26	159.00	2.53	0.87	79.00	5.28	2.25	238.00	6.05	2.35	491.00
		Spring	5.78	1.29	54.00	8.10	0.44	52.00	3.16	0.18	8.00	2.95	1.30	54.00	6.91	1.51	106.00	2.98	1.21	62.00	5.46	2.37	168.00	6.15	2.39	356.00
		All	5.64	1.32	173.00	7.52	0.68	171.00	3.01	0.40	28.00	2.45	1.16	160.00	6.58	1.41	344.00	2.53	1.10	188.00	5.15	2.33	532.00	5.94	2.39	1116.00
	- 2.3 m TAW	Neap	4.74	1.30	33.00	6.95	0.48	49.00	3.60	2.26	37.00	3.59	0.90	24.00	6.07	1.39	84.00	3.59	1.83	61.00	5.01	2.01	143.00	5.57	2.19	295.00
		Avg	5.95	1.24	79.00	7.58	0.53	74.00	4.04	2.43	53.00	3.53	0.82	24.00	6.74	1.26	153.00	3.88	2.07	77.00	5.78	2.07	230.00	6.27	2.23	517.00
		Spring	5.85	1.25	60.00	8.10	0.49	53.00	5.41	2.38	36.00	3.84	0.83	32.00	6.90	1.49	113.00	4.67	1.98	68.00	6.06	2.00	181.00	6.22	2.19	393.00
		All	5.68	1.33	172.00	7.56	0.67	176.00	4.30	2.46	126.00	3.67	0.85	80.00	6.63	1.40	350.00	4.06	2.01	206.00	5.67	2.07	554.00	6.08	2.22	1205.00
Prosperpolder	- 1.5 m TAW	Neap	2.93	0.46	26.00	2.93	0.46	44.00	2.96	0.60	50.00	2.54	0.59	44.00	2.94	0.45	72.00	2.76	0.63	94.00	2.83	0.57	164.00	2.87	0.52	280.00
		Avg	3.47	0.46	46.00	3.60	0.53	63.00	3.63	0.62	72.00	3.26	0.61	52.00	3.54	0.50	109.00	3.48	0.64	124.00	3.51	0.58	233.00	3.55	0.54	459.00
		Spring	3.96	0.29	48.00	4.08	0.61	51.00	4.17	0.65	47.00	3.86	0.75	56.00	4.02	0.49	99.00	4.00	0.72	103.00	4.01	0.62	202.00	4.00	0.59	379.00
		All	3.55	0.56	120.00	3.57	0.70	158.00	3.58	0.77	169.00	3.27	0.85	152.00	3.56	0.64	280.00	3.44	0.82	321.00	3.49	0.74	599.00	3.54	0.70	1118.00
Liefkenshoek		Neap	2.06	0.58	26.00	2.53	0.79	34.00	2.30	0.71	35.00	1.44	0.31	25.00	2.34	0.73	62.00	1.94	0.72	60.00	2.13	0.75	120.00	2.10	0.66	252.00
		Avg	2.20	0.58	70.00	2.58	0.45	62.00	2.24	0.62	68.00	1.68	0.55	32.00	2.38	0.55	132.00	2.06	0.65	100.00	2.24	0.62	232.00	2.23	0.65	485.00
		Spring	2.32	0.58	52.00	2.56	0.66	44.00	2.39	0.66	43.00	1.69	0.53	51.00	2.43	0.63	96.00	2.01	0.69	94.00	2.22	0.69	190.00	2.17	0.62	359.00
		All	2.22	0.58	148.00	2.56	0.61	140.00	2.30	0.65	146.00	1.63	0.50	108.00	2.39	0.62	290.00	2.02	0.68	254.00	2.21	0.67	542.00	2.18	0.65	1096.00

Annex-Table D-2: Averaged-tidal salinity amplitude [ppt] (ΔS), standard deviation (σ), and amount of tide in the sample (N) for every measurement station during the period considered (April 2010 – March 2012) – year 2 (April 2011-March 2012). Summer = April to September, Winter = October to March.

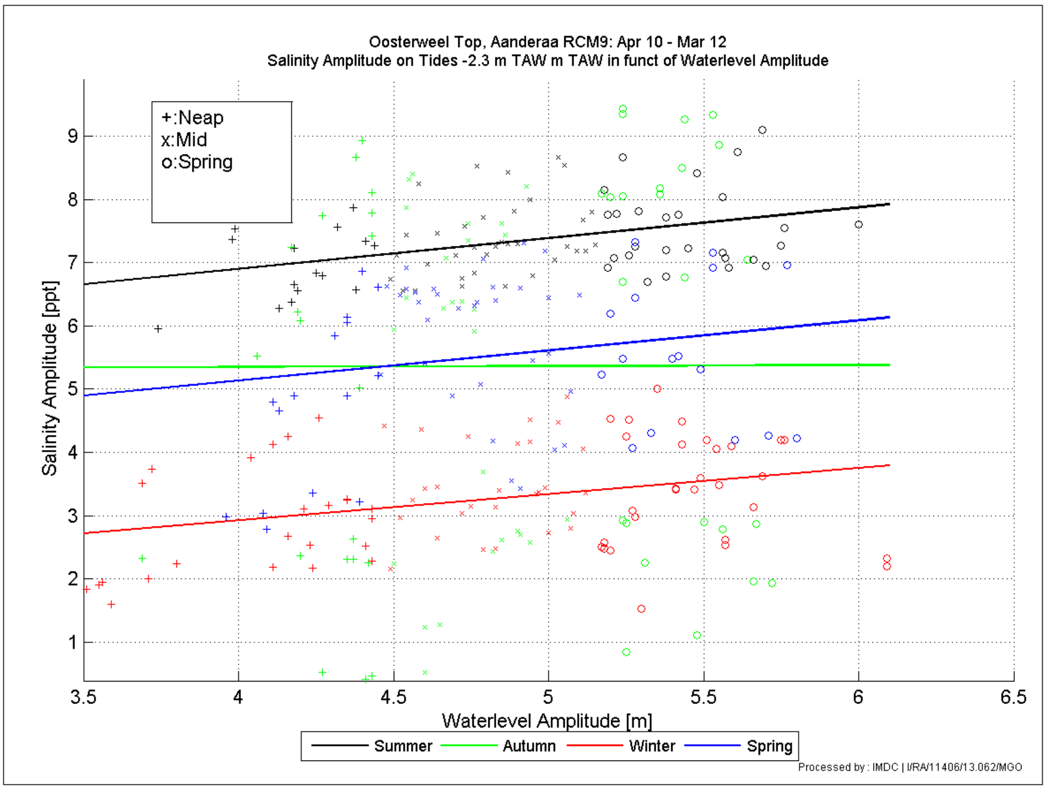
			Apr-Jun			Jul-Sep			Oct-Dec			Jan-Mar			Summer			Winter			Year 2			Total period		
			Δ	σ	N	Δ	σ	N	Δ	σ	N	Δ	σ	N	Δ	σ	N	Δ	σ	N	Δ	σ	N	Δ	σ	N
Buoy 84	-8.1 m TAW	Neap	2.77	0.33	36.00	3.12	0.64	34.00	3.18	0.41	44.00	2.68	0.34	15.00	2.94	0.53	70.00	3.05	0.45	59.00	2.99	0.50	129.00	2.88	0.58	275.00
		Avg	3.22	0.29	77.00	3.32	0.60	59.00	3.88	0.78	83.00	3.06	0.40	11.00	3.26	0.45	136.00	3.78	0.79	94.00	3.48	0.66	230.00	3.27	0.65	446.00
		Spring	3.69	0.36	58.00	3.67	0.70	67.00	4.10	0.50	47.00	3.08	0.43	16.00	3.68	0.56	127.00	3.84	0.65	63.00	3.73	0.60	188.00	3.55	0.67	380.00
		All	3.29	0.46	171.00	3.42	0.69	160.00	3.76	0.72	174.00	2.93	0.42	42.00	3.36	0.59	333.00	3.60	0.75	216.00	3.45	0.67	547.00	3.27	0.69	1101.00
	-5.6 m TAW	Neap	2.39	0.22	35.00	2.76	0.65	34.00	2.81	0.51	40.00	2.46	0.23	34.00	2.57	0.52	69.00	2.65	0.44	74.00	2.61	0.48	143.00	2.55	0.54	282.00
		Avg	2.85	0.26	87.00	2.91	0.54	57.00	3.49	0.84	56.00	2.85	0.64	37.00	2.87	0.40	144.00	3.24	0.83	93.00	3.02	0.63	237.00	2.87	0.59	454.00
		Spring	3.25	0.29	51.00	3.23	0.62	68.00	3.55	0.43	36.00	3.08	0.61	54.00	3.24	0.50	121.00	3.27	0.59	90.00	3.25	0.54	209.00	3.14	0.58	381.00
		All	2.88	0.40	173.00	3.01	0.63	159.00	3.30	0.73	132.00	2.85	0.60	125.00	2.95	0.52	334.00	3.08	0.70	257.00	3.00	0.61	589.00	2.88	0.62	1117.00
Oosterweel	- 5.8 m TAW	Neap	6.04	0.50	31.00	7.05	0.63	37.00	8.11	1.15	48.00	2.72	0.94	27.00	6.59	0.77	68.00	6.17	2.82	75.00	6.37	2.11	143.00	5.48	2.41	269.00
		Avg	6.71	0.68	76.00	7.73	0.58	59.00	7.79	2.59	81.00	3.20	1.03	37.00	7.16	0.81	135.00	6.35	3.08	118.00	6.78	2.22	253.00	6.05	2.35	491.00
		Spring	6.78	0.71	36.00	7.91	0.48	70.00	8.13	2.46	40.00	3.50	1.11	42.00	7.54	0.78	108.00	5.76	3.00	82.00	6.76	2.24	188.00	6.15	2.39	356.00
		All	6.58	0.71	143.00	7.65	0.64	166.00	7.96	2.24	169.00	3.20	1.07	106.00	7.17	0.86	311.00	6.13	2.98	275.00	6.67	2.20	584.00	5.94	2.39	1116.00
	- 2.3 m TAW	Neap	6.20	0.56	34.00	7.12	0.61	30.00	8.00	1.48	48.00	2.98	0.91	40.00	6.63	0.74	64.00	5.72	2.81	88.00	6.10	2.23	152.00	5.57	2.19	295.00
		Avg	6.65	0.70	84.00	7.72	0.55	59.00	8.15	2.37	86.00	3.37	0.95	58.00	7.09	0.83	143.00	6.22	3.04	144.00	6.66	2.27	287.00	6.27	2.23	517.00
		Spring	6.77	0.67	47.00	7.92	0.46	63.00	8.43	2.16	36.00	3.41	0.93	66.00	7.44	0.80	112.00	5.18	2.83	102.00	6.35	2.33	212.00	6.22	2.19	393.00
		All	6.59	0.69	165.00	7.68	0.60	152.00	8.17	2.11	170.00	3.29	0.94	164.00	7.12	0.85	319.00	5.77	2.94	334.00	6.43	2.29	651.00	6.08	2.22	1205.00
Prosperpolder	- 1.5 m TAW	Neap	2.80	0.36	35.00	2.99	0.45	30.00	3.12	0.39	15.00	2.89	0.50	36.00	2.89	0.41	65.00	2.96	0.48	51.00	2.92	0.44	116.00	2.87	0.52	280.00
		Avg	3.34	0.43	86.00	3.81	0.44	58.00	3.87	0.50	40.00	3.59	0.45	42.00	3.53	0.49	144.00	3.73	0.49	82.00	3.60	0.50	226.00	3.55	0.54	459.00
		Spring	3.75	0.70	44.00	4.03	0.46	68.00	4.29	0.48	16.00	4.08	0.55	49.00	3.92	0.58	114.00	4.13	0.53	65.00	4.00	0.57	177.00	4.00	0.59	379.00
		All	3.34	0.60	165.00	3.75	0.59	156.00	3.80	0.61	71.00	3.58	0.69	127.00	3.54	0.63	323.00	3.66	0.67	198.00	3.58	0.65	519.00	3.54	0.70	1118.00
Liefkenshoek		Neap	1.78	0.35	34.00	2.30	0.77	28.00	2.35	0.55	36.00	1.85	0.33	34.00	2.02	0.63	62.00	2.11	0.52	70.00	2.06	0.57	132.00	2.10	0.66	252.00
		Avg	1.86	0.30	80.00	2.51	0.77	56.00	2.44	0.79	78.00	2.06	0.53	39.00	2.13	0.63	136.00	2.31	0.73	117.00	2.21	0.68	253.00	2.23	0.65	485.00
		Spring	1.87	0.34	37.00	2.26	0.57	59.00	2.20	0.61	32.00	2.06	0.50	41.00	2.11	0.53	96.00	2.12	0.55	73.00	2.12	0.54	169.00	2.17	0.62	359.00
		All	1.85	0.32	151.00	2.37	0.70	143.00	2.37	0.70	146.00	2.00	0.47	114.00	2.10	0.60	294.00	2.20	0.64	260.00	2.15	0.62	554.00	2.18	0.65	1096.00



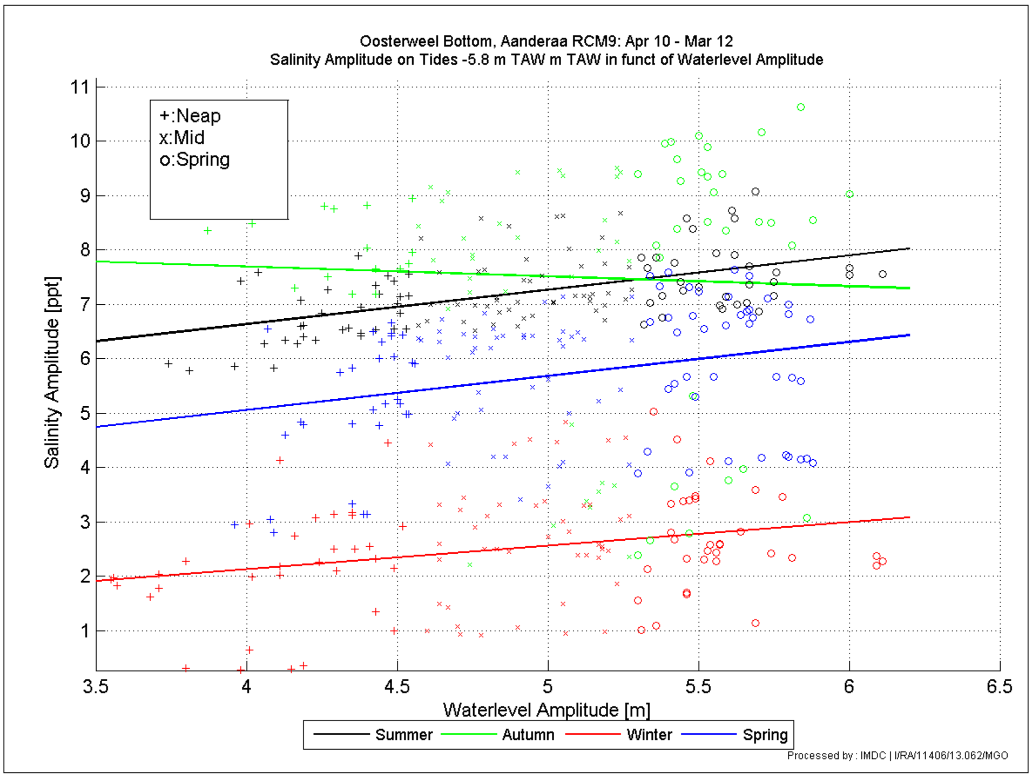
Annex-Figure D-8: Buoy 84 (-5.6m TAW). Amplitude of the salinity vs. tidal amplitude. Saline regime. Apr 2010 – Mar 2012. (R = 0.43; sig = 0.00; n = 1092).



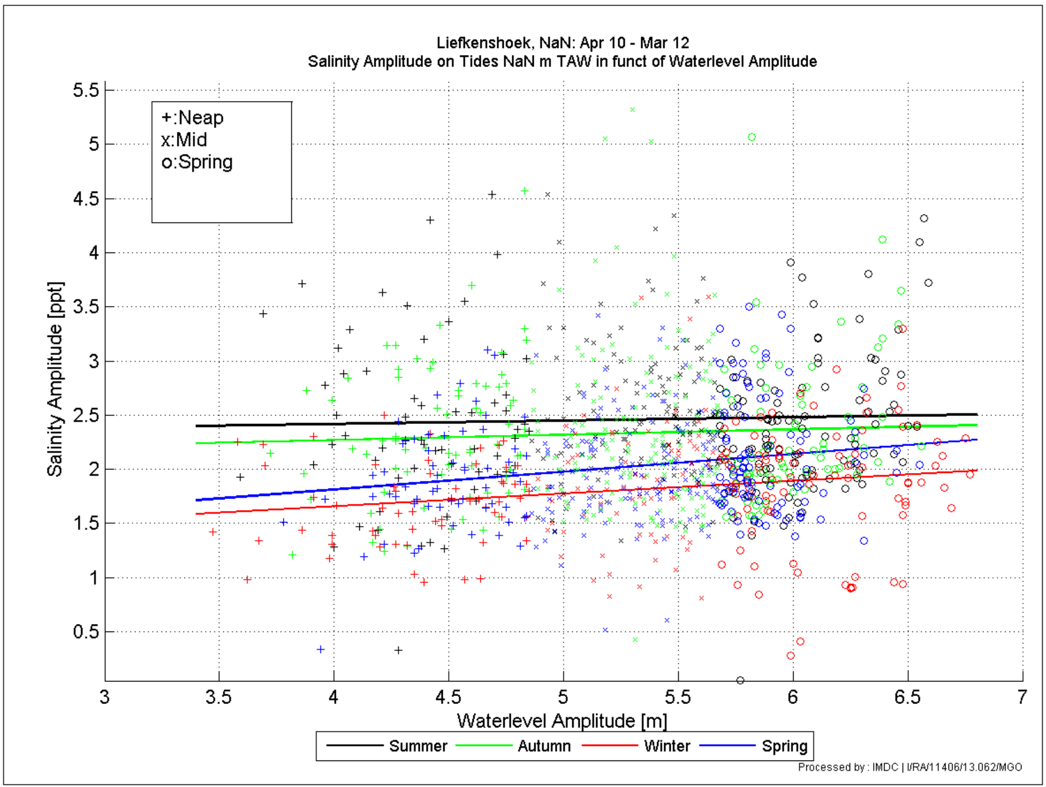
Annex-Figure D-9: Buoy 84 (-8.1m TAW). Amplitude of the salinity vs. tidal amplitude. Saline regime. Apr 2010 – Mar 2012. (R = 0.40; sig = 0.00; n = 1083).



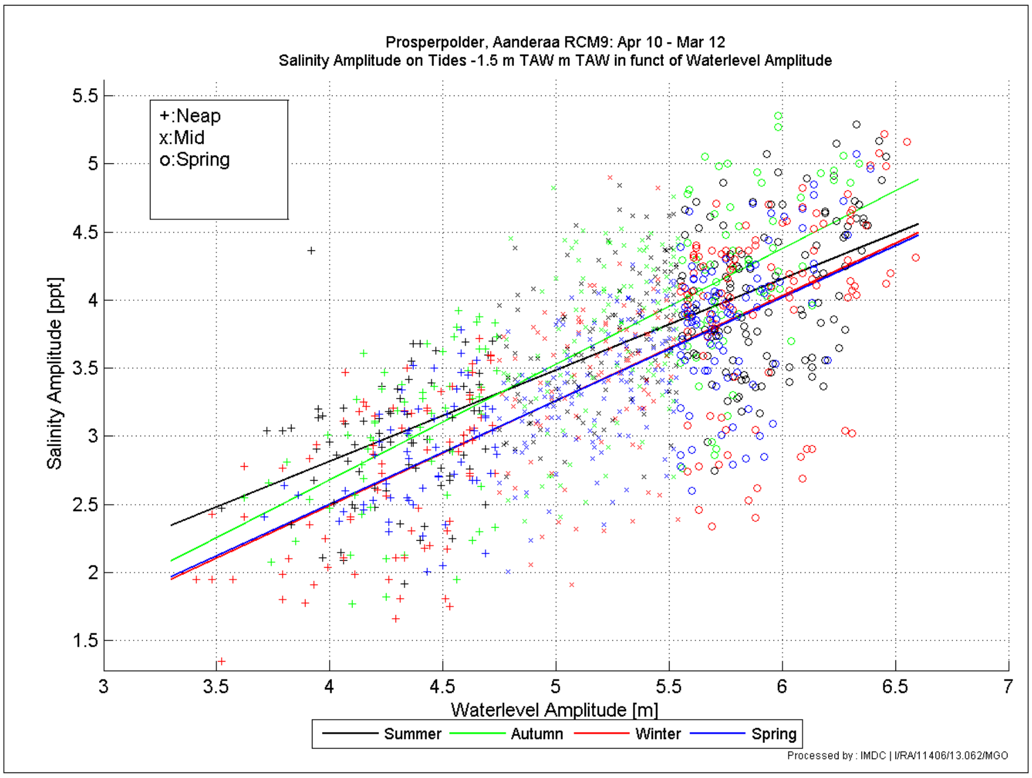
Annex-Figure D-10: Oosterweel (-2.3m TAW). Amplitude of the salinity vs. tidal amplitude. Slightly brackish regime. Apr 2010 – Mar 2012. (R = 0.13; sig = 0.03; n = 295).



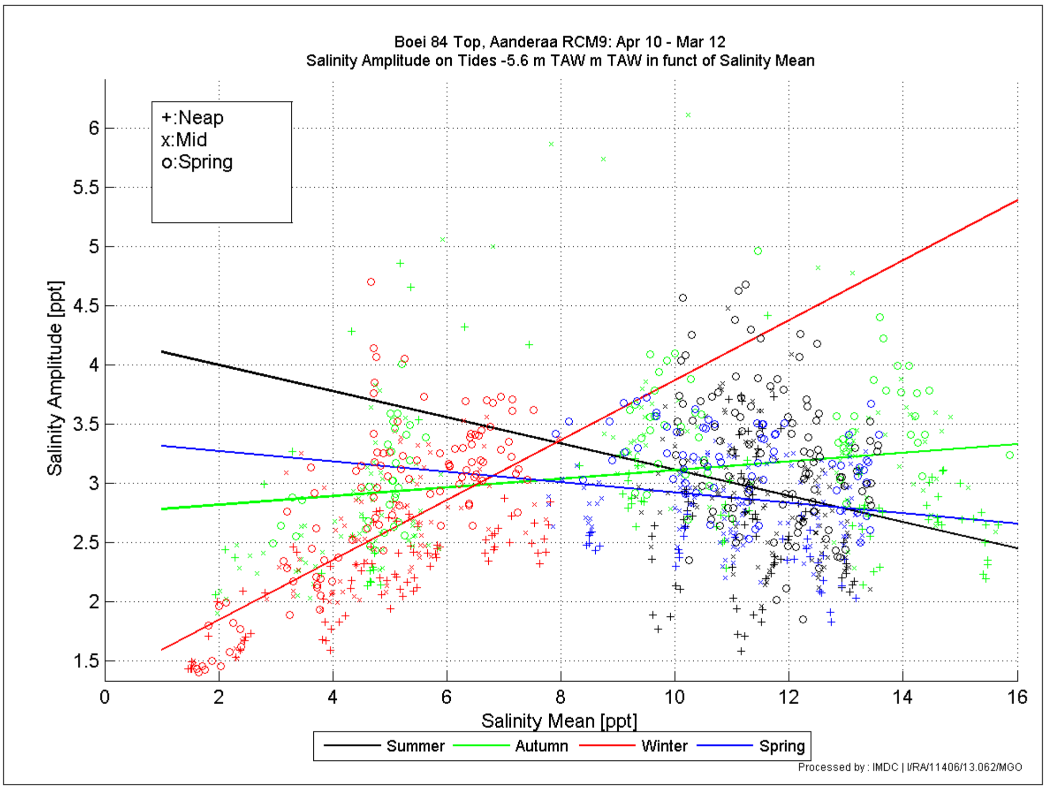
Annex-Figure D-11: Oosterweel (-5.8m TAW). Amplitude of the salinity vs. tidal amplitude. Slightly brackish regime. Apr 2010 – Mar 2012. (R = 0.17; sig = 0.00; n = 424).



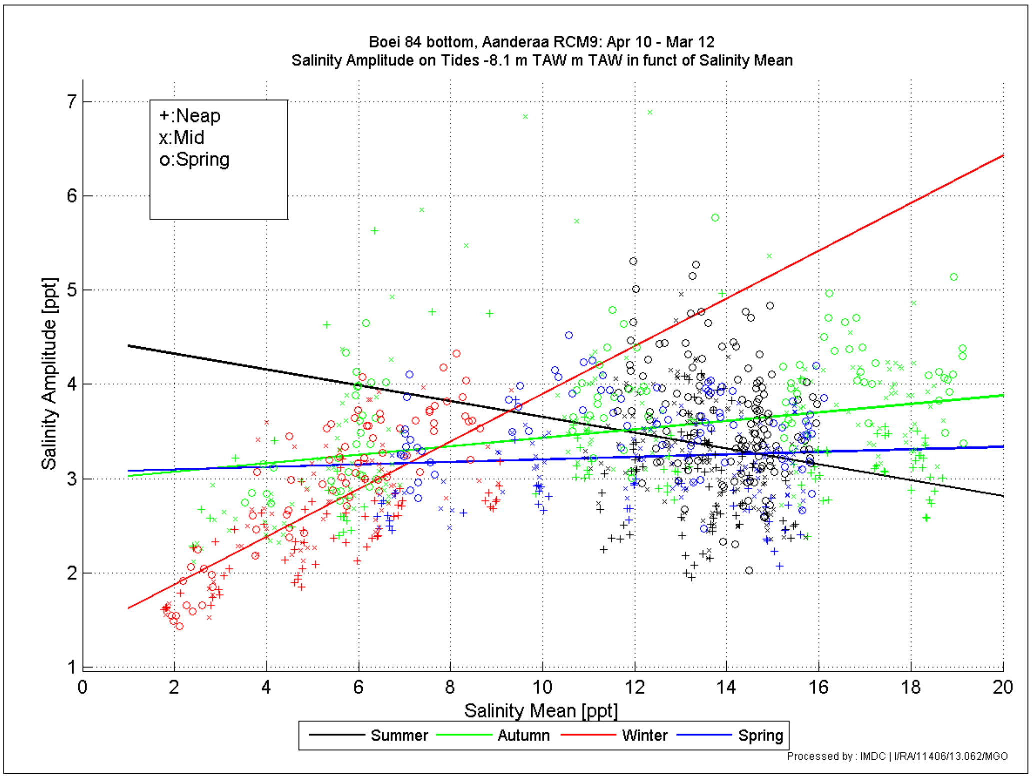
Annex-Figure D-12: Liefkenshoek. Amplitude of the salinity vs. tidal amplitude. Slightly brackish regime. Apr 2010 – Mar 2012. (R = 0.08; sig = 0.01; n = 1096).



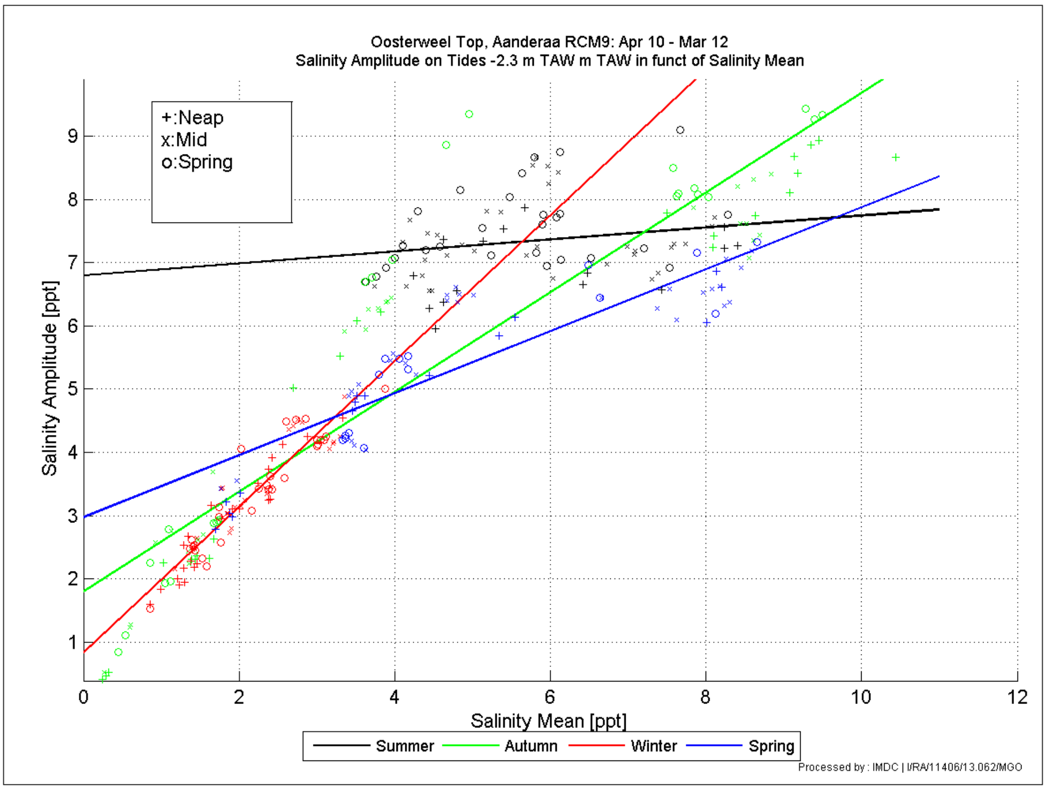
Annex-Figure D-13: Prosperpolder (-1.5m TAW). Amplitude of the salinity vs. tidal amplitude. Slightly brackish regime. Apr 2010 – Mar 2012. (R = 0.68; sig = 0.00; n = 1118).



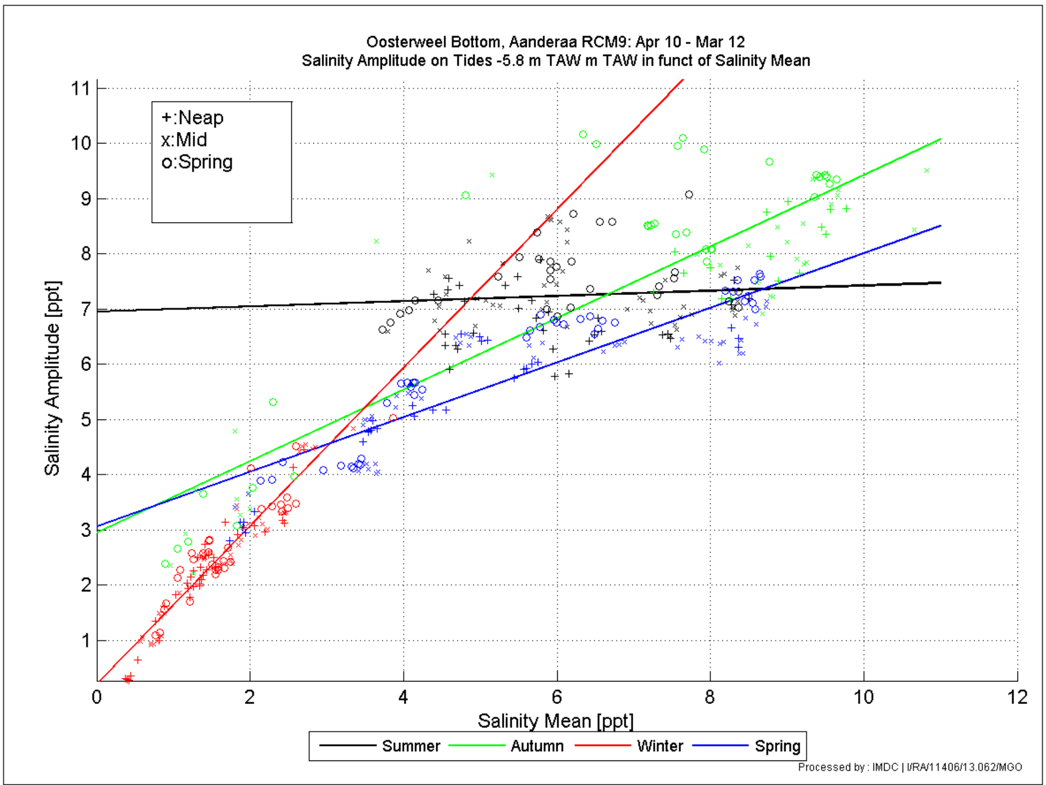
Annex-Figure D-14: Buoy 84 (-5.6m TAW). Amplitude of the salinity vs. salinity mean. Saline regime. Apr 2010 – Mar 2012. (R = 0.29; sig = 0.00; n = 1077).



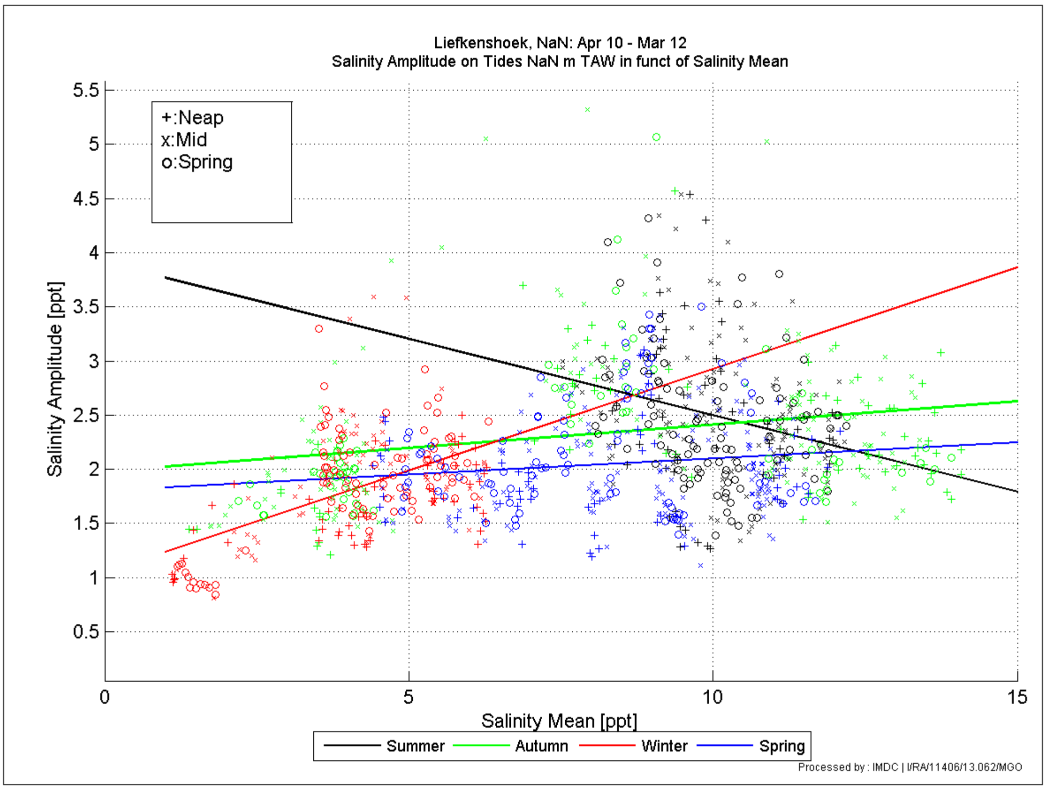
Annex-Figure D-15: Buoy 84 (-8.1m TAW). Amplitude of the salinity vs. salinity mean. Saline regime. Apr 2010 – Mar 2012. (R = 0.39; sig = 0.00; n = 1055).



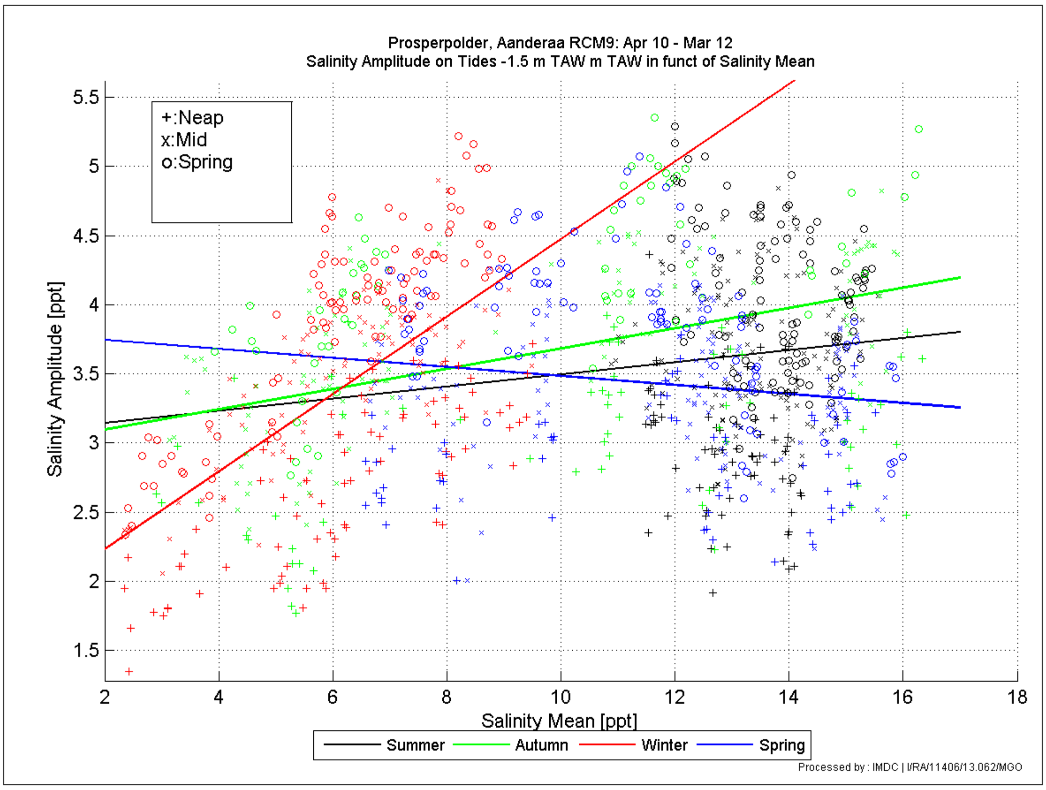
Annex-Figure D-16: Oosterweel (-2.3m TAW). Amplitude of the salinity vs. salinity mean. Slightly brackish regime. Apr 2010 – Mar 2012. (R = 0.88; sig = 0.00; n = 297).



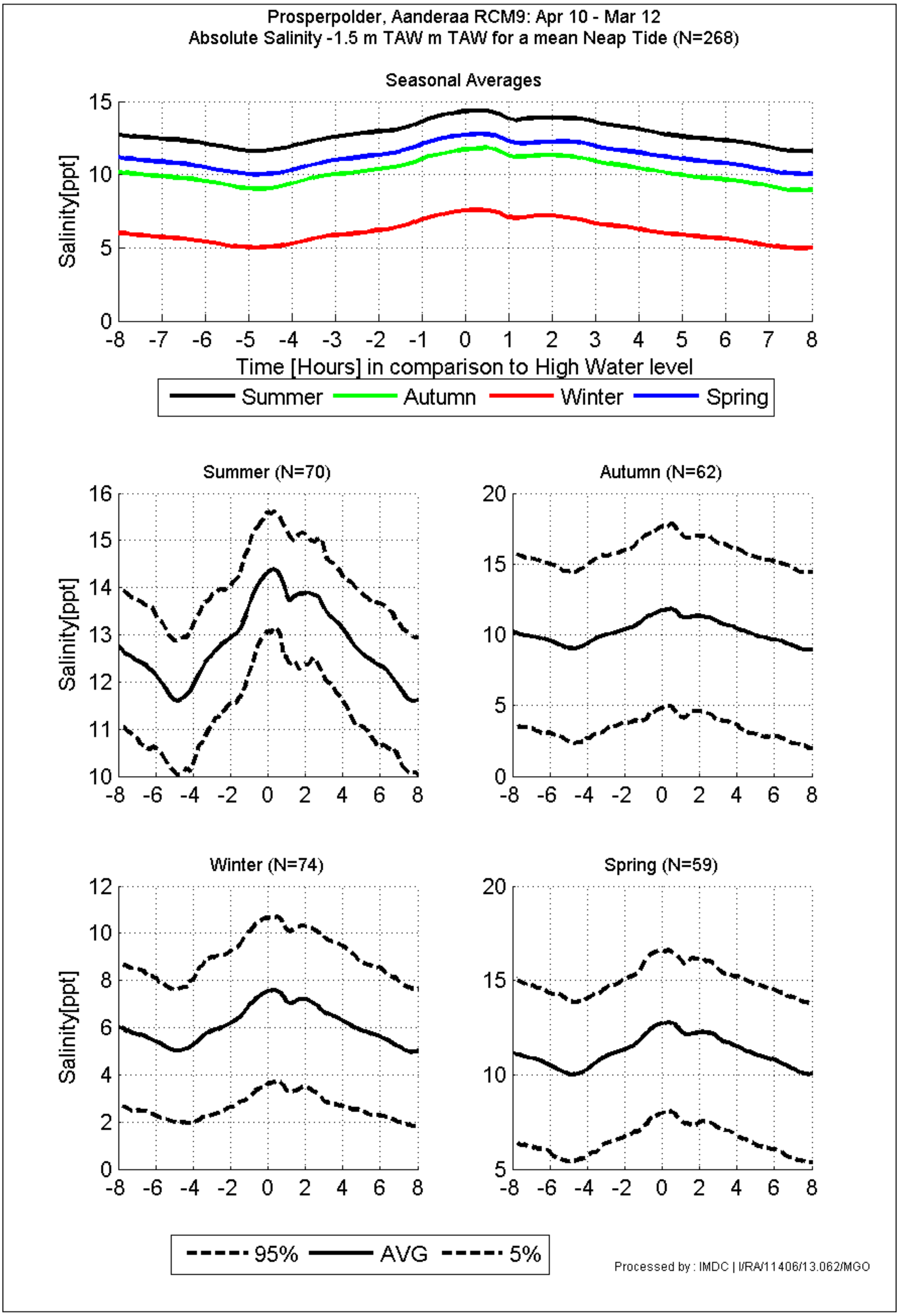
Annex-Figure D-17: Oosterweel (-5.8m TAW). Amplitude of the salinity vs. salinity mean. Slightly brackish regime. Apr 2010 – Mar 2012. (R = 0.90; sig = 0.00; n = 422).



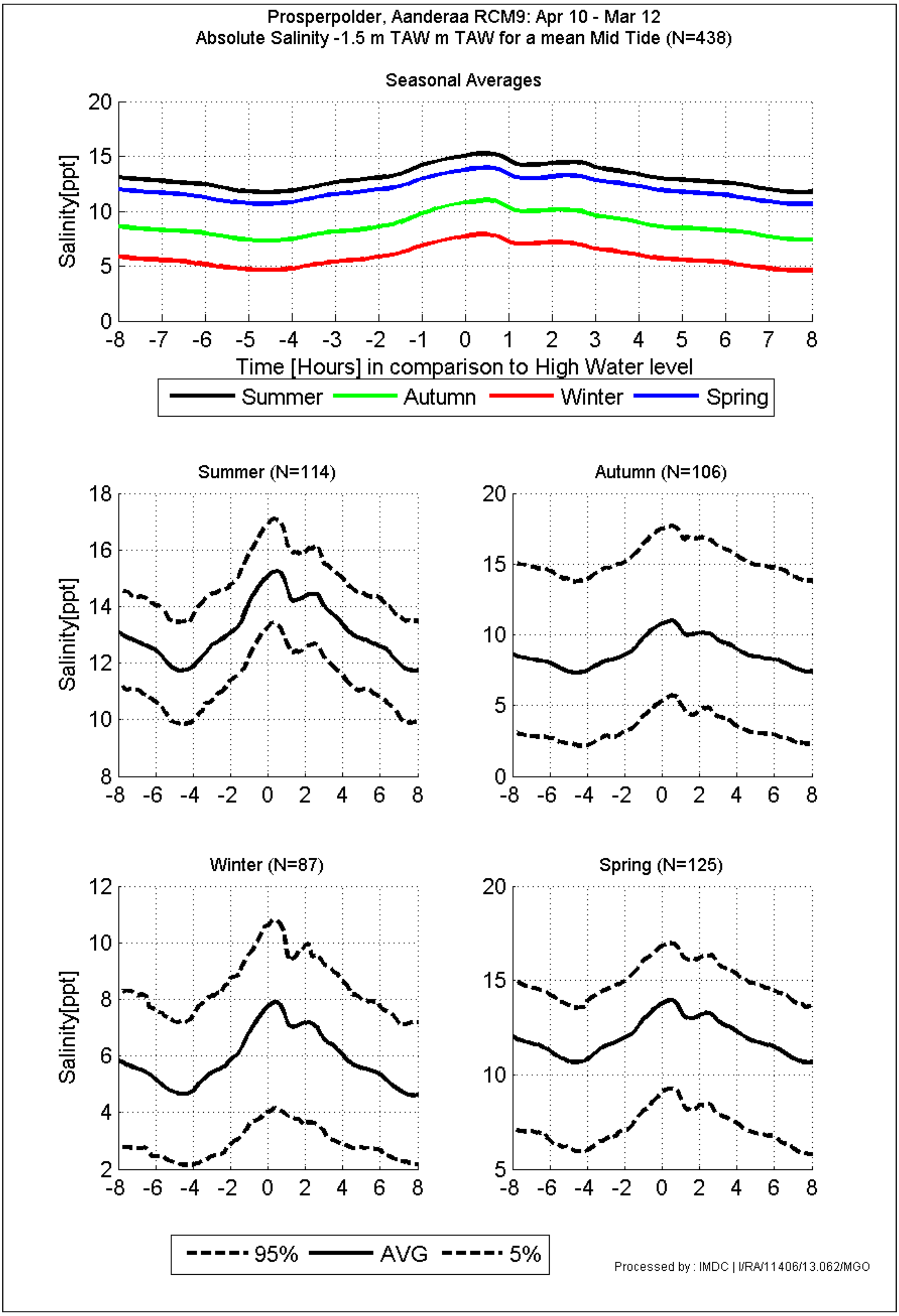
Annex-Figure D-18: Liefkenshoek. Amplitude of the salinity vs salinity mean. Slightly brackish regime. Apr 2010 – Mar 2012. (R = 0.34; sig = 0.00; n = 1028).



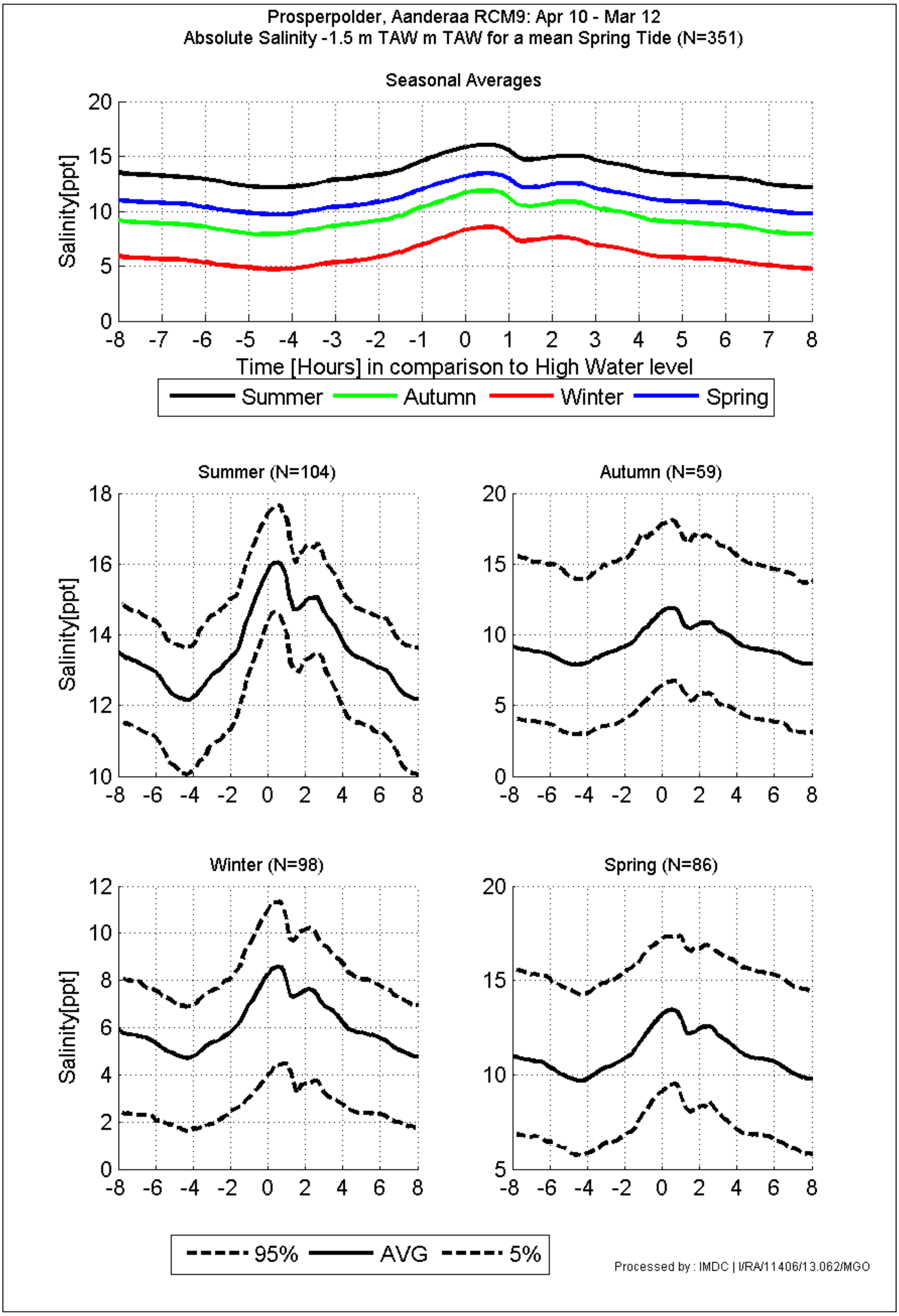
Annex-Figure D-19: Prosperpolder (-1.5m TAW). Amplitude of the salinity vs. salinity mean. Slightly brackish regime. Apr 2010 – Mar 2012. (R = 0.23; sig = 0.00; n = 1072).



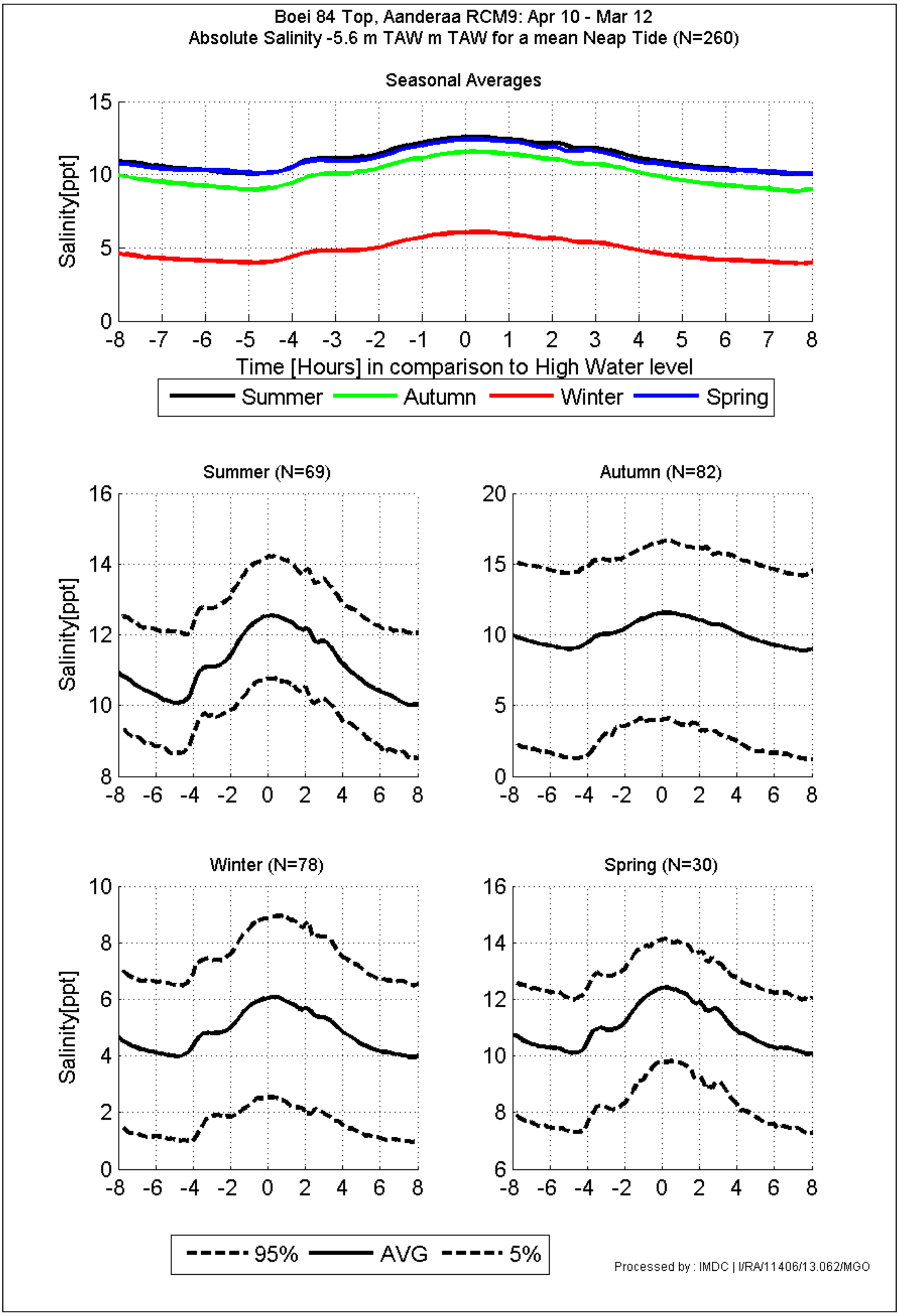
Annex-Figure D-20: Prosperpolder (-1.5m TAW), April 2010 – March 2012, Average tidal curve of the salinity for an average (a) neap tide.



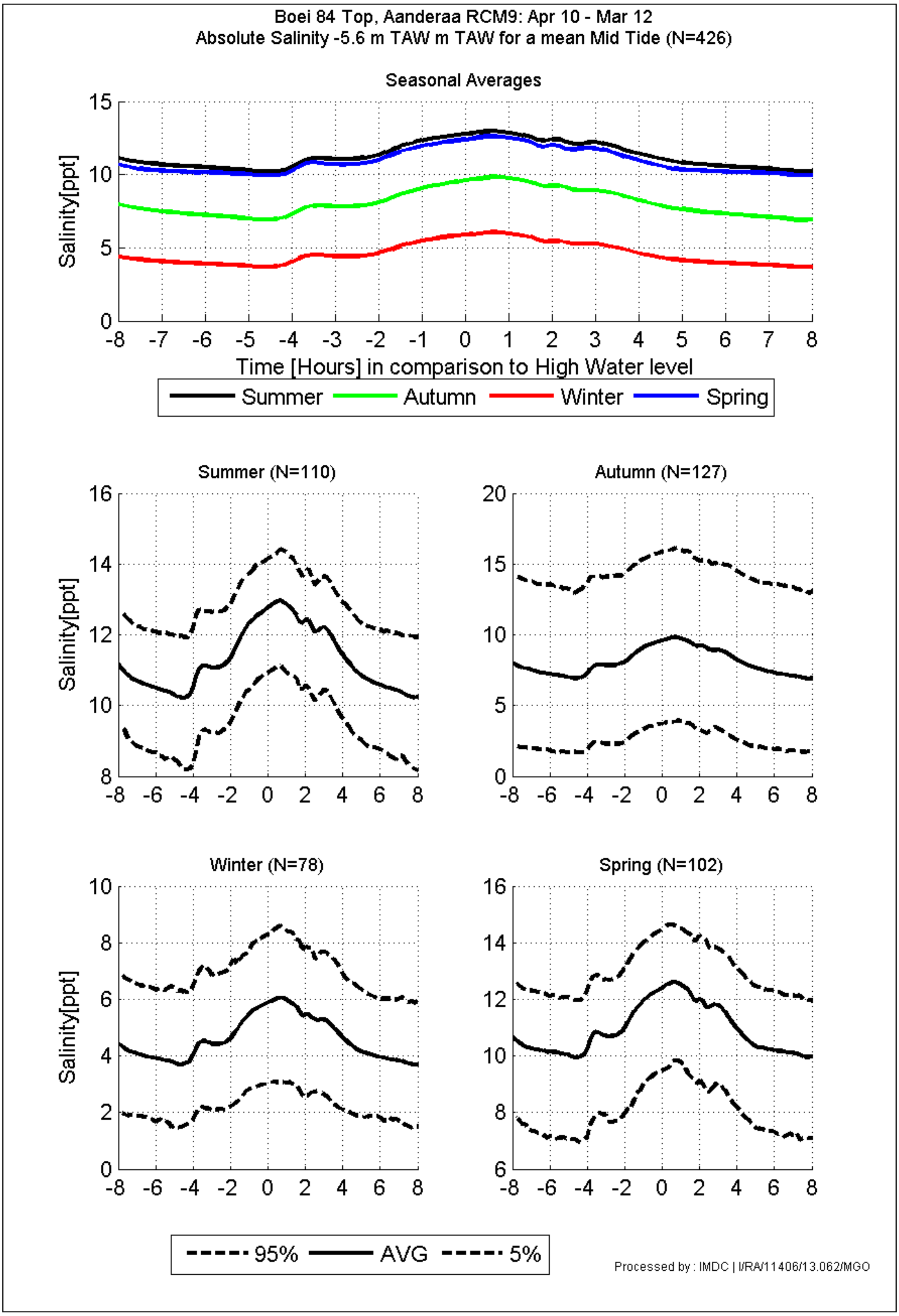
Annex-Figure D-21: Prosperpolder (-1.5m TAW), April 2010 – March 2012, Average tidal curve of the salinity for an average (b) average tide.



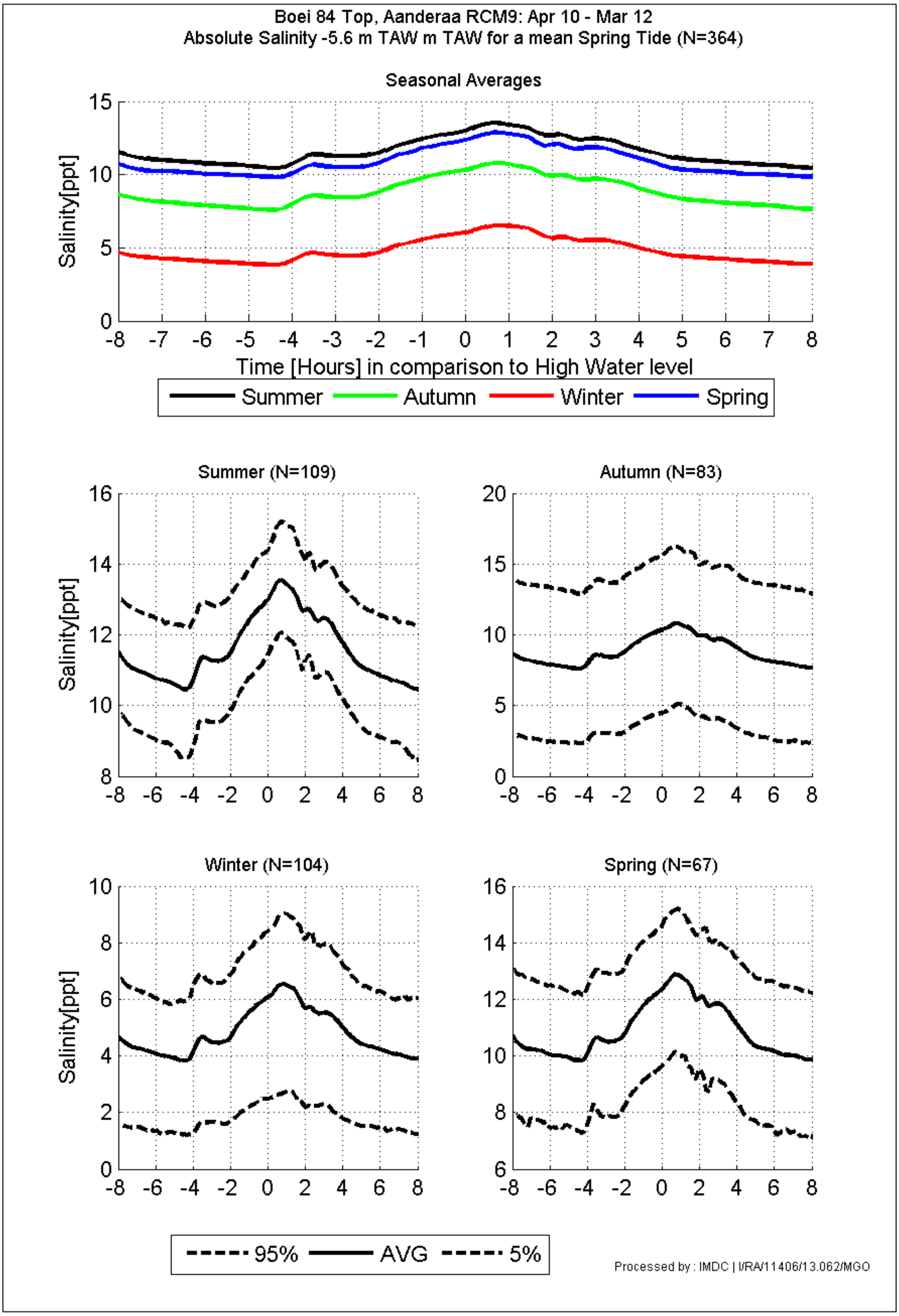
Annex-Figure D-22: Prosperpolder (-1.5m TAW), April 2010 – March 2012, Average tidal curve of the salinity for an average (c) spring tide.



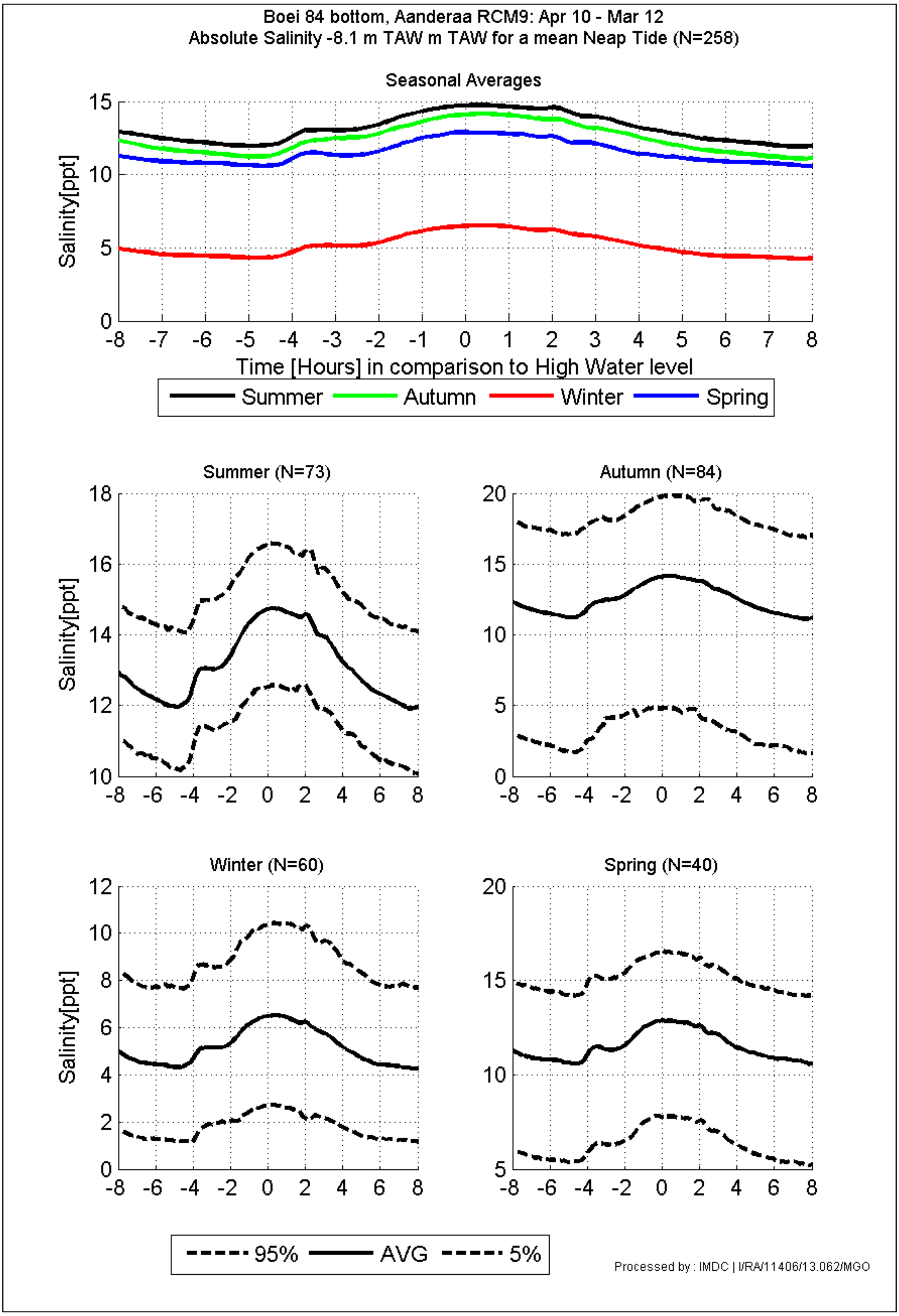
Annex-Figure D-23: Buoy 84 (-5.6m TAW), April 2010 – March 2012, Average tidal curve of the salinity for an average (a) neap tide.



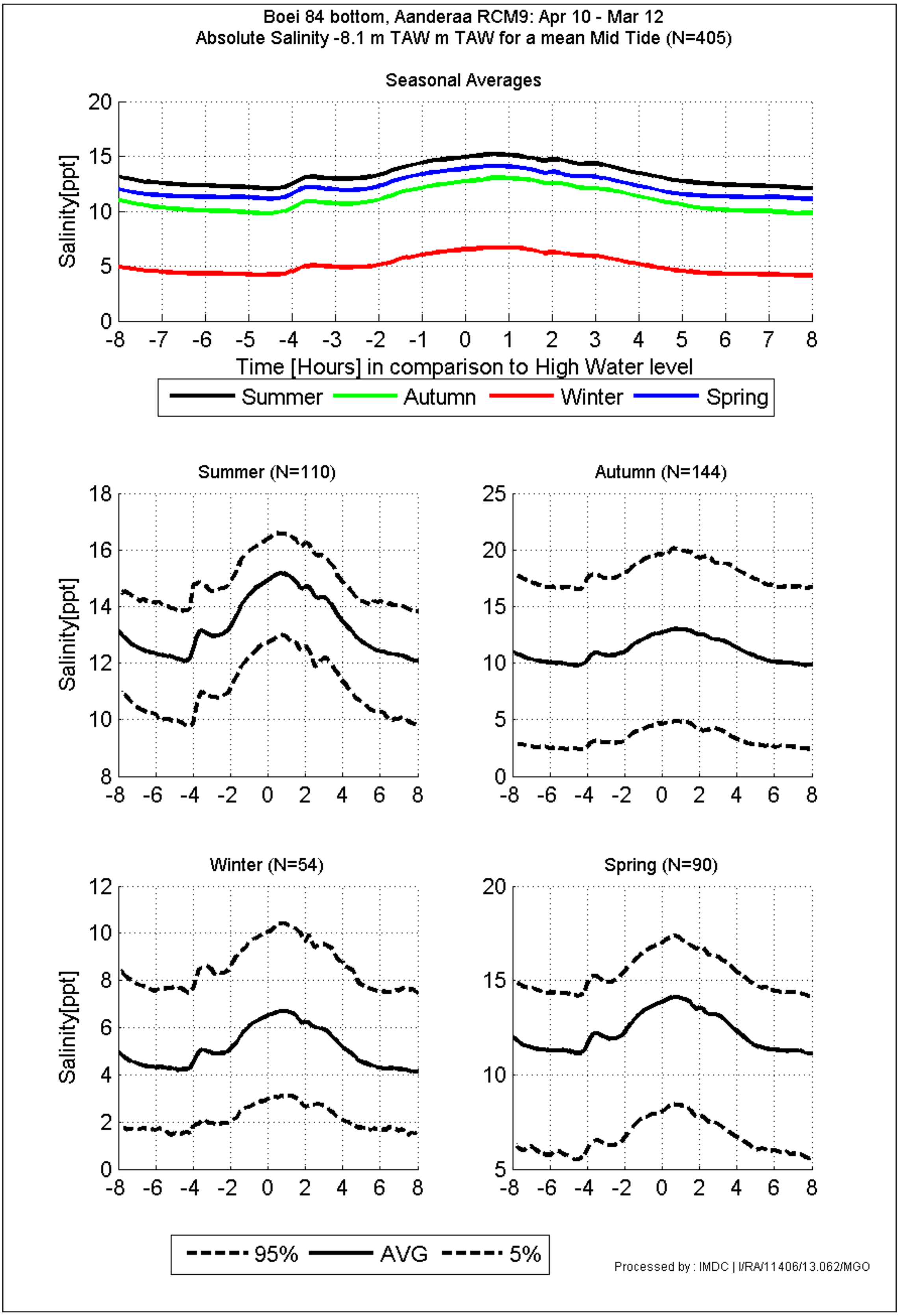
Annex-Figure D-24: Buoy 84 (-5.6m TAW), April 2010 – March 2012, Average tidal curve of the salinity for an average (b) mean tide.



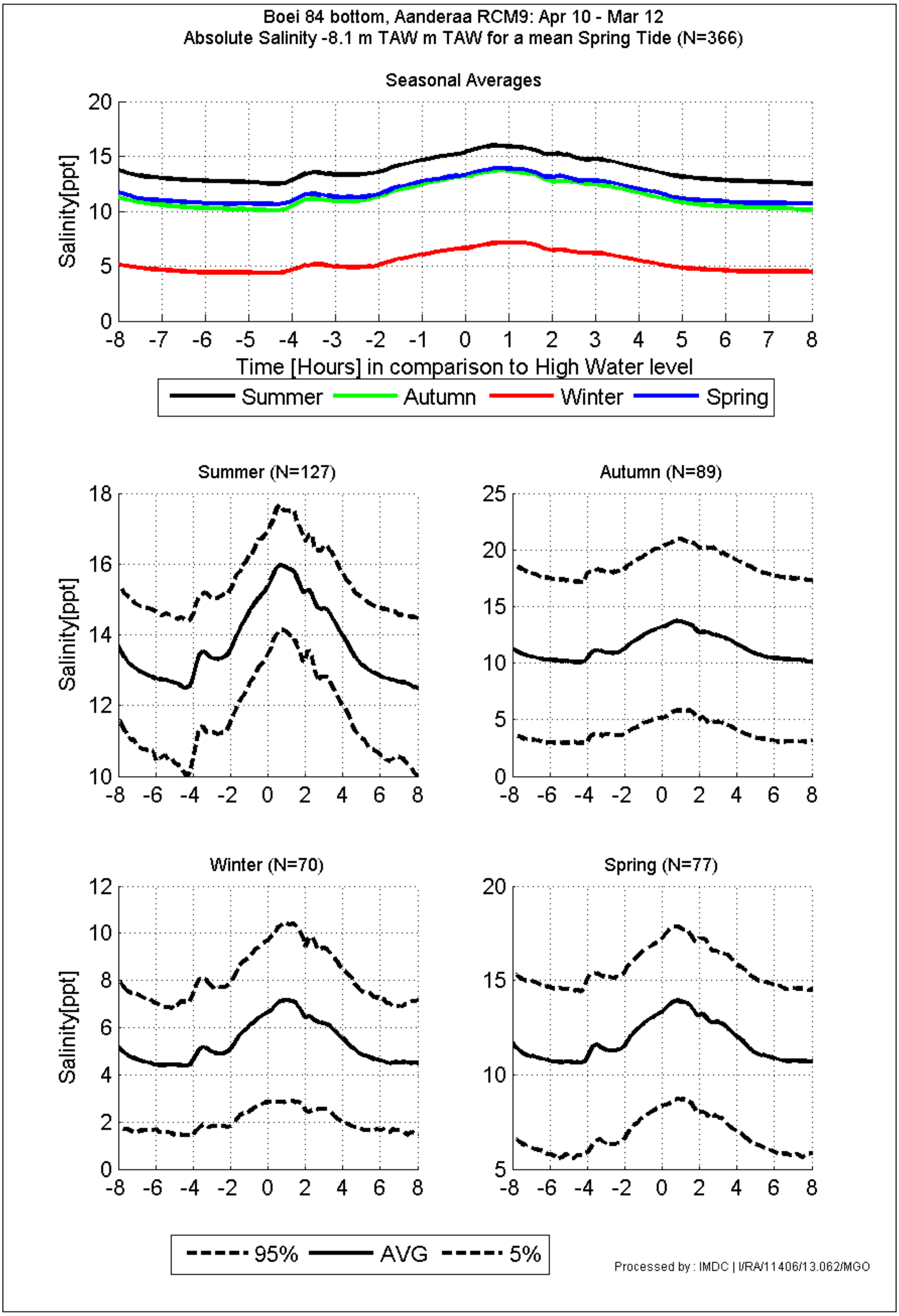
Annex-Figure D-25: Buoy 84 (-5.6m TAW), April 2010 – March 2012, Average tidal curve of the salinity for an average (c) spring tide.



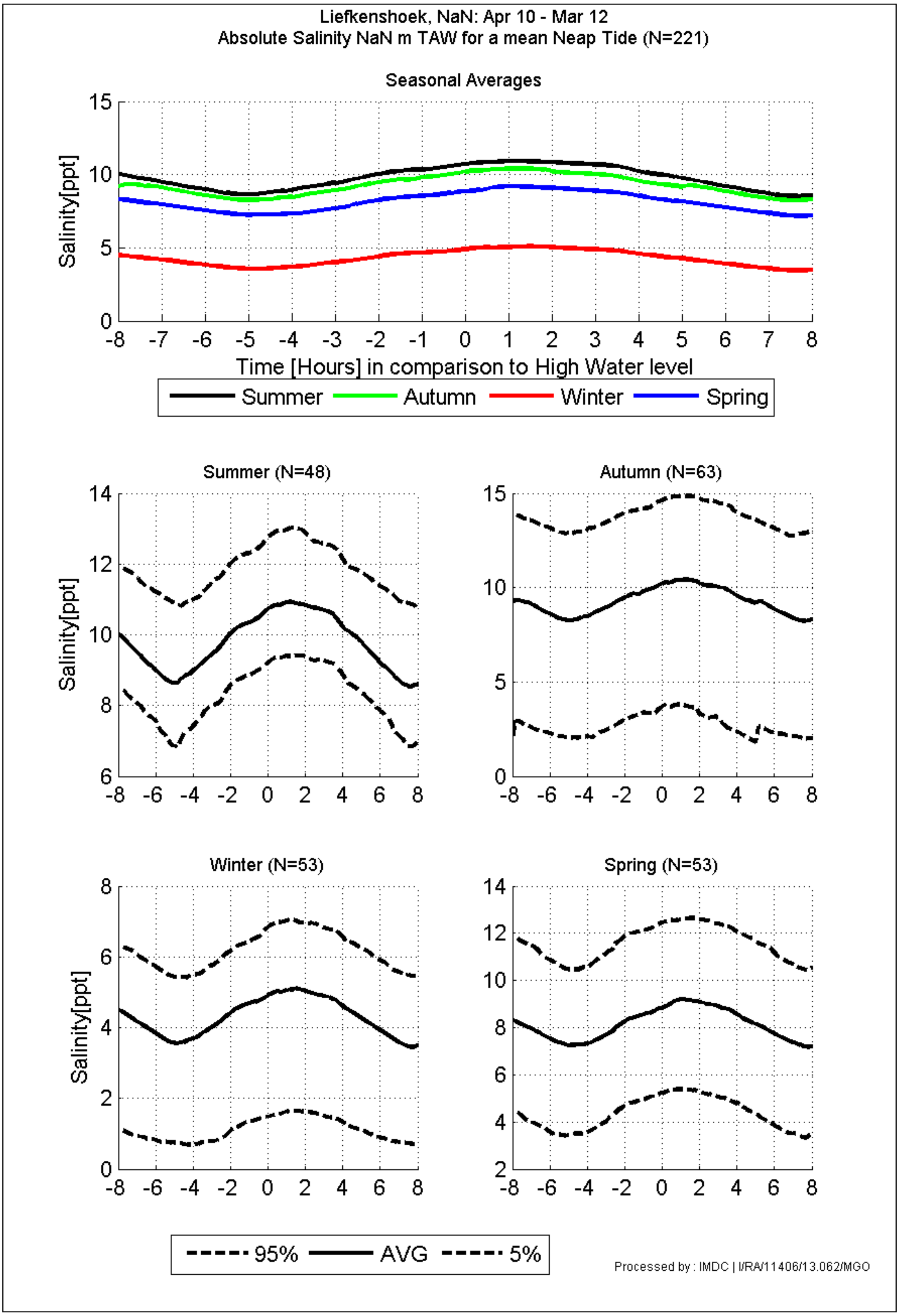
Annex-Figure D-26: Buoy 84 (-8.1m TAW), April 2010 – March 2012, Average tidal curve of the salinity for an average (a) neap tide.



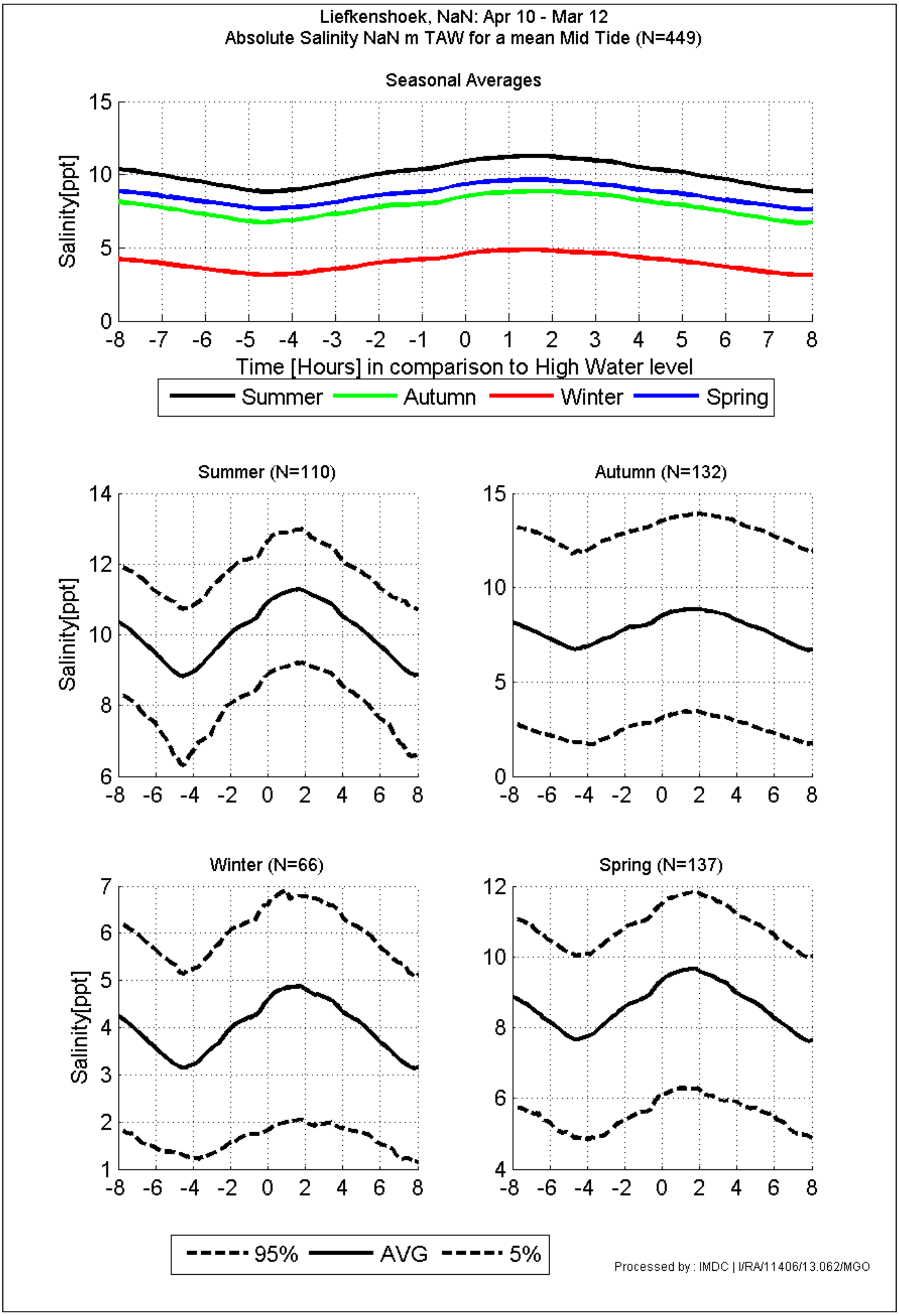
Annex-Figure D-27: Buoy 84 (-8.1m TAW), April 2010 – March 2012, Average tidal curve of the salinity for an average (b) average tide.



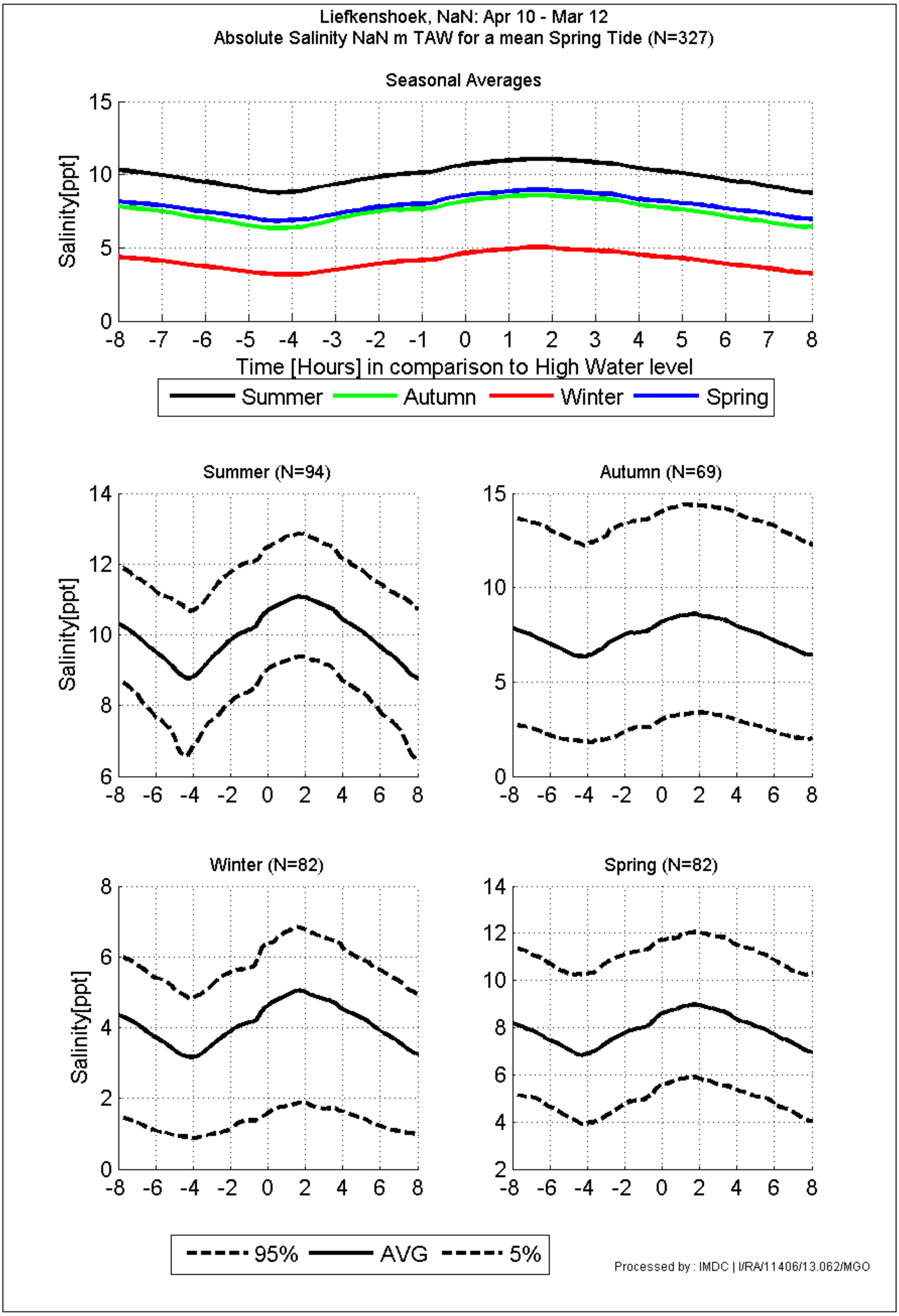
Annex-Figure D-28: Buoy 84 (-8.1m TAW), April 2010 – March 2012, Average tidal curve of the salinity for an average (c) spring tide.



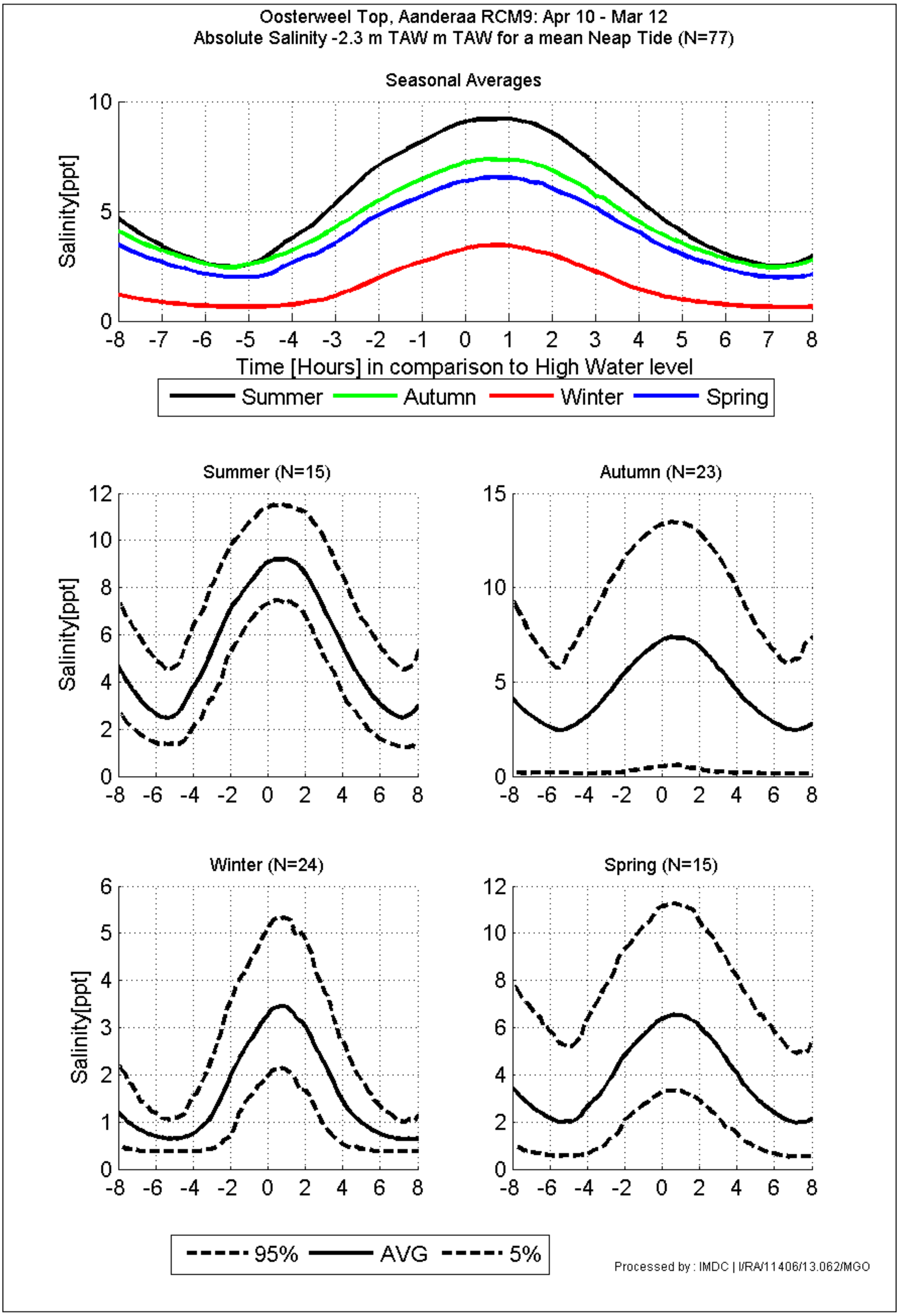
Annex-Figure D-29: Liefkenshoek, April 2010 – March 2012, Average tidal curve of the salinity for an average (a) neap tide.



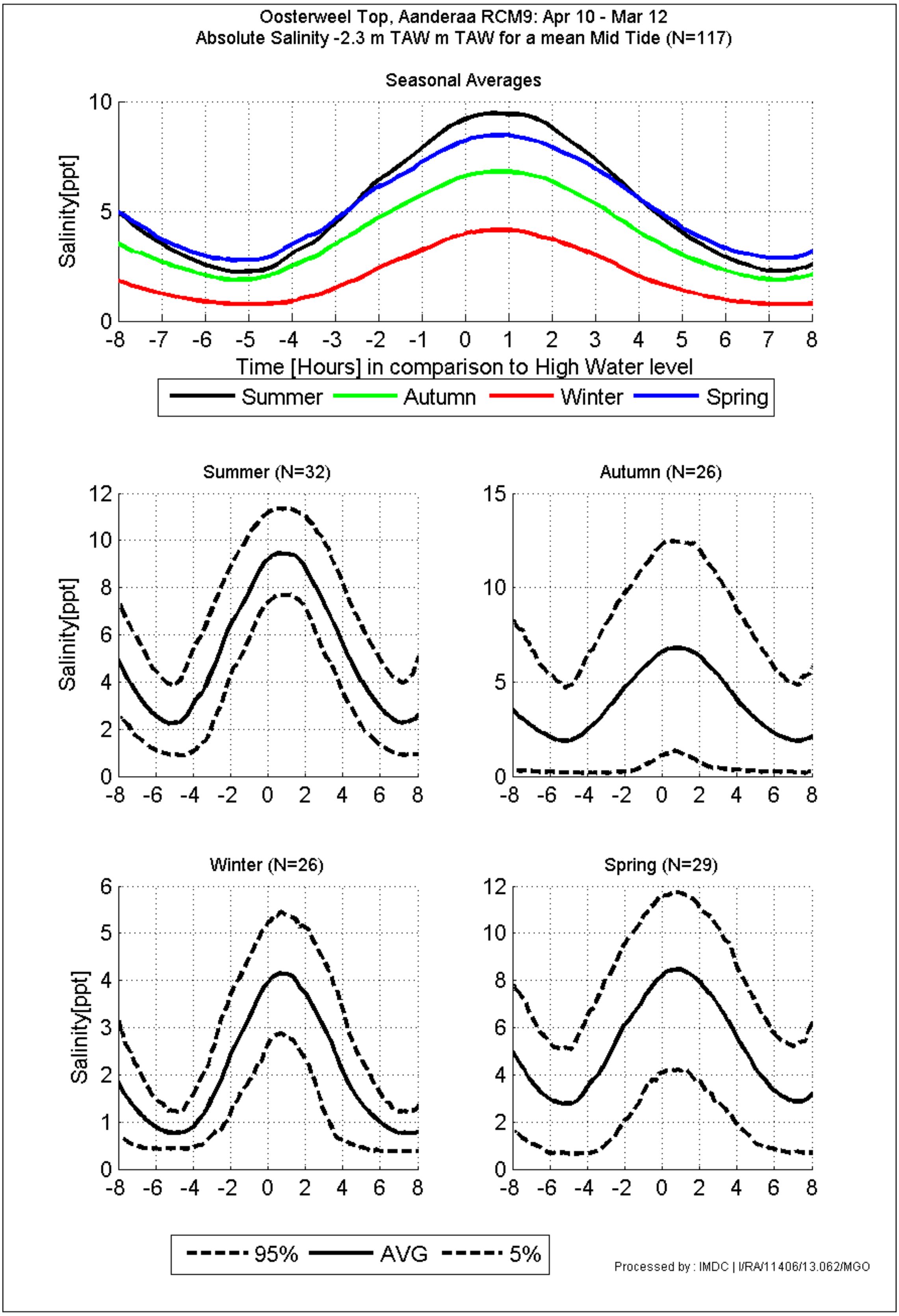
Annex-Figure D-30: Liefkenshoek, April 2010 – March 2012, Average tidal curve of the salinity for an average (b) mean tide.



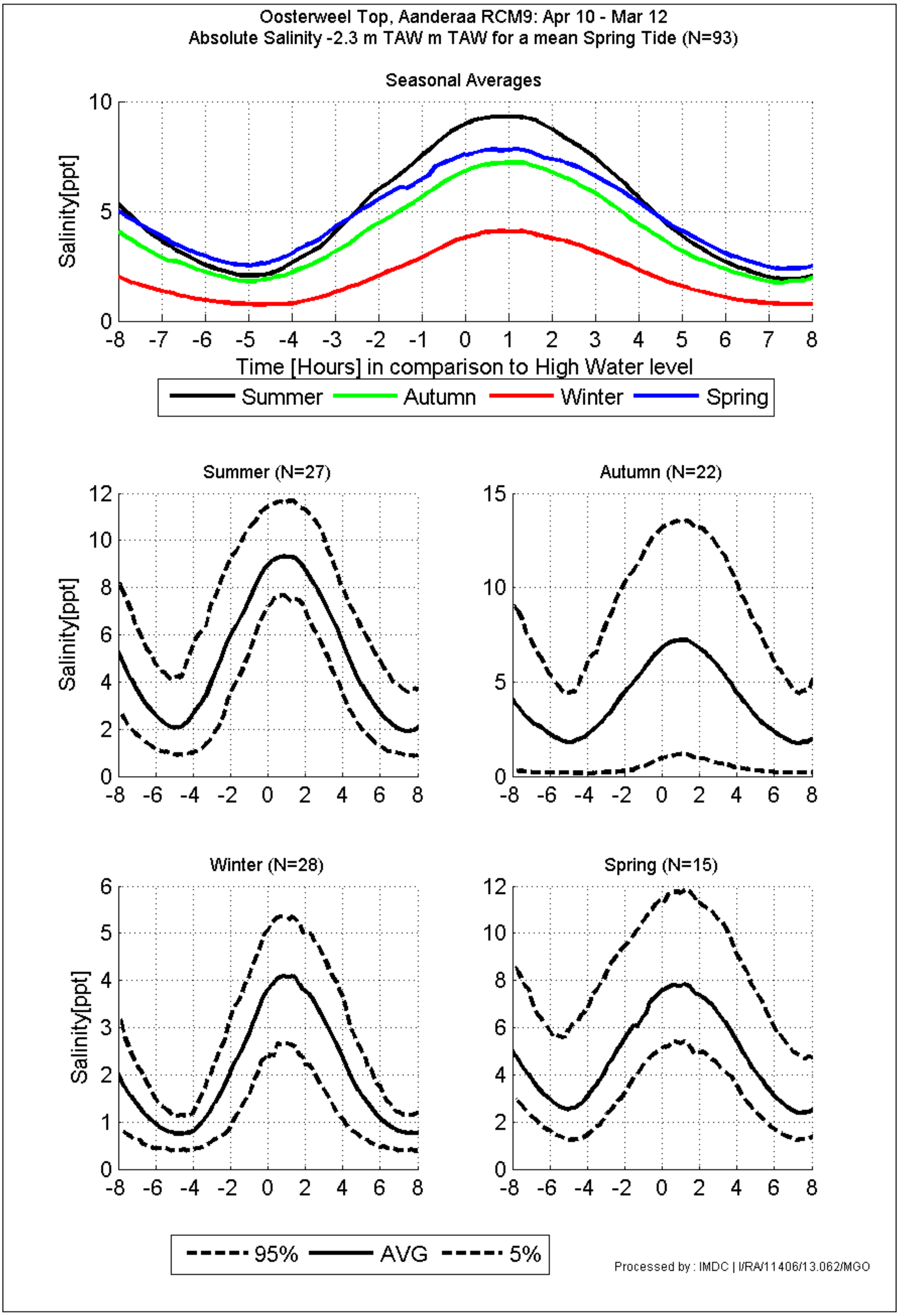
Annex-Figure D-31: Liefkenshoek, April 2010 – March 2012, Average tidal curve of the salinity for an average (c) spring tide.



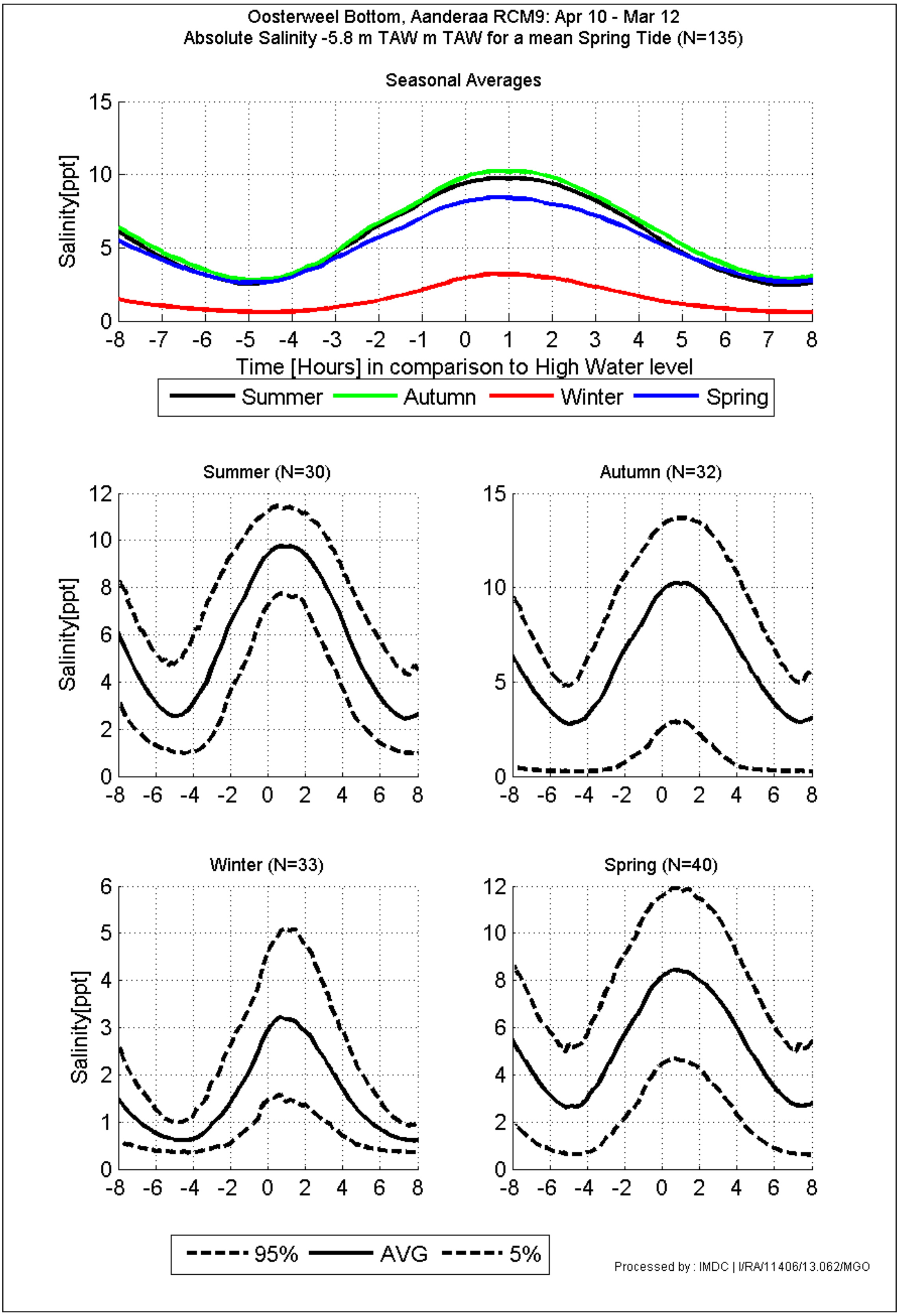
Annex-Figure D-32: Oosterweel (-2.3m TAW), April 2010 – March 2012, Average tidal curve of the salinity for an average (a) neap tide.



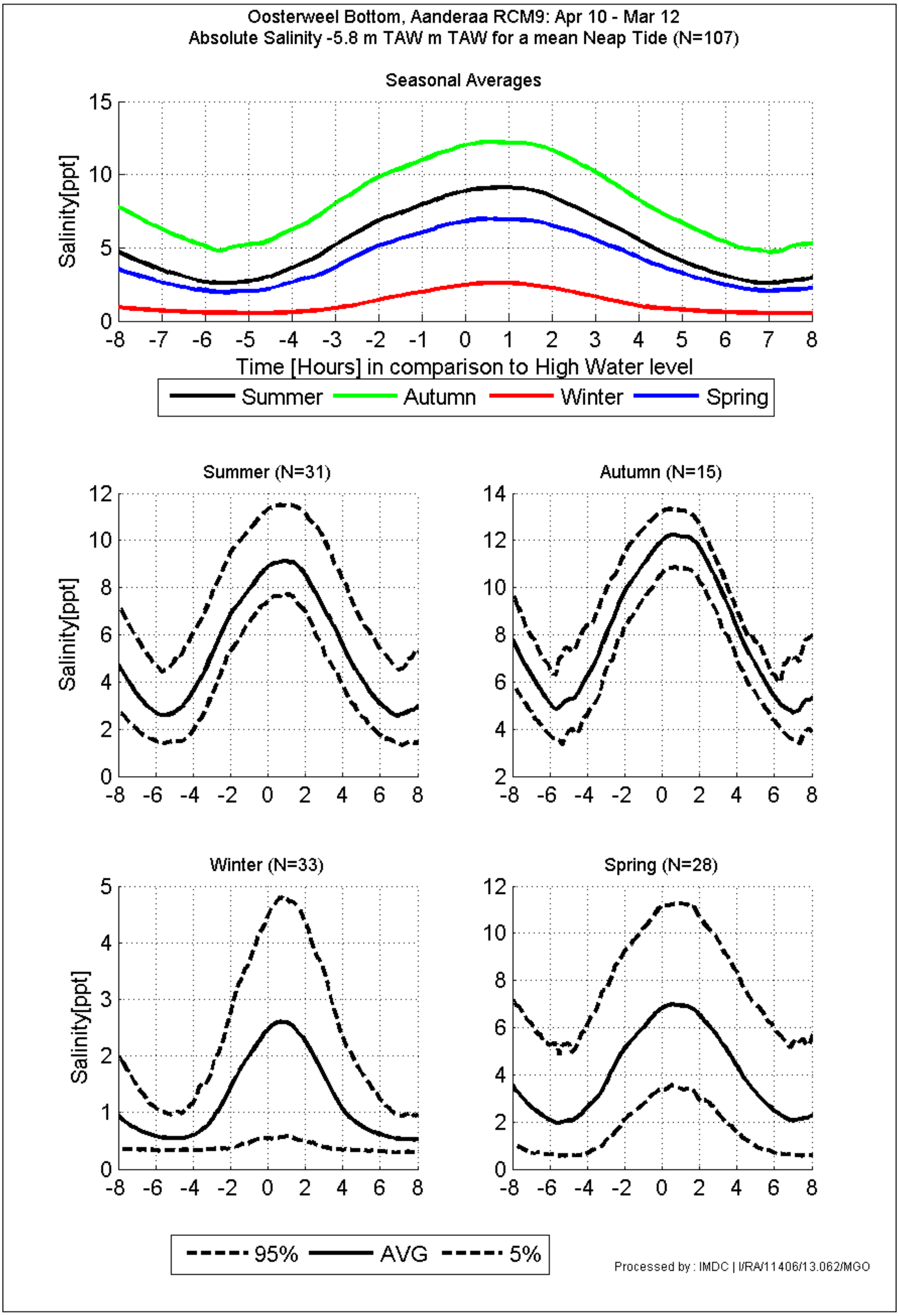
Annex-Figure D-33: Oosterweel (-2.3m TAW), April 2010 – March 2012, Average tidal curve of the salinity for an average (b) mean tide.



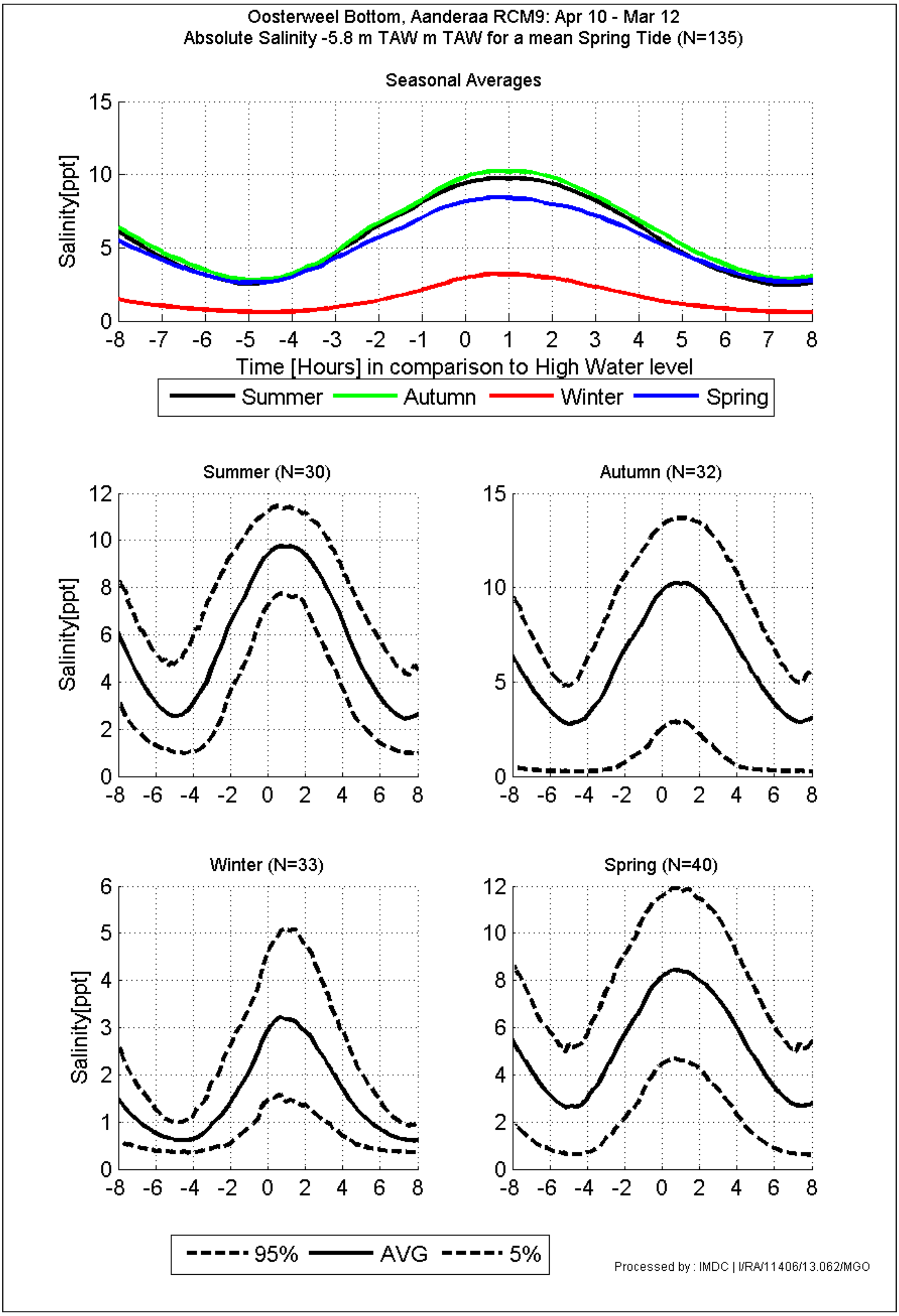
Annex-Figure D-34: Oosterweel (-2.3m TAW), April 2010 – March 2012, Average tidal curve of the salinity for an average (c) spring tide.



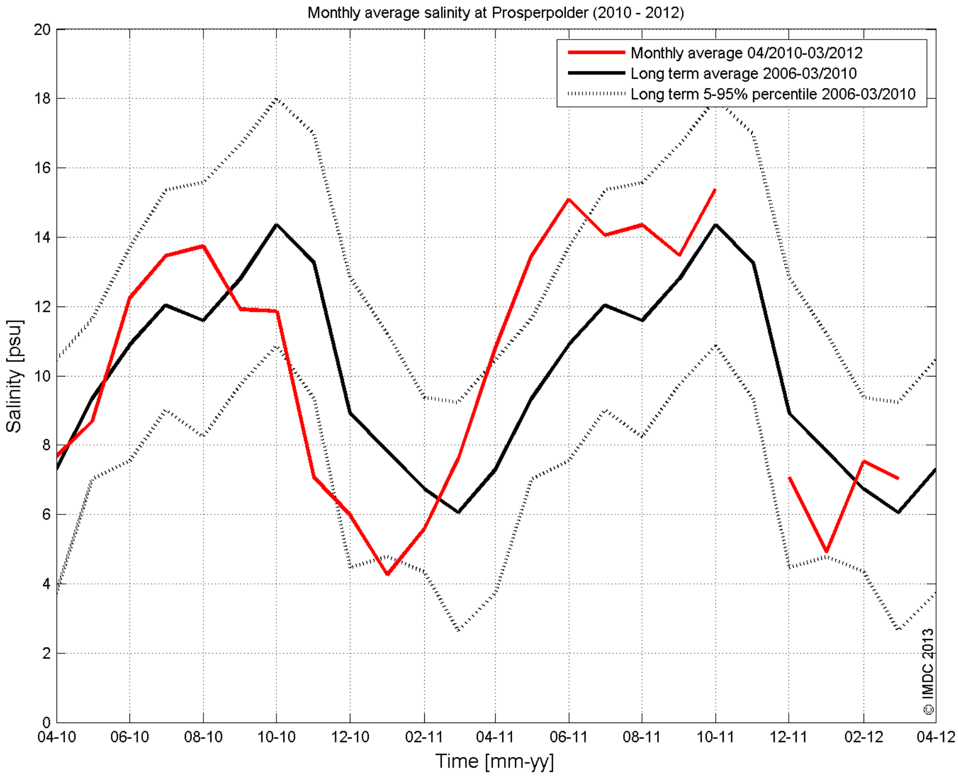
Annex-Figure D-35: Oosterweel (-5.8m TAW), April 2010 – March 2012, Average tidal curve of the salinity for an average (a) neap tide.



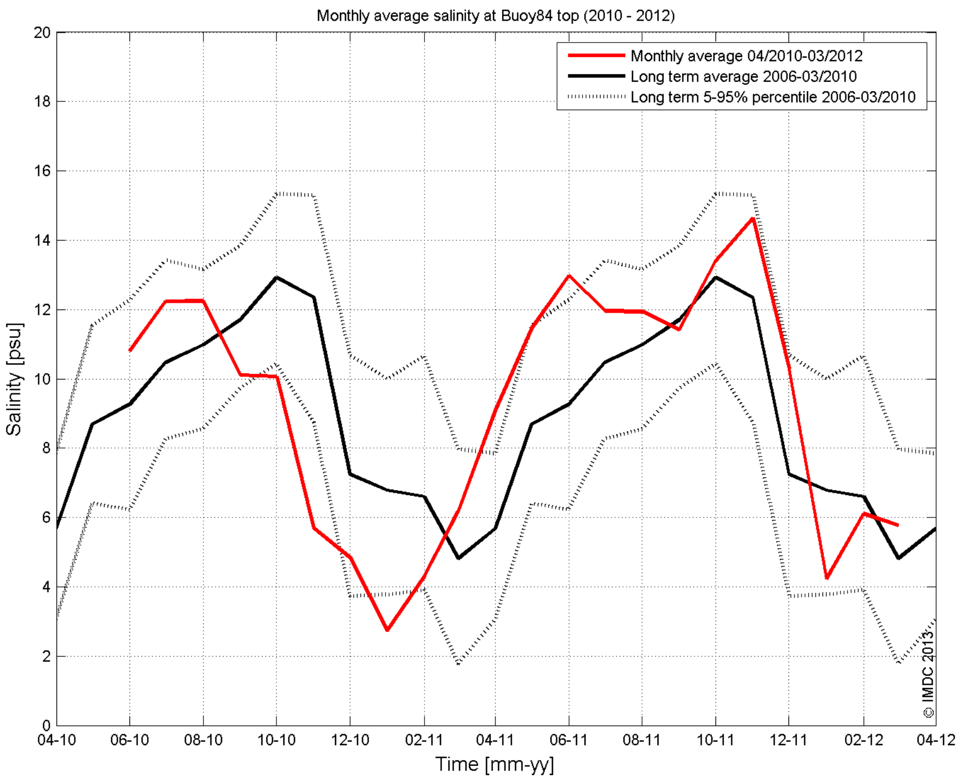
Annex-Figure D-36: Oosterweel (-5.8m TAW), April 2010 – March 2012, Average tidal curve of the salinity for an average (b) mean tide.

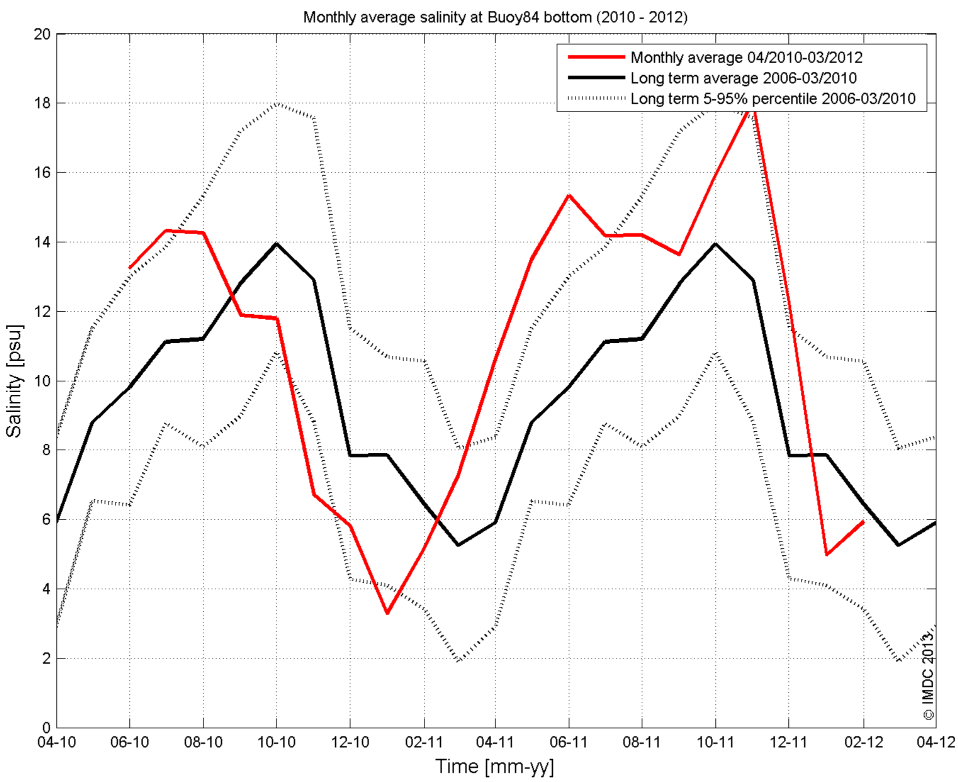


Annex-Figure D-37: Oosterweel (-5.8m TAW), April 2010 – March 2012, Average tidal curve of the salinity for an average (c) spring tide

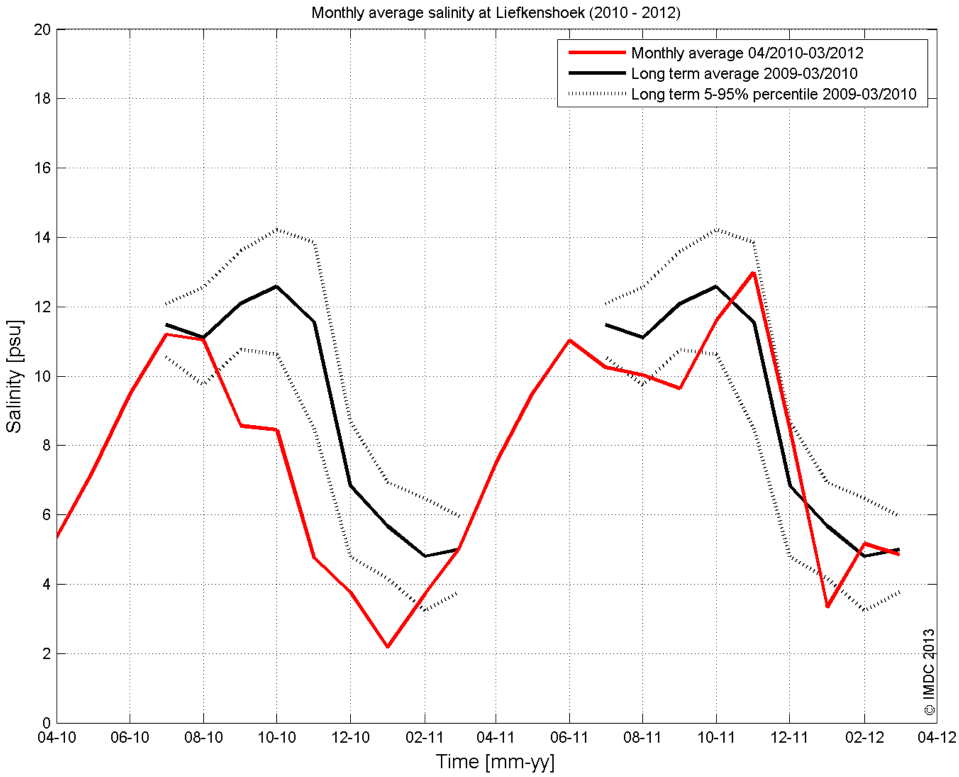


Annex-Figure D-38: The monthly average salinity of Prosperpolder bottom between April 2010 – March 2012 and 2006 – March 2010 including the monthly 5/95%-percentiles for period 2006 – March 2010.

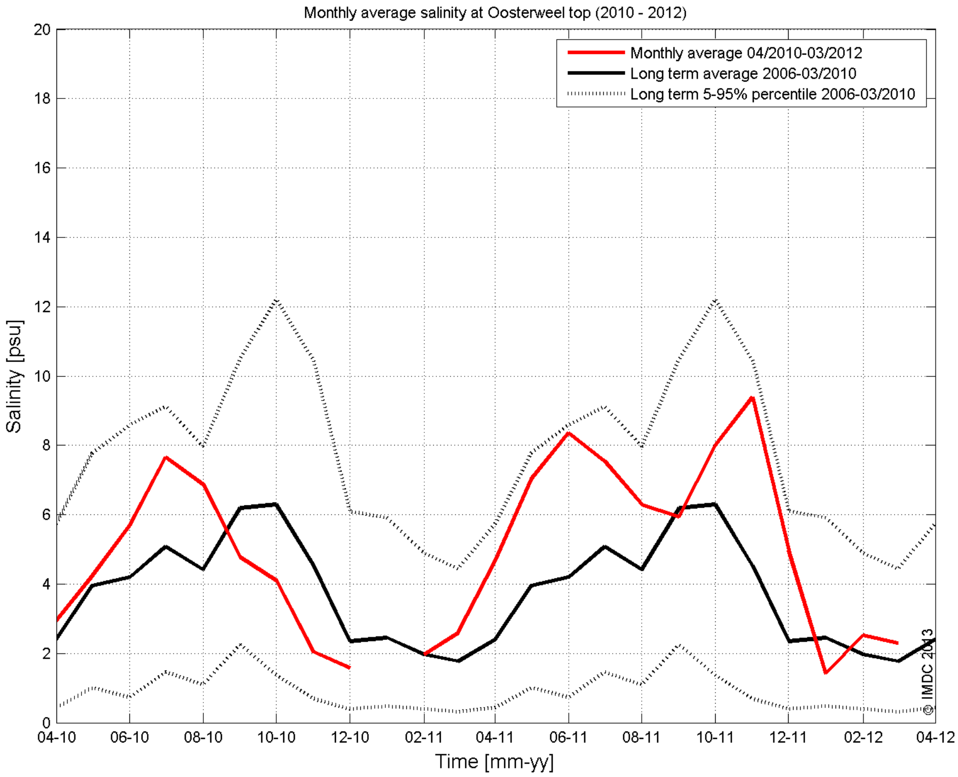


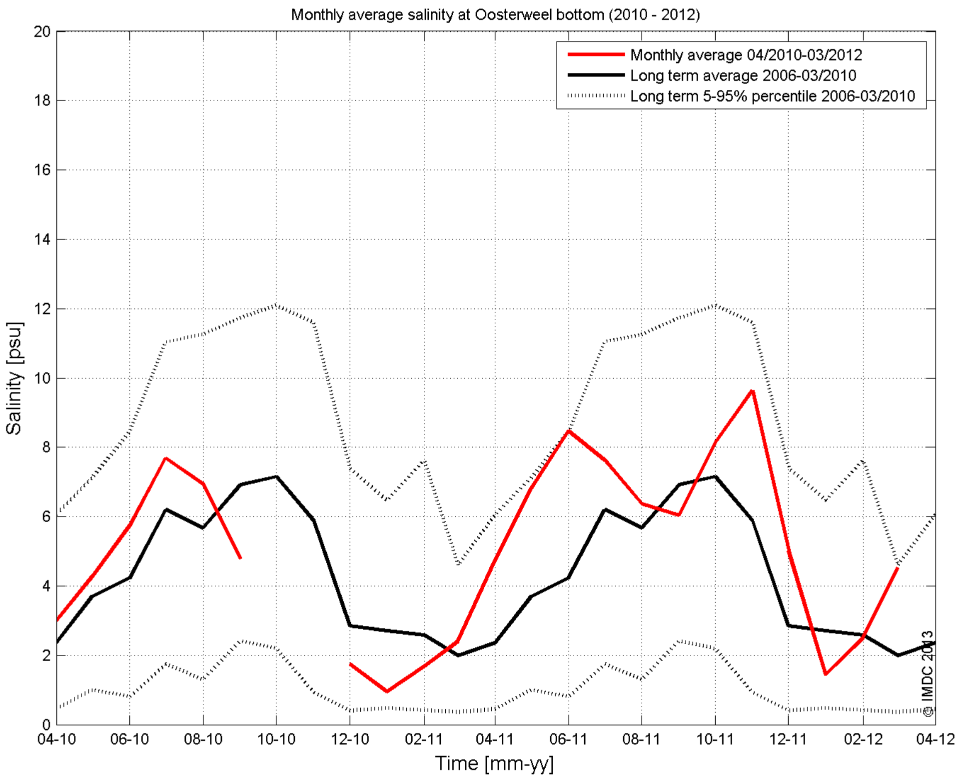


Annex-Figure D-39: The monthly average salinity of Buoy84 (a) top and (b) bottom between April 2010 – March 2012 and 2006 – March 2010 including the monthly 5/95%-percentiles for period 2006 – March 2010.



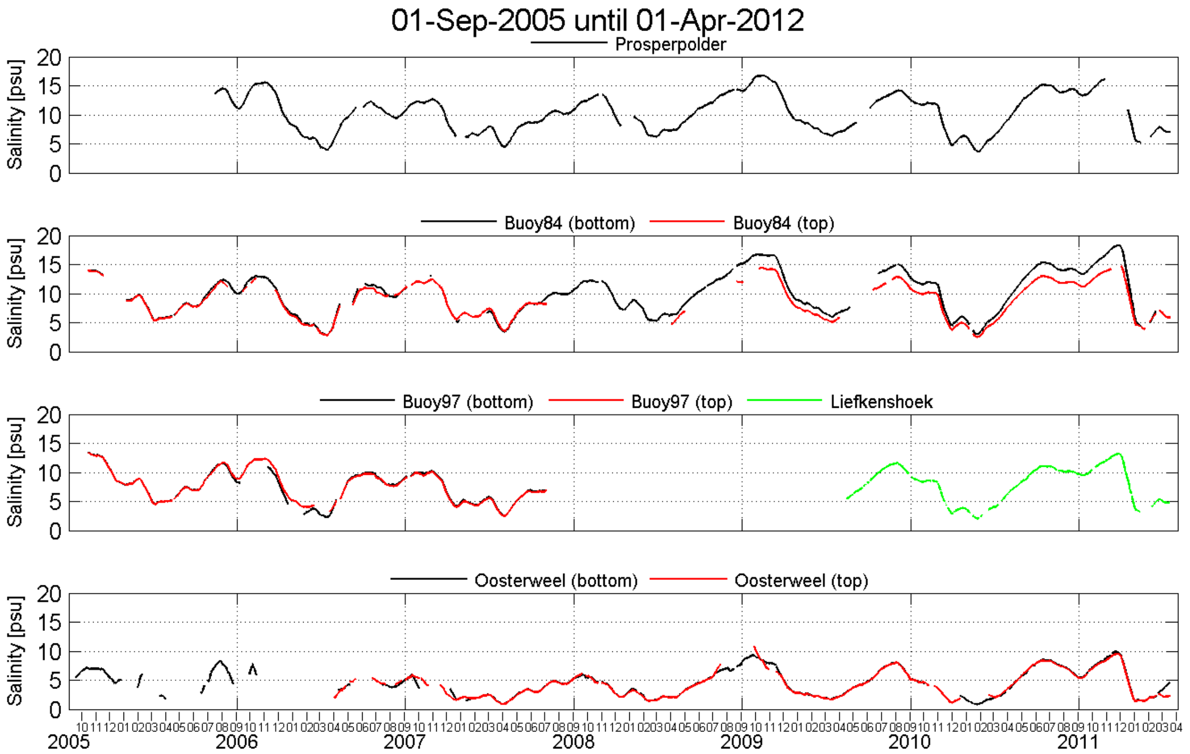
Annex-Figure D-40: The monthly average salinity of Liefkenshoek between April 2010 – March 2012 and 2006 – March 2010 including the monthly 5/95%-percentiles for period 2006 – March 2010.





Annex-Figure D-41: The monthly average salinity of Oosterweel (a) top and (b) bottom between April 2010 – March 2012 and 2006 – March 2010 including the monthly 5/95%-percentiles for period 2006 – March 2010..

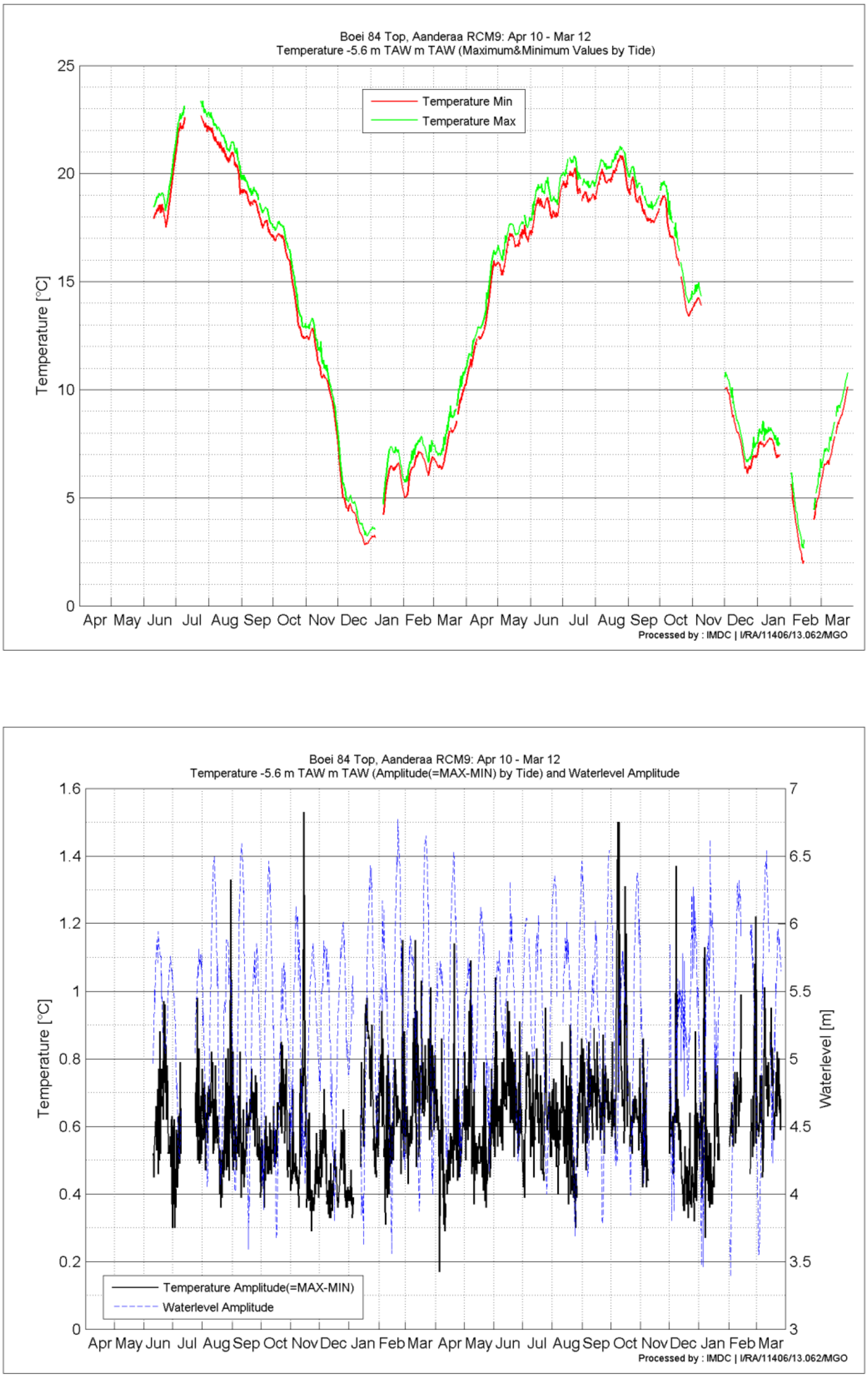
11406 - External effects siltation Deurganckdok (2012-2014)



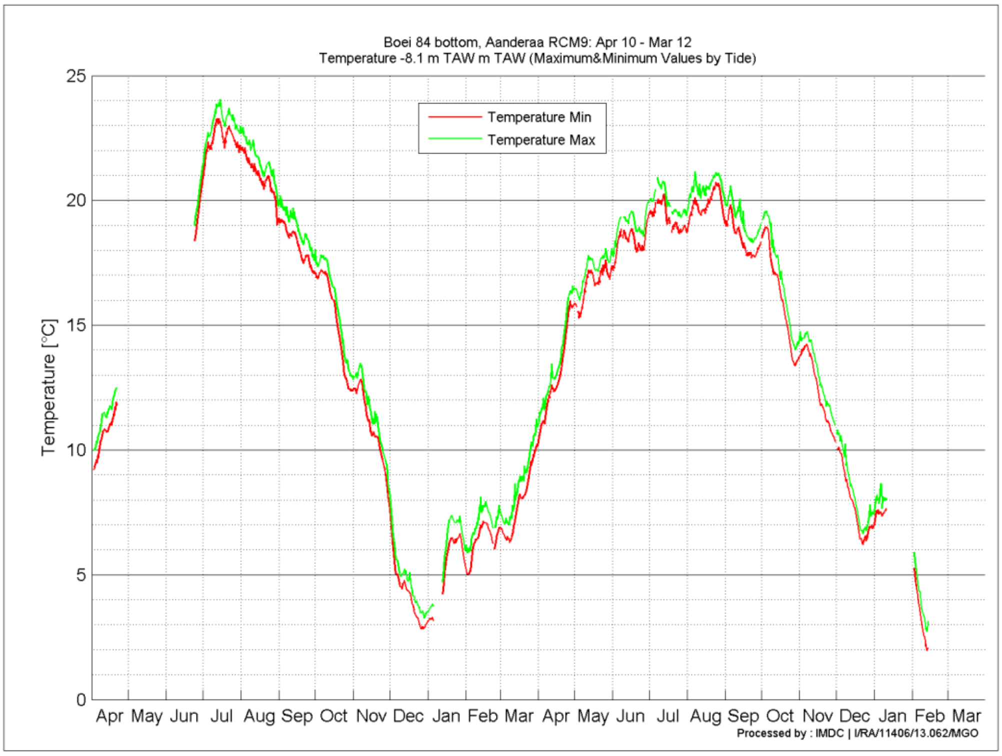
Timeseries of monthly moving average of salinity	Processed by: IMDC
Location: Lower Sea Scheldt	I/RA/11406/13.143/MGO

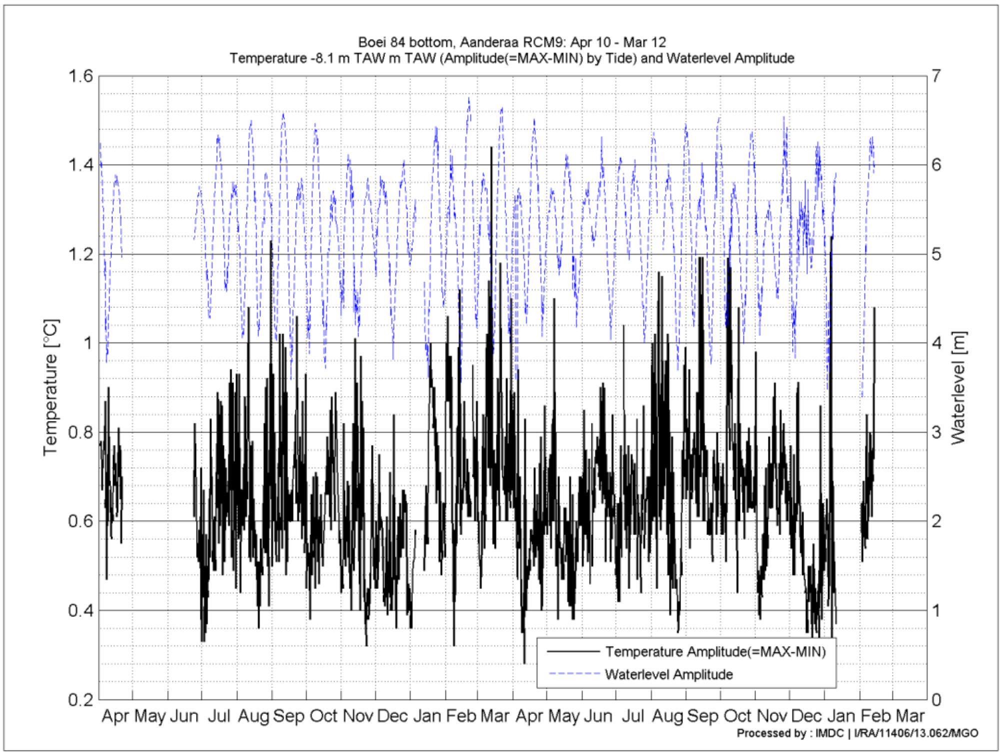
Annex-Figure D-42: Time series of monthly moving average of salinity.

Annex E **Temperature**

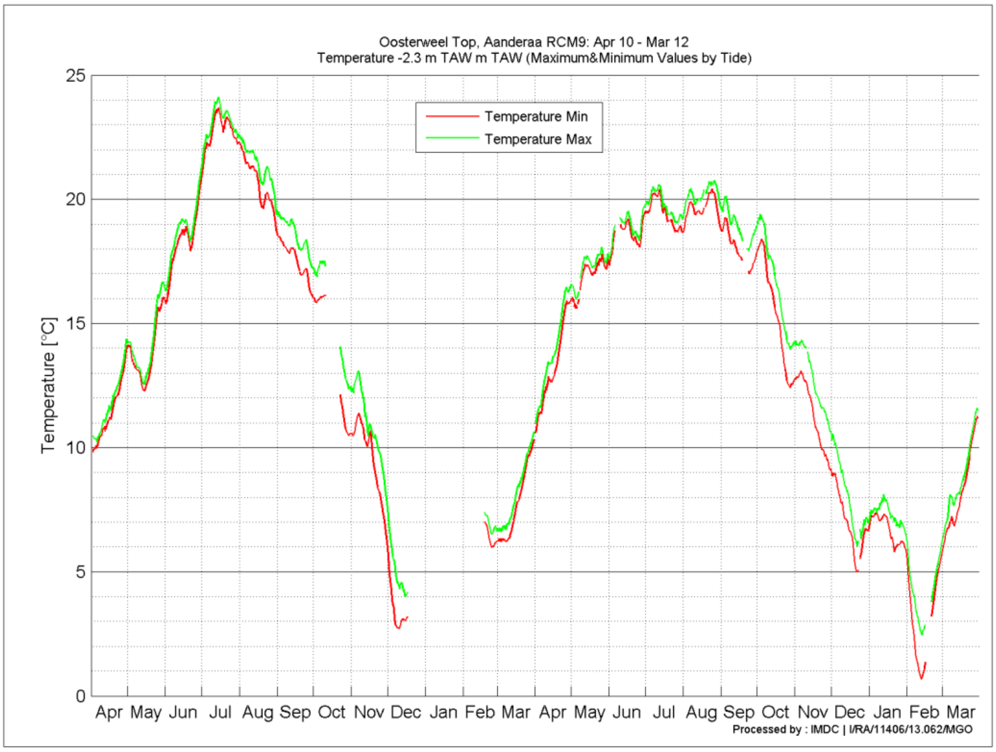


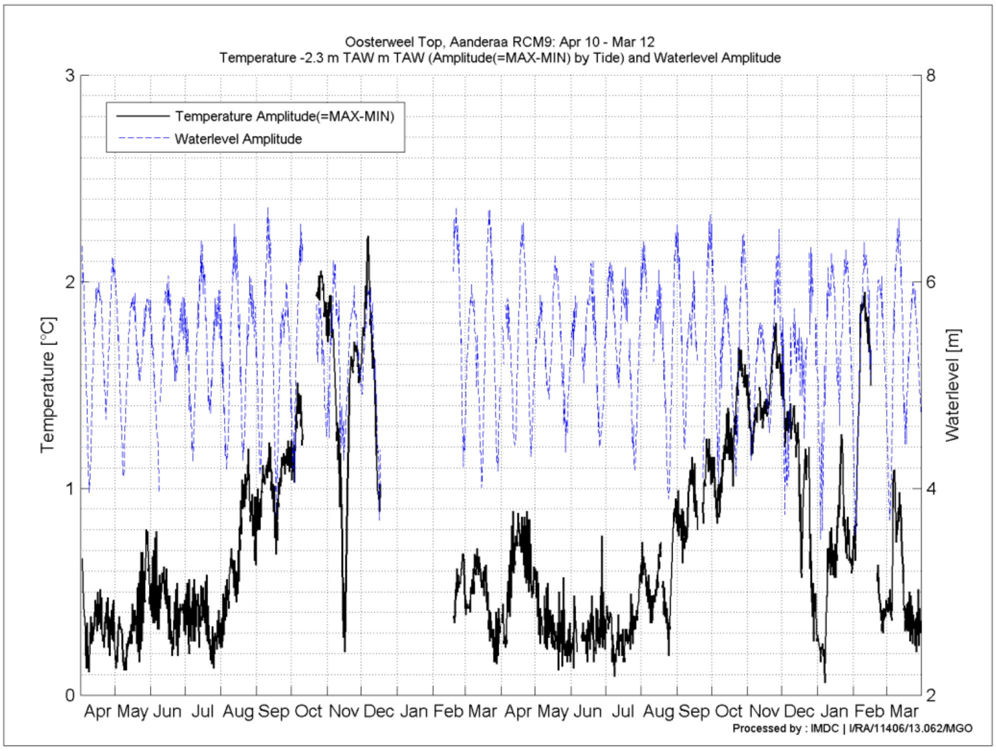
Annex-Figure E-1: Buoy 84 (-5.6m TAW), April 2010 – March 2012 (a) tidal minimum & maximum temperature (b) tidal temperature and water level amplitude.



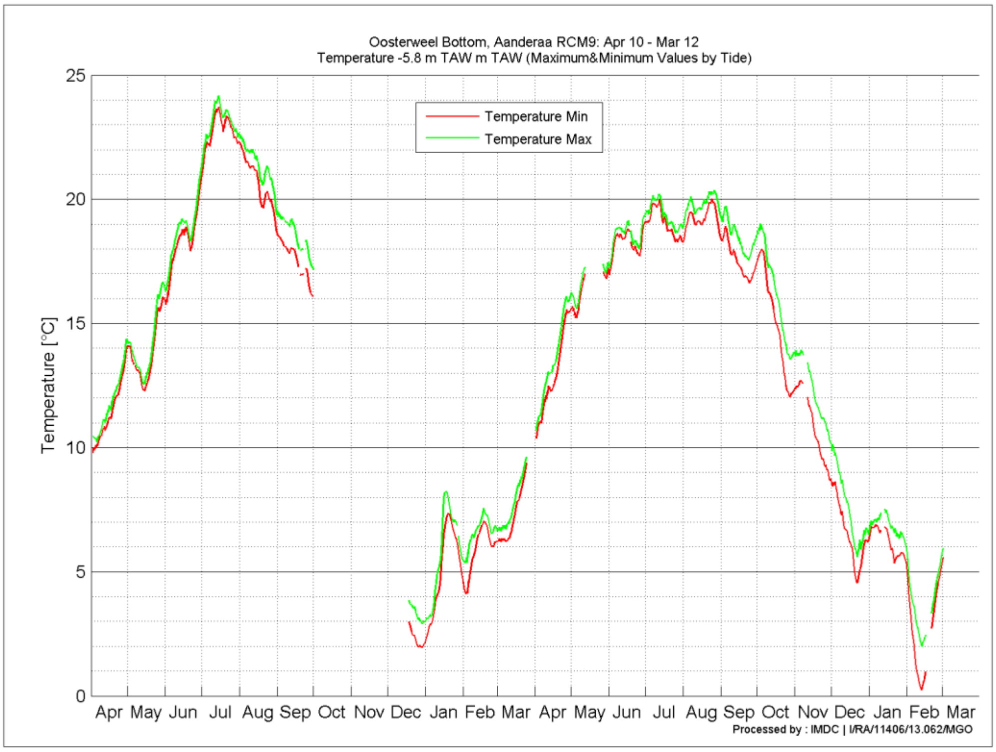


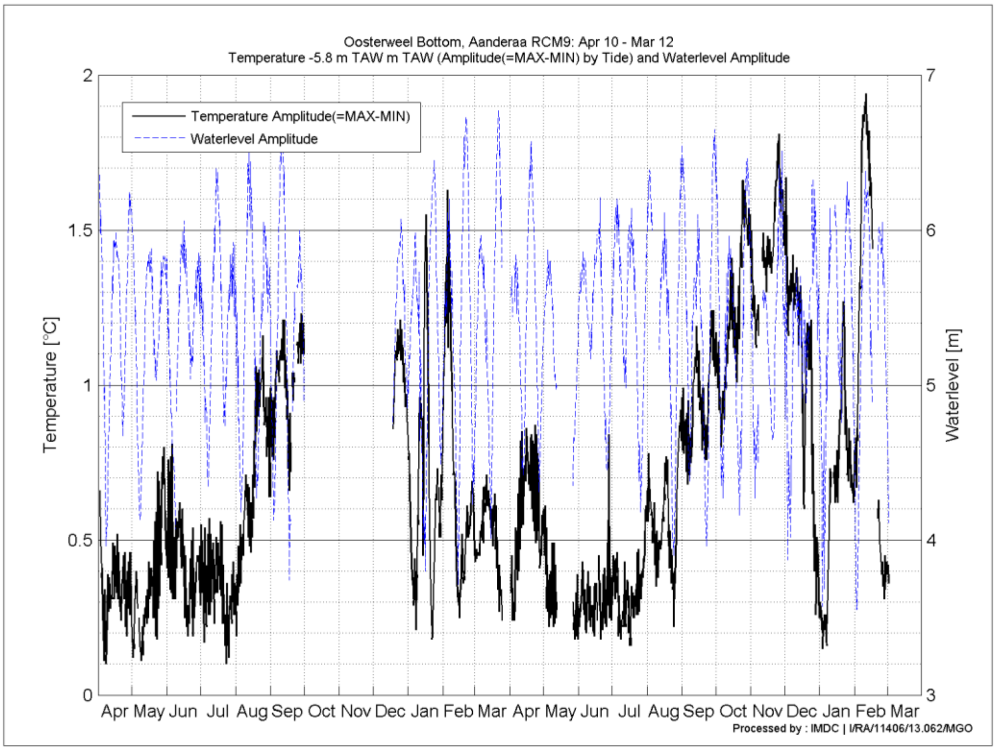
Annex-Figure E-2: Buoy 84 (-8.1m TAW), April 2010 – March 2012, (a) tidal minimum & maximum temperature (b) tidal temperature and water level amplitude.



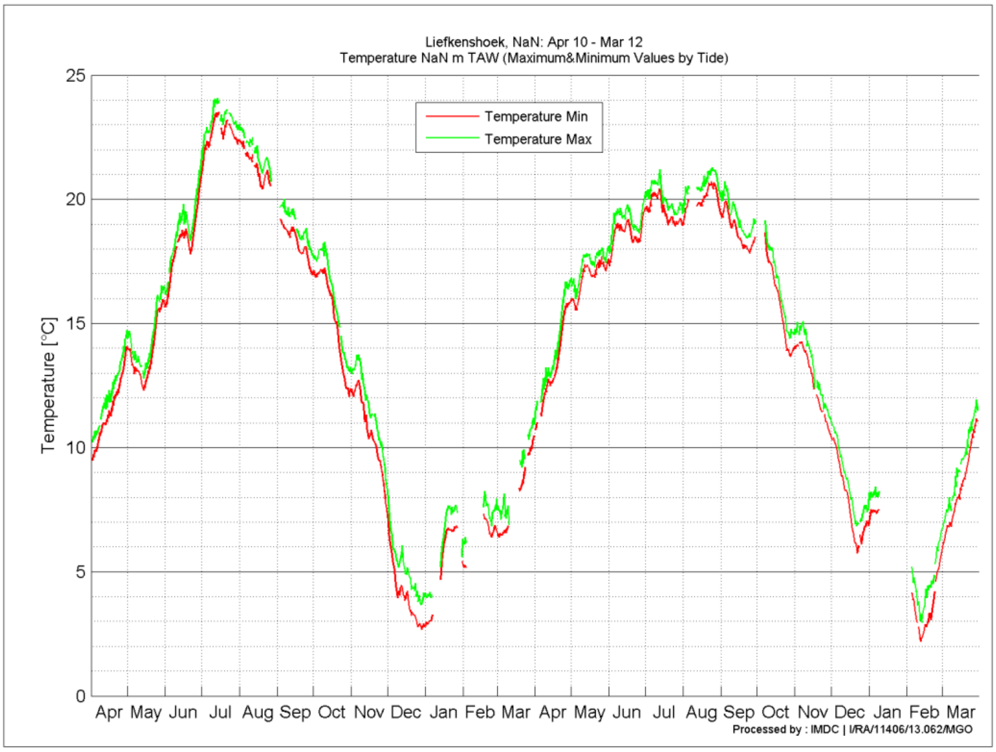


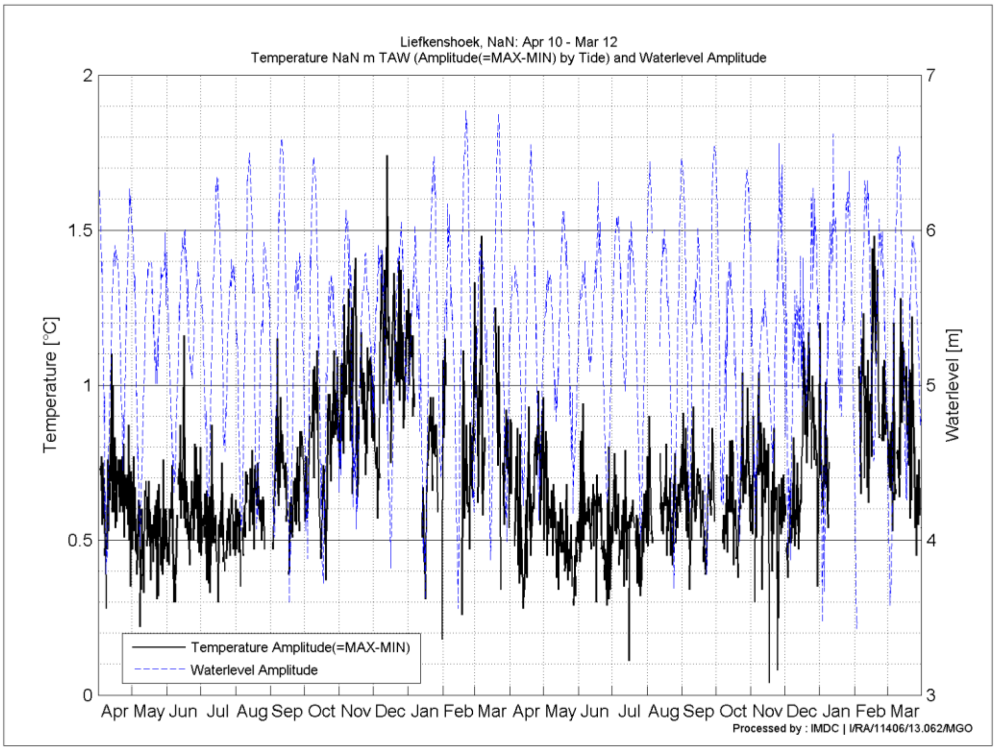
Annex-Figure E-3: Oosterweel (-2.3m TAW), April 2010 – March 2012 (a) tidal minimum & maximum temperature (b) tidal temperature and water level amplitude.



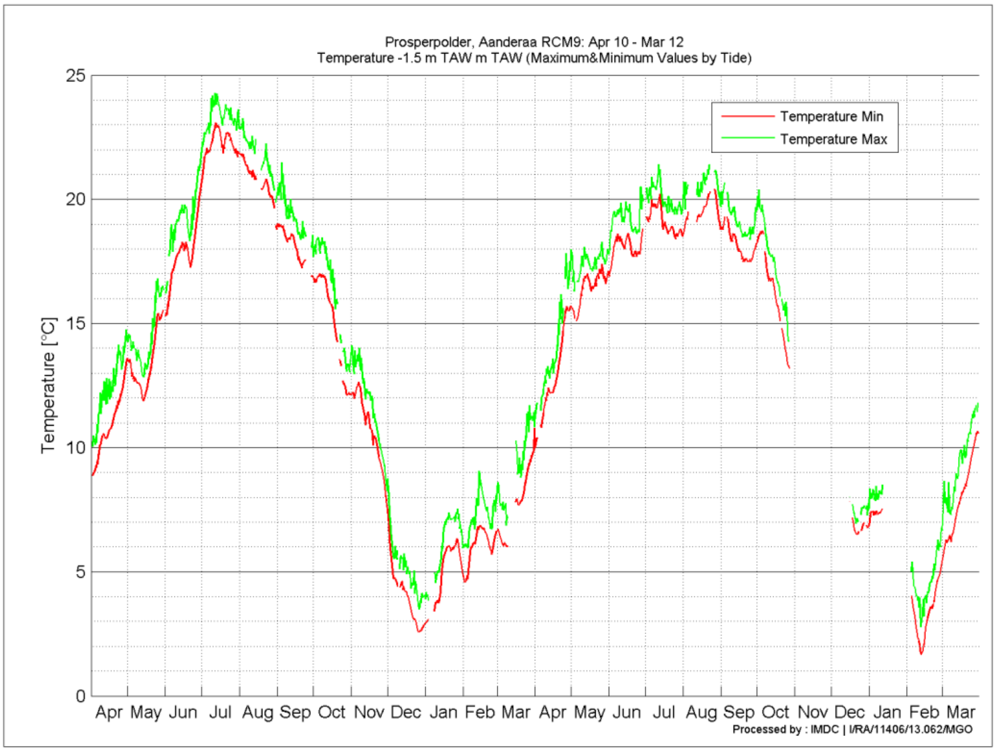


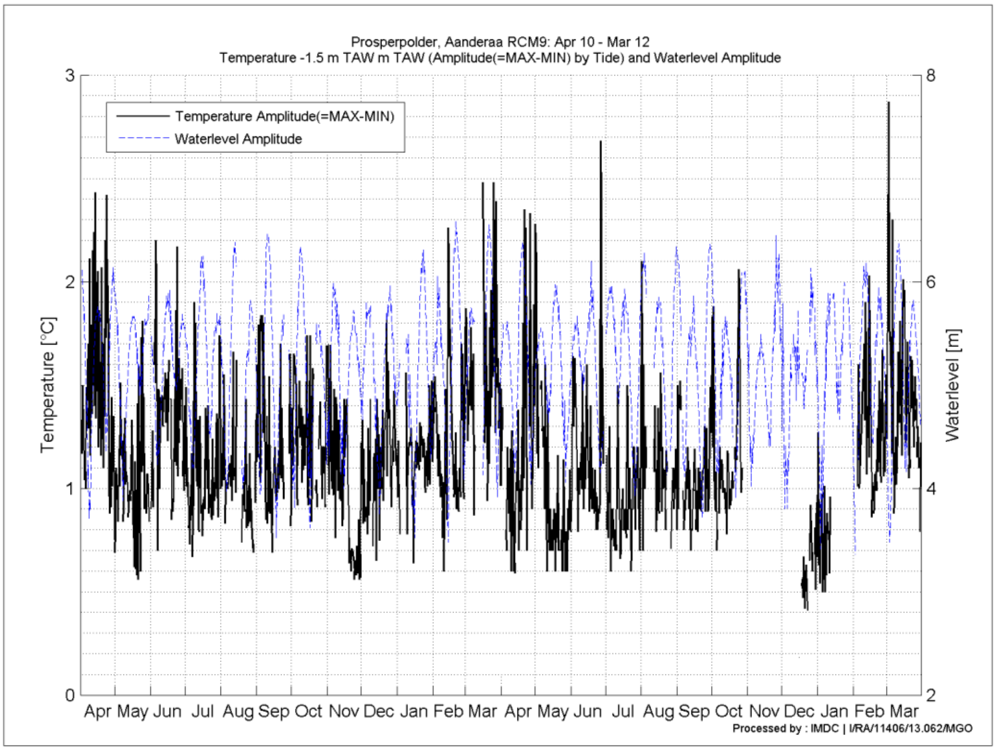
Annex-Figure E-4: Oosterweel (-5.8m TAW), April 2010 – March 2012 (a) tidal minimum & maximum temperature (b) tidal temperature and water level amplitude.



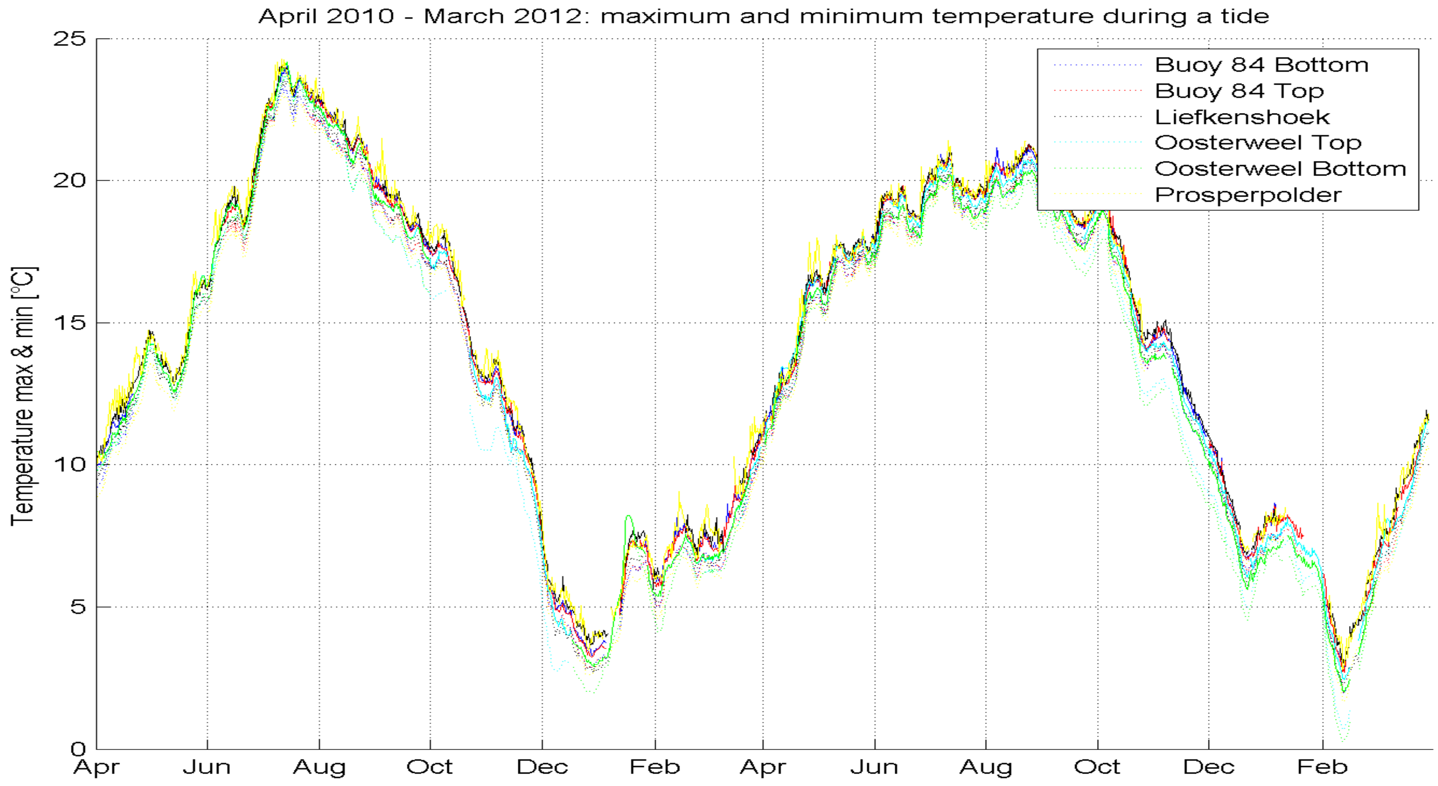


Annex-Figure E-5: Liefkenshoek April 2010 – March 2012 (a) tidal minimum & maximum temperature (b) tidal temperature and water level amplitude.

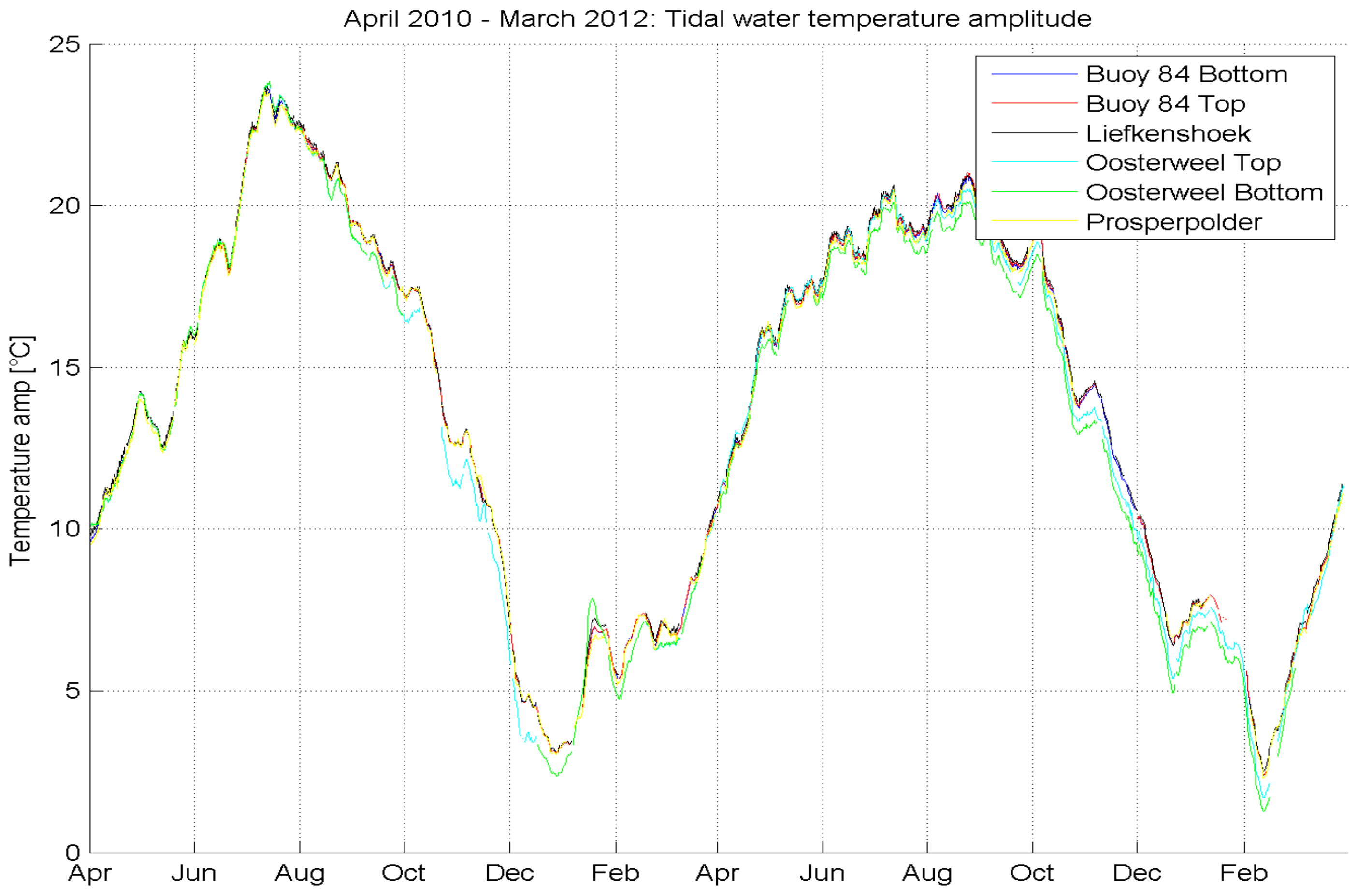




Annex-Figure E-6: Prosperpolder April 2010 – March 2012 (a) tidal minimum & maximum temperature (b) tidal temperature and water level amplitude.



Annex-Figure E-7: Minimal & maximal tidal temperature for all measurement stations.



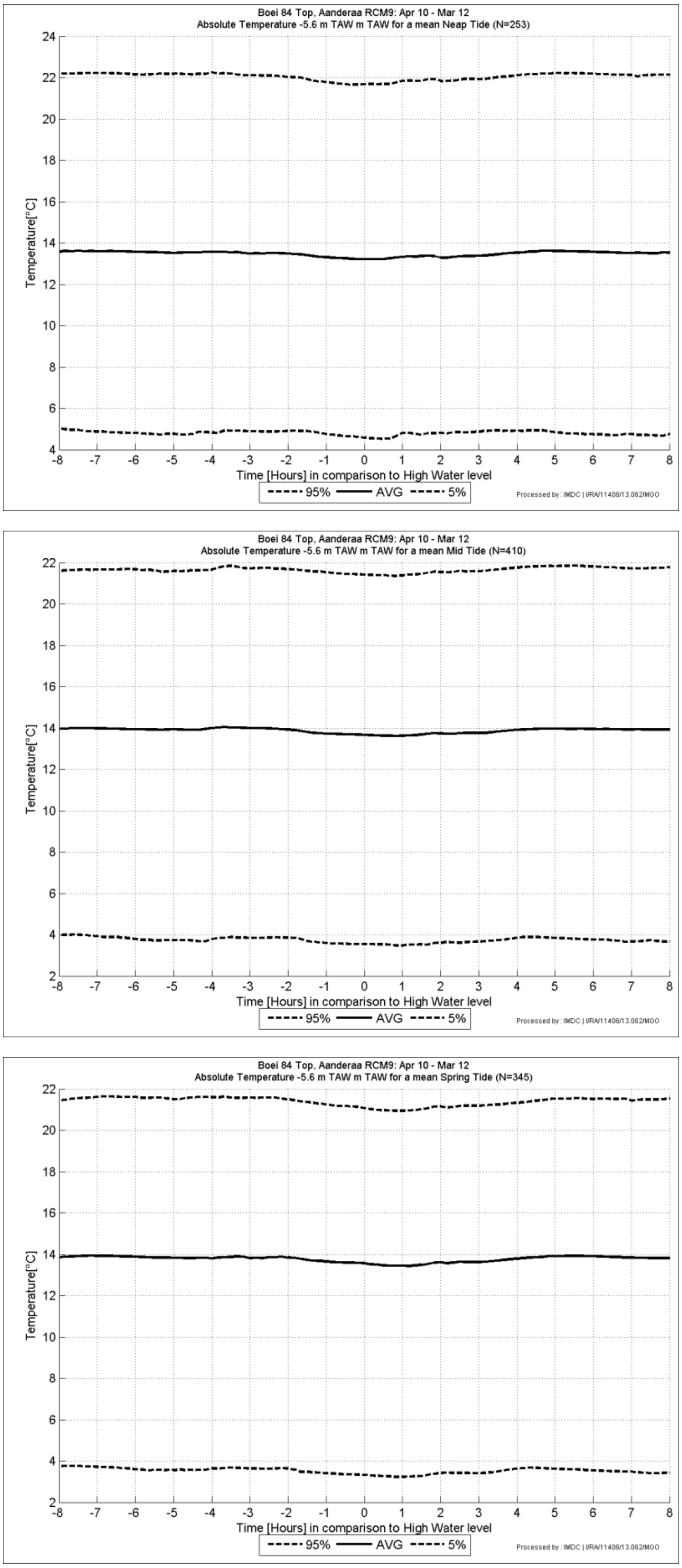
Annex-Figure E-8: Tidal temperature amplitude for all measurement stations.

Annex-Table E-1: Averaged tidal temperature amplitude [°C] (ΔT), standard deviation (σ) and amount of tide in the sample (N) for every measurement station during period considered (Summer: Apr–Sep, Winter: Oct–Mar, Year 1: April 2010 – March 2011. Total period: April 2010 – March 2012).

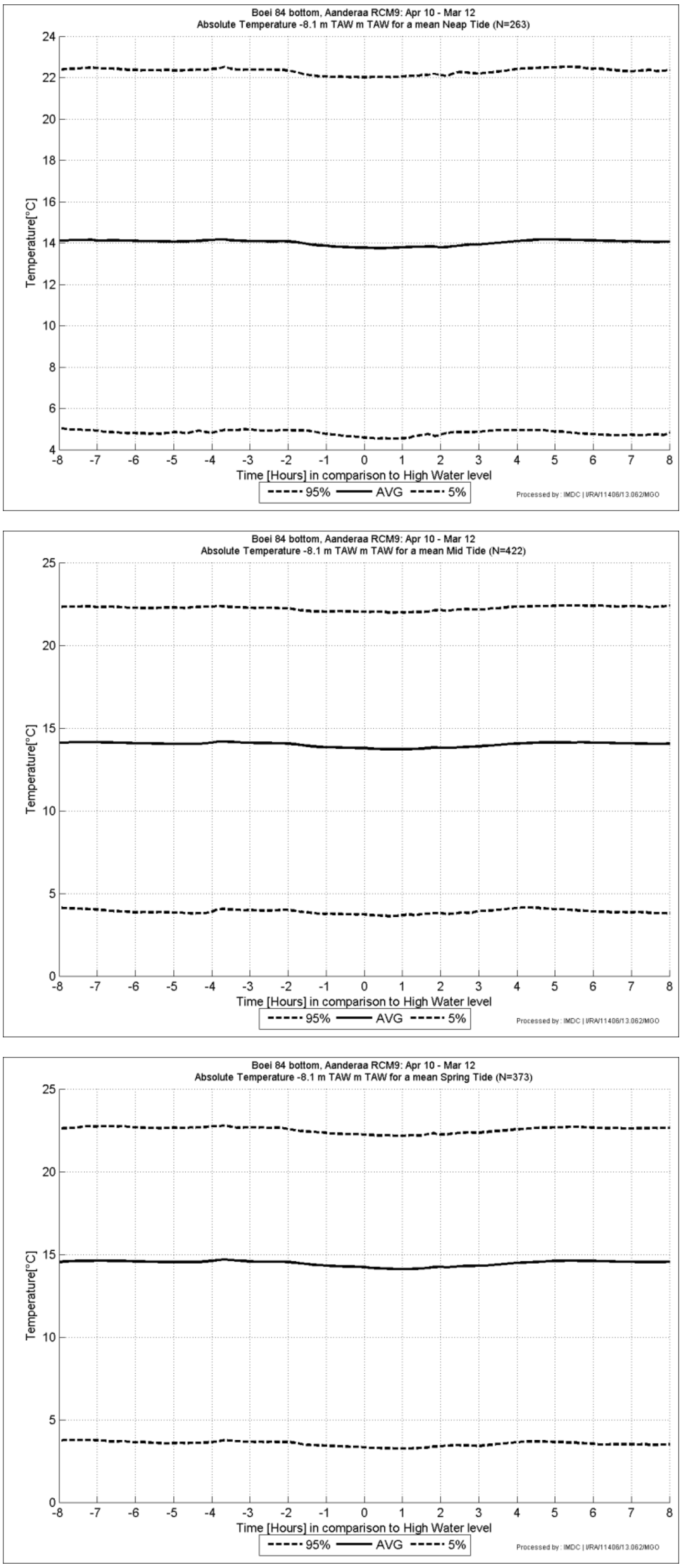
			Apr-Jun			Jul-Sep			Oct-Dec			Jan-Mar			Summer			Winter			Year 1			Total period		
			ΔT	σ	N	ΔT	σ	N	ΔT	σ	N	ΔT	σ	N	ΔT	σ	N	ΔT	σ	N	ΔT	σ	N	ΔT	σ	N
Buoy 84	-8.1 m TAW	Neap	0.48	0.09	26	0.61	0.11	38	0.49	0.08	23	0.54	0.09	22	0.56	0.12	64	0.51	0.09	45	0.54	0.11	109	0.53	0.12	279
		Avg	0.62	0.13	75	0.71	0.17	50	0.50	0.12	45	0.58	0.14	33	0.66	0.15	127	0.53	0.13	78	0.61	0.16	203	0.56	0.15	472
		Spring	0.67	0.11	58	0.73	0.17	62	0.64	0.11	27	0.71	0.08	8	0.70	0.15	120	0.66	0.10	35	0.69	0.14	155	0.65	0.15	388
		All	0.62	0.13	159	0.69	0.16	150	0.53	0.12	95	0.58	0.13	63	0.65	0.15	311	0.55	0.13	158	0.62	0.15	467	0.58	0.15	1139
	-5.6 m TAW	Neap	0.51	0.11	19	0.69	0.16	13	0.44	0.08	21	0.52	0.10	21	0.58	0.16	32	0.48	0.10	42	0.53	0.14	74	0.53	0.19	227
		Avg	0.58	0.17	49	0.77	0.64	24	0.48	0.12	43	0.55	0.13	31	0.64	0.40	73	0.51	0.13	74	0.58	0.30	147	0.53	0.22	408
		Spring	0.61	0.09	39	0.71	0.12	33	0.58	0.10	21	0.65	0.07	10	0.65	0.11	72	0.60	0.10	31	0.64	0.11	103	0.59	0.13	321
		All	0.58	0.17	107	0.72	0.38	70	0.50	0.12	85	0.56	0.12	62	0.64	0.27	177	0.52	0.12	147	0.58	0.23	324	0.55	0.19	956
Oosterweel	- 5.8 m TAW	Neap	0.46	0.23	25	0.32	0.12	26	-	-	1	-	-	1	0.39	0.19	51	-	-	1	0.39	0.19	51	0.68	0.44	215
		Avg	0.35	0.15	66	0.32	0.12	48	-	-	1	-	-	1	0.34	0.14	114	-	-	1	0.34	0.14	114	0.69	0.46	389
		Spring	0.40	0.14	48	0.30	0.09	36	-	-	1	-	-	1	0.36	0.13	84	-	-	1	0.36	0.13	84	0.60	0.44	310
		All	0.39	0.17	139	0.31	0.11	110	-	-	1	-	-	1	0.36	0.15	249	-	-	1	0.36	0.15	249	0.66	0.45	914
	- 2.3 m TAW	Neap	0.46	0.24	25	0.48	0.16	4	-	-	1	-	-	1	0.47	0.23	29	-	-	1	0.47	0.23	29	0.73	0.45	189
		Avg	0.35	0.16	67	0.32	0.10	18	-	-	1	-	-	1	0.35	0.15	85	-	-	1	0.35	0.15	85	0.73	0.48	356
		Spring	0.40	0.14	47	0.26	0.08	6	-	-	1	-	-	1	0.38	0.14	53	-	-	1	0.38	0.14	53	0.63	0.46	274
		All	0.39	0.17	139	0.33	0.12	28	-	-	1	-	-	1	0.38	0.17	167	-	-	1	0.38	0.17	167	0.69	0.47	819
Prosperpolder	- 1.5 m TAW	Neap	1.17	0.45	31	0.98	0.21	38	0.85	0.22	39	1.58	0.59	39	1.07	0.35	69	1.21	0.57	78	1.14	0.49	147	1.14	0.49	147
		Avg	1.23	0.44	70	0.97	0.18	48	0.79	0.23	78	1.49	0.43	44	1.12	0.38	120	1.04	0.46	122	1.08	0.43	240	1.08	0.43	240
		Spring	1.22	0.32	53	0.96	0.24	42	0.84	0.21	55	1.29	0.50	62	1.11	0.31	95	1.08	0.45	117	1.09	0.40	212	1.09	0.40	212
		All	1.21	0.40	154	0.97	0.21	128	0.82	0.23	172	1.43	0.52	145	1.10	0.35	284	1.10	0.49	317	1.10	0.43	599	1.10	0.43	599
Liefkenshoek		Neap	-	-	1	0.47	0.11	34	0.52	0.11	4	0.54	0.14	2	0.47	0.11	34	0.53	0.11	6	0.48	0.11	40	0.48	0.11	40
		Avg	-	-	1	0.57	0.16	31	0.56	0.09	21	-	-	1	0.57	0.15	33	0.56	0.09	21	0.57	0.13	52	0.57	0.13	52
		Spring	-	-	1	0.70	0.11	45	0.55	0.05	16	-	-	1	0.70	0.11	45	0.55	0.05	16	0.66	0.12	61	0.66	0.12	61
		All	-	-	1	0.59	0.16	110	0.55	0.08	41	0.54	0.14	2	0.59	0.16	112	0.55	0.08	43	0.58	0.14	153	0.58	0.14	153

Annex-Table E-2: Averaged tidal temperature amplitude [°C] (ΔT) standard deviation (σ) and amount of tide in the sample (N) for every measurement station during period considered (Summer: Apr–Sep, Winter: Oct–Mar, Year 2: April 2011 – March 2012. Total period: April 2010 – March 2012).

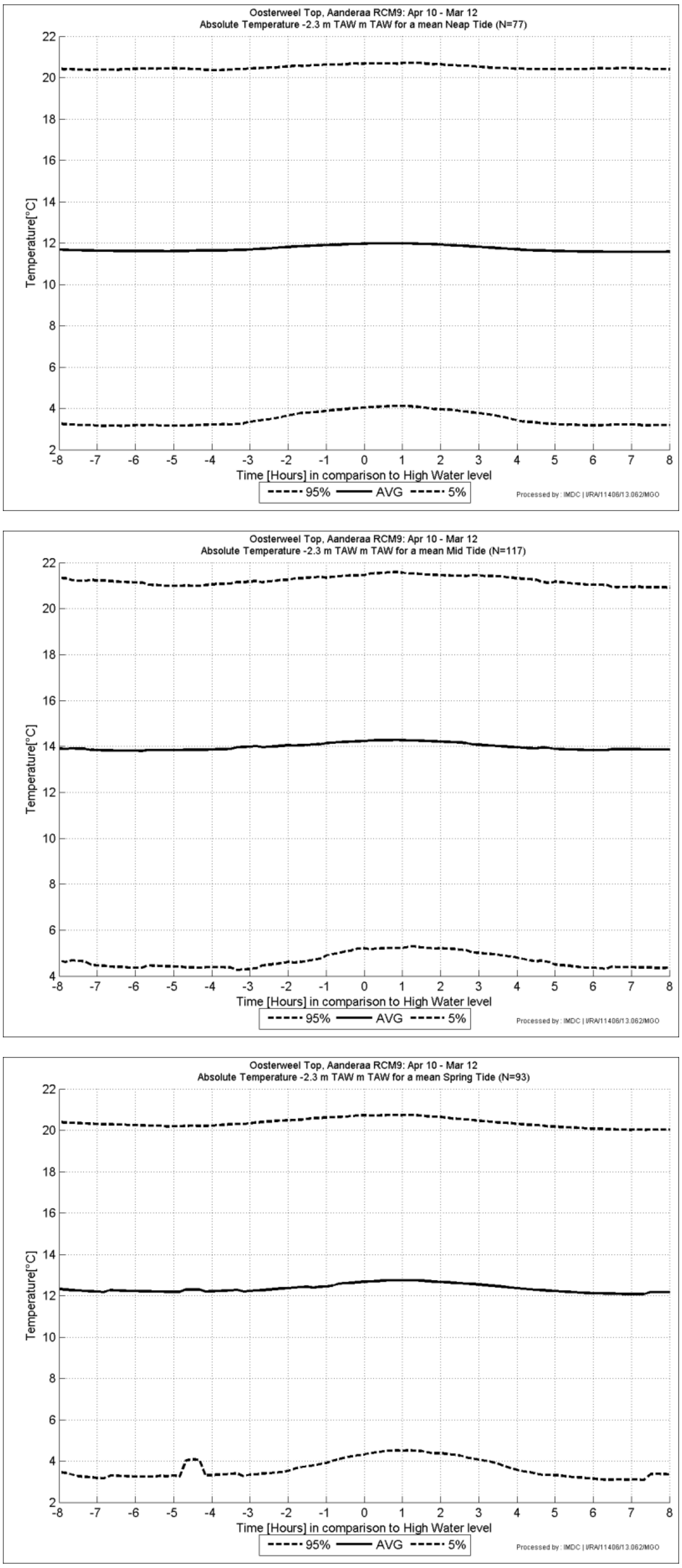
			Apr-Jun			Jul-Sep			Oct-Dec			Jan-Mar			Summer			Winter			Year 1			Total period		
			ΔT	σ	N	ΔT	σ	N	ΔT	σ	N	ΔT	σ	N	ΔT	σ	N	ΔT	σ	N	ΔT	σ	N	ΔT	σ	N
Buoy 84	-8.1 m TAW	Neap	0.58	0.13	37.00	0.58	0.13	34.00	0.63	0.20	45.00	0.61	0.18	15.00	0.58	0.13	71.00	0.62	0.19	60.00	0.60	0.16	131.00	0.61	0.16	280.00
		Avg	0.60	0.13	78.00	0.67	0.16	59.00	0.63	0.19	84.00	0.65	0.24	11.00	0.63	0.14	137.00	0.63	0.19	95.00	0.63	0.17	232.00	0.63	0.17	455.00
		Spring	0.63	0.14	58.00	0.73	0.19	67.00	0.63	0.15	47.00	0.67	0.18	16.00	0.68	0.17	127.00	0.64	0.16	63.00	0.67	0.17	188.00	0.67	0.16	382.00
		All	0.61	0.13	173.00	0.68	0.17	160.00	0.63	0.18	176.00	0.64	0.19	42.00	0.64	0.16	335.00	0.63	0.18	218.00	0.64	0.17	551.00	0.64	0.16	1117.00
	-5.6 m TAW	Neap	0.55	0.13	33.00	0.59	0.15	33.00	0.66	0.26	40.00	0.67	0.17	34.00	0.57	0.14	66.00	0.66	0.22	74.00	0.62	0.19	140.00	0.60	0.18	278.00
		Avg	0.61	0.15	87.00	0.63	0.11	56.00	0.61	0.21	57.00	0.63	0.17	37.00	0.62	0.14	143.00	0.62	0.19	94.00	0.62	0.16	237.00	0.60	0.17	454.00
		Spring	0.63	0.15	51.00	0.65	0.11	67.00	0.60	0.15	35.00	0.63	0.16	53.00	0.64	0.13	120.00	0.61	0.15	88.00	0.63	0.14	206.00	0.62	0.14	376.00
		All	0.60	0.15	171.00	0.63	0.12	156.00	0.62	0.21	132.00	0.64	0.16	124.00	0.62	0.14	329.00	0.63	0.19	256.00	0.62	0.16	583.00	0.61	0.16	1108.00
Oosterweel	-5.8 m TAW	Neap	0.46	0.20	31.00	0.58	0.24	37.00	1.22	0.19	48.00	0.58	0.38	27.00	0.52	0.23	68.00	0.99	0.41	75.00	0.77	0.41	143.00	0.68	0.38	268.00
		Avg	0.39	0.18	77.00	0.64	0.30	59.00	1.19	0.33	81.00	0.86	0.48	37.00	0.50	0.27	136.00	1.09	0.41	118.00	0.77	0.45	254.00	0.68	0.40	491.00
		Spring	0.46	0.21	36.00	0.65	0.32	70.00	1.28	0.43	40.00	1.01	0.56	42.00	0.60	0.30	108.00	1.14	0.52	82.00	0.83	0.49	188.00	0.71	0.44	356.00
		All	0.42	0.19	144.00	0.63	0.30	166.00	1.22	0.33	169.00	0.85	0.52	106.00	0.54	0.28	312.00	1.08	0.45	275.00	0.79	0.46	585.00	0.69	0.41	1115.00
	-2.3 m TAW	Neap	0.44	0.22	34.00	0.51	0.23	30.00	1.23	0.21	48.00	0.49	0.29	40.00	0.47	0.23	64.00	0.89	0.45	88.00	0.72	0.42	152.00	0.69	0.42	296.00
		Avg	0.39	0.18	84.00	0.58	0.30	60.00	1.23	0.33	85.00	0.75	0.48	58.00	0.47	0.26	144.00	1.04	0.46	143.00	0.75	0.47	287.00	0.77	0.51	517.00
		Spring	0.43	0.22	46.00	0.68	0.33	64.00	1.36	0.36	36.00	0.86	0.50	66.00	0.58	0.31	112.00	1.03	0.52	102.00	0.80	0.48	212.00	0.78	0.50	394.00
		All	0.41	0.20	164.00	0.61	0.31	154.00	1.26	0.31	169.00	0.73	0.47	164.00	0.51	0.28	320.00	1.00	0.48	333.00	0.76	0.46	651.00	0.75	0.49	1207.00
Prosperpolder	-1.5 m TAW	Neap	1.06	0.50	35.00	0.99	0.14	29.00	1.12	0.26	15.00	1.26	0.51	36.00	1.03	0.38	64.00	1.22	0.45	51.00	1.11	0.42	115.00	1.22	0.41	285.00
		Avg	1.10	0.36	83.00	0.96	0.20	58.00	0.87	0.37	40.00	1.20	0.34	41.00	1.04	0.31	141.00	1.04	0.39	81.00	1.04	0.34	222.00	1.10	0.34	485.00
		Spring	1.09	0.38	44.00	1.06	0.29	68.00	1.02	0.37	17.00	1.32	0.31	50.00	1.08	0.33	114.00	1.24	0.34	67.00	1.13	0.34	179.00	1.16	0.33	396.00
		All	1.09	0.40	162.00	1.01	0.24	155.00	0.96	0.36	72.00	1.26	0.38	127.00	1.05	0.33	319.00	1.15	0.40	199.00	1.09	0.36	516.00	1.15	0.36	1166.00
Liefkenshoek		Neap	0.48	0.19	36.00	0.51	0.12	34.00	0.59	0.16	39.00	0.87	0.24	36.00	0.49	0.16	70.00	0.73	0.24	75.00	0.62	0.24	145.00	0.65	0.25	295.00
		Avg	0.57	0.15	89.00	0.59	0.11	59.00	0.69	0.20	84.00	0.86	0.23	40.00	0.58	0.13	148.00	0.75	0.23	124.00	0.66	0.20	272.00	0.70	0.22	526.00
		Spring	0.61	0.12	45.00	0.62	0.12	65.00	0.70	0.16	35.00	0.86	0.18	41.00	0.62	0.12	110.00	0.78	0.19	76.00	0.69	0.17	186.00	0.72	0.21	388.00
		All	0.56	0.16	170.00	0.58	0.12	158.00	0.67	0.19	158.00	0.87	0.22	117.00	0.57	0.14	328.00	0.75	0.22	275.00	0.66	0.20	603.00	0.69	0.23	1209.00



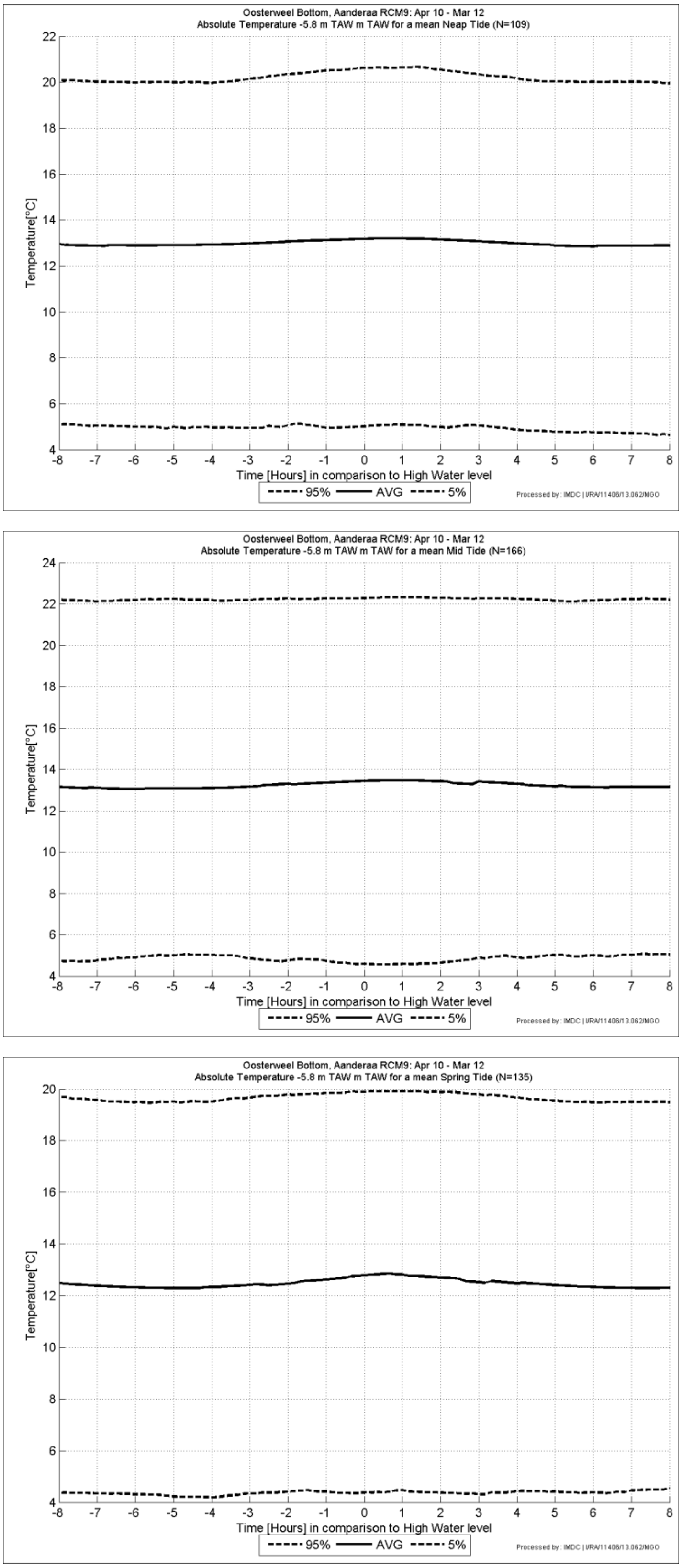
Annex-Figure E-9: Buoy 84 (-5.6m TAW), April 2010 – March 2012, average tidal curve of the temperature for a (a) neap (b) average (c) spring tide.



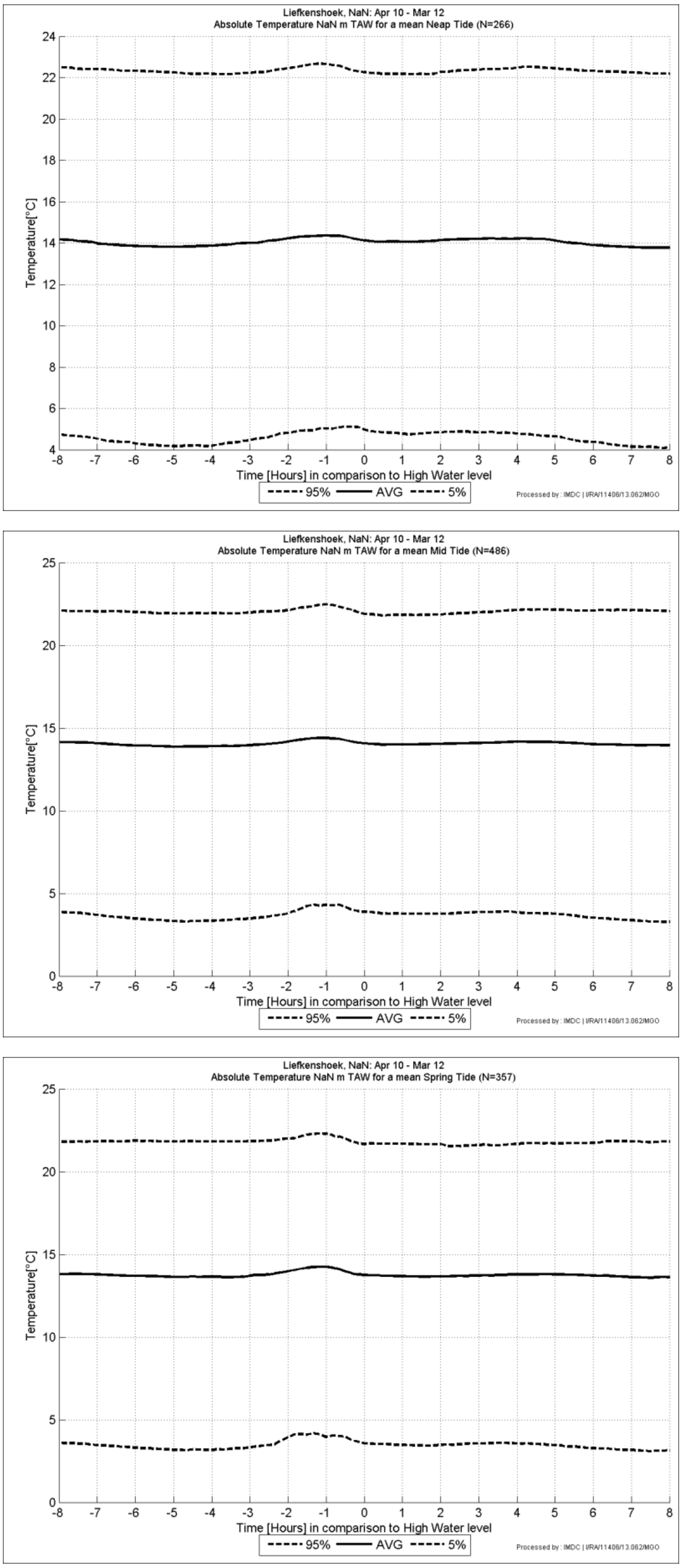
Annex-Figure E-10: Buoy 84 (-8.1m TAW), April 2010 – March 2012, average tidal curve of the temperature for a (a) neap (b) average (c) spring tide.



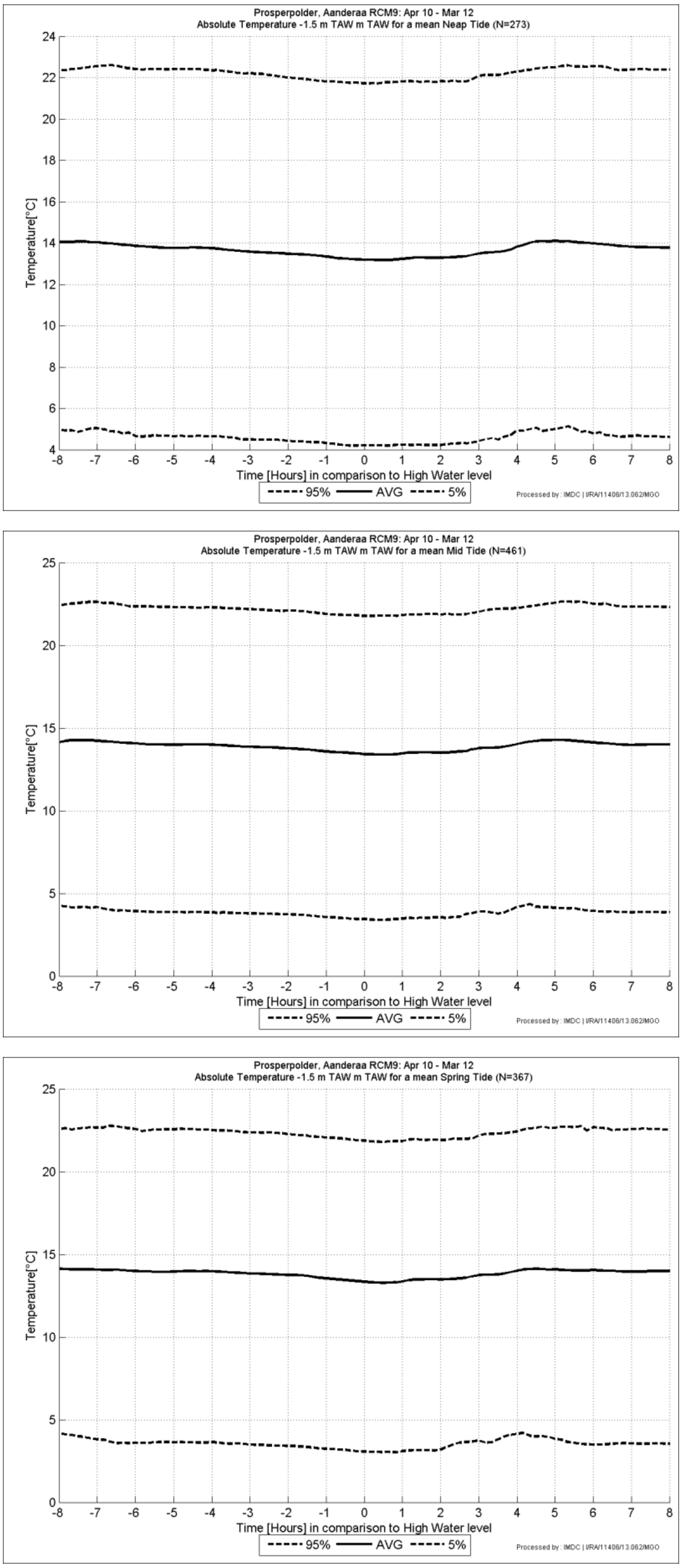
Annex-Figure E-11: Oosterweel (-2.3m TAW), April 2010 – March 2012, average tidal curve of the temperature for a (a) neap (b) average, (c) spring tide.



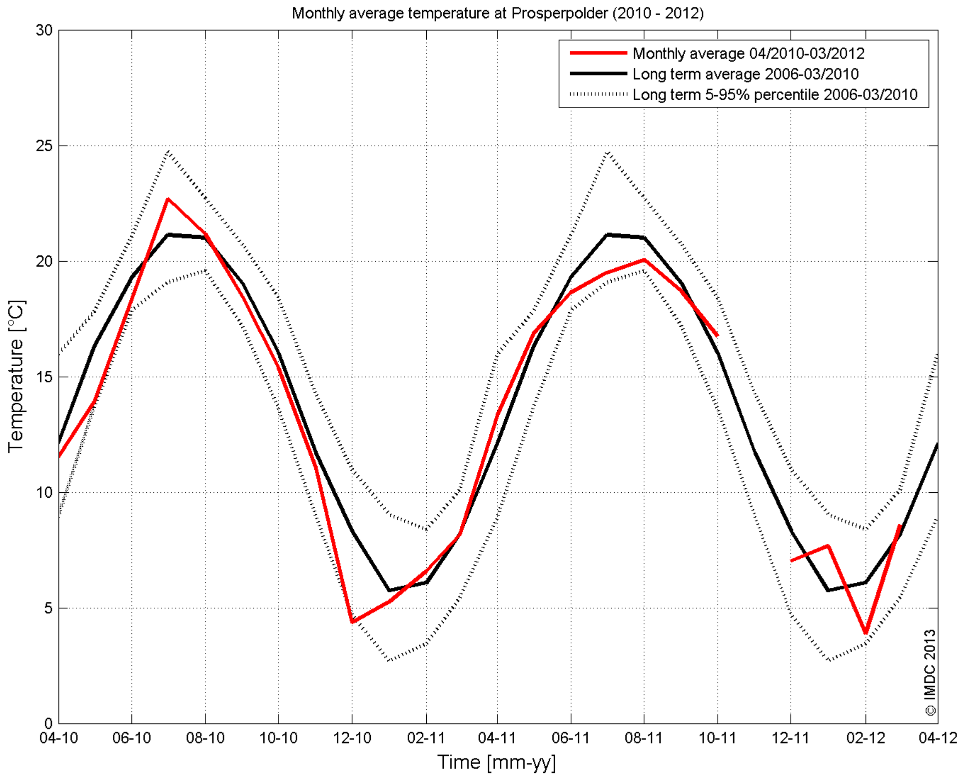
Annex-Figure E-12: Oosterweel (-5.8m TAW), April 2010 —March 2012, average tidal curve of the temperature for a (a) neap (b) average (c) spring tide.



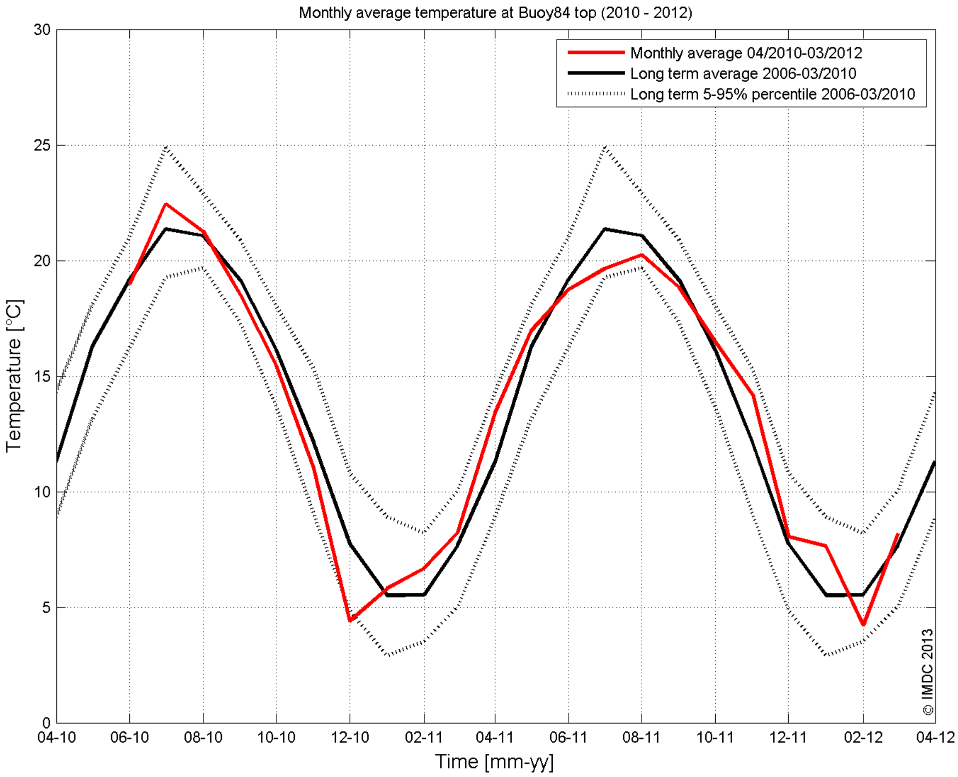
Annex-Figure E-13: Liefkenshoek, April 2010 – March 2012, average tidal curve of the temperature for a (a) neap (b) average (c) spring tide.

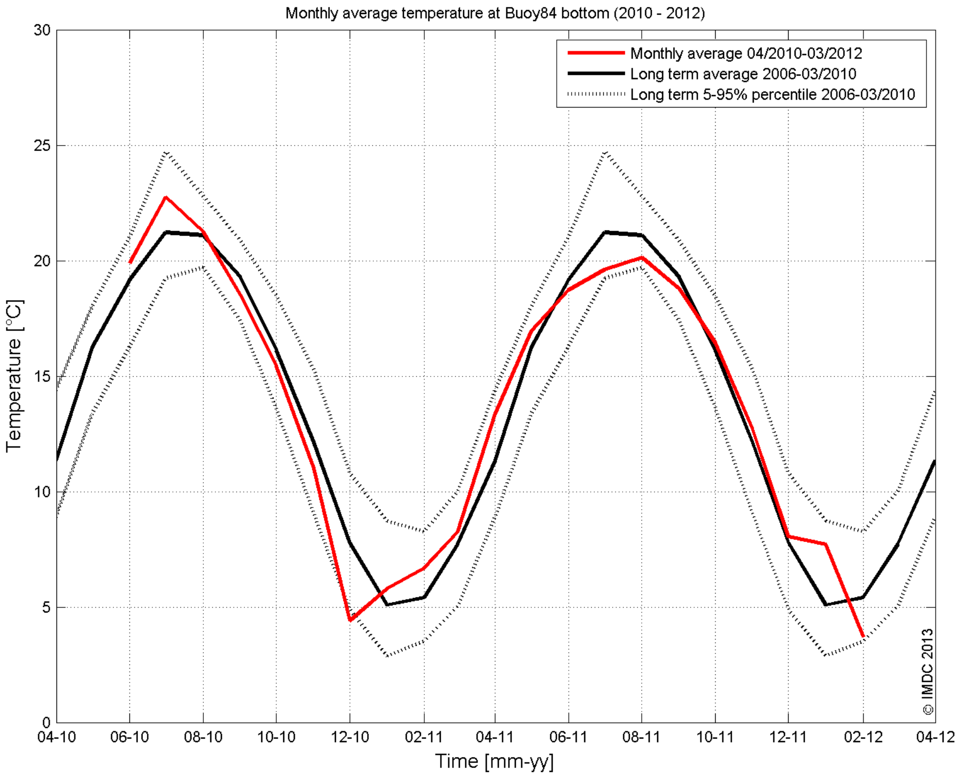


Annex-Figure E-14: Prosperpolder (-1.5m TAW), April 2010 – March 2012, average tidal curve of the temperature for a (a) neap (b) average (c) spring tide.

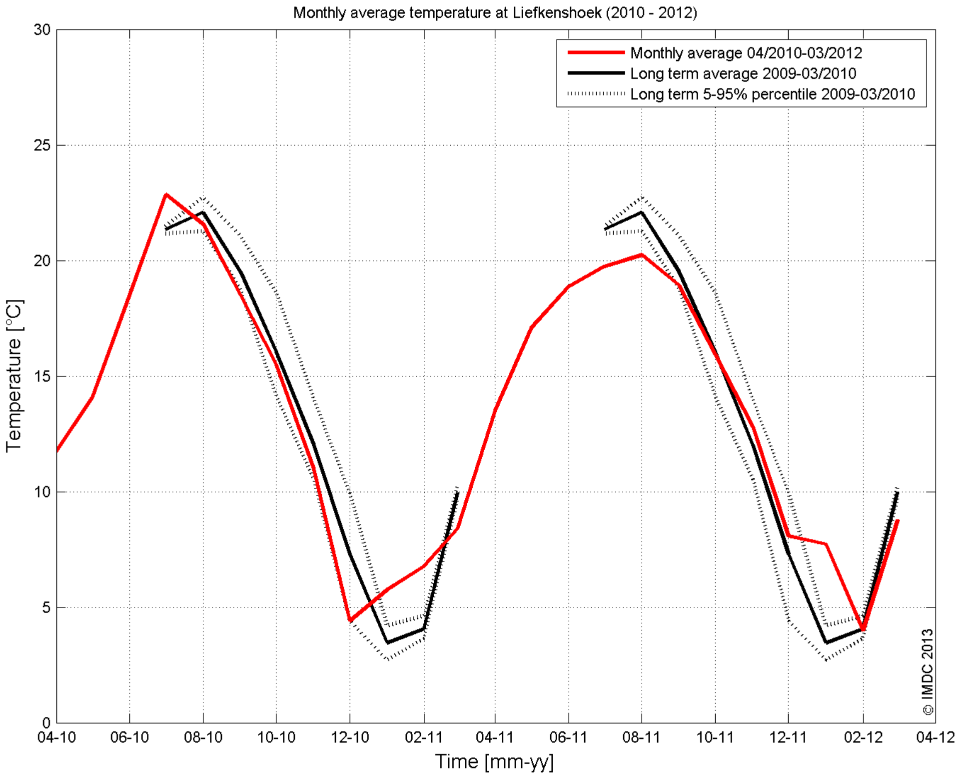


Annex-Figure E-15: The monthly average temperature of Prosperpolder between April 2010 – March 2012 and 2006 – March 2010 including the monthly 5/95%-percentiles for period 2006 – March 2010.

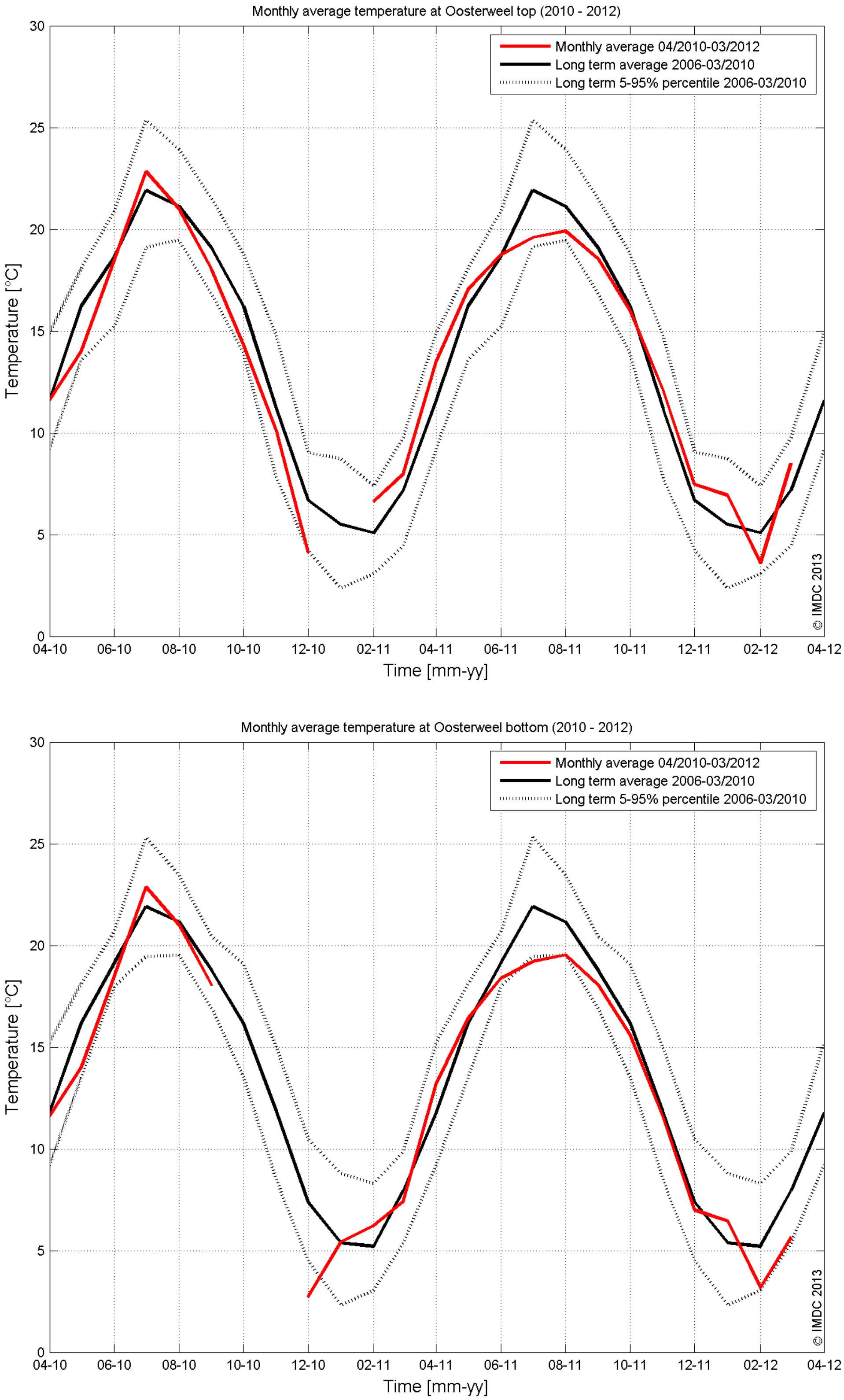




Annex-Figure E-16: The monthly average temperature of Buoy84 (a) top and (b) bottom between April 2010 – March 2012 and 2006 – March 2010 including the monthly 5/95%-percentiles for period 2006 – March 2010.

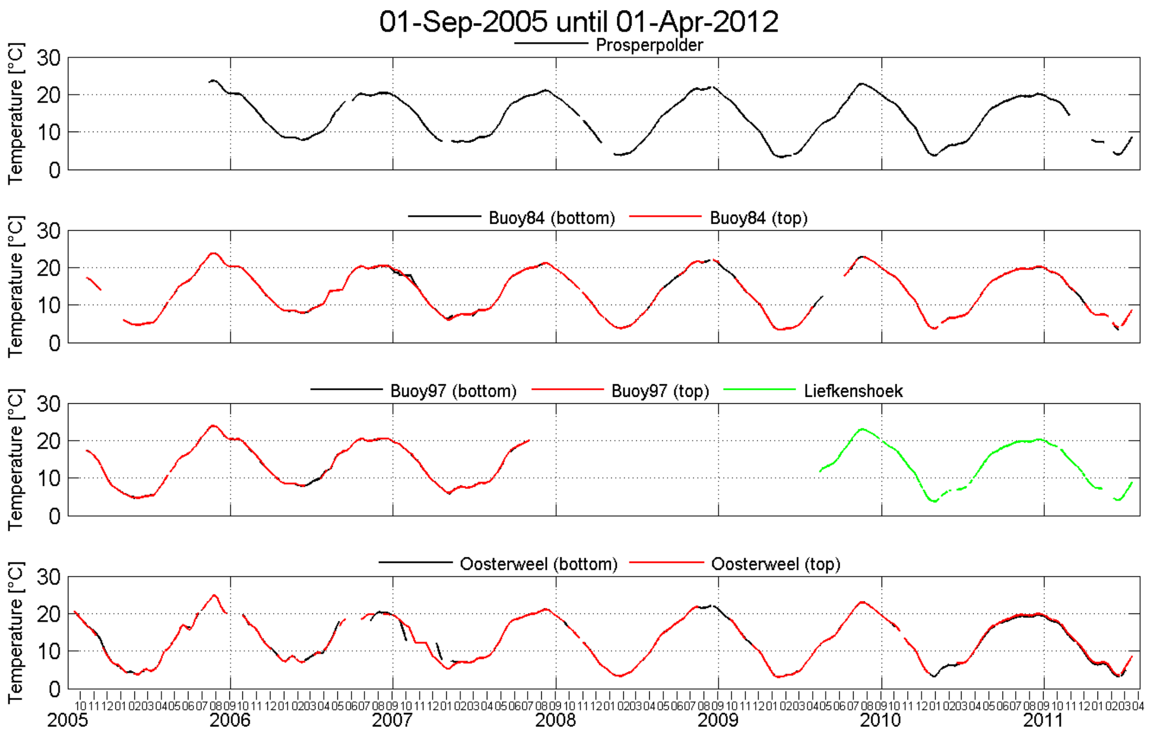


Annex-Figure E-17: The monthly temperature curves of Liefkenshoek between April 2010 – March 2012 and 2006 – March 2010 including the monthly 5/95%-percentiles for period 2006 – March 2010.



Annex-Figure E-18: The monthly average temperature of Oosterweel (a) top and (b) bottom between April 2010 – March 2012 and 2006 – March 2010 including the monthly 5/95%-percentiles for period 2006 – March 2010.

11406 - External effects siltation Deurganckdok (2012-2014)



Timeseries of monthly moving average of temperature

Processed by:

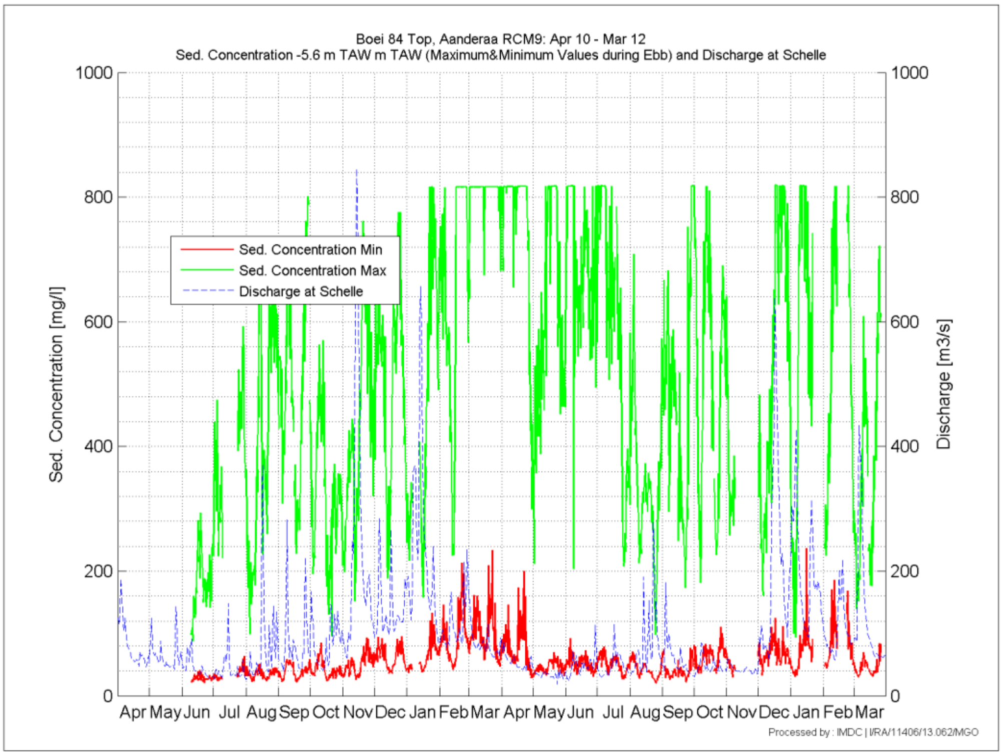
Location:

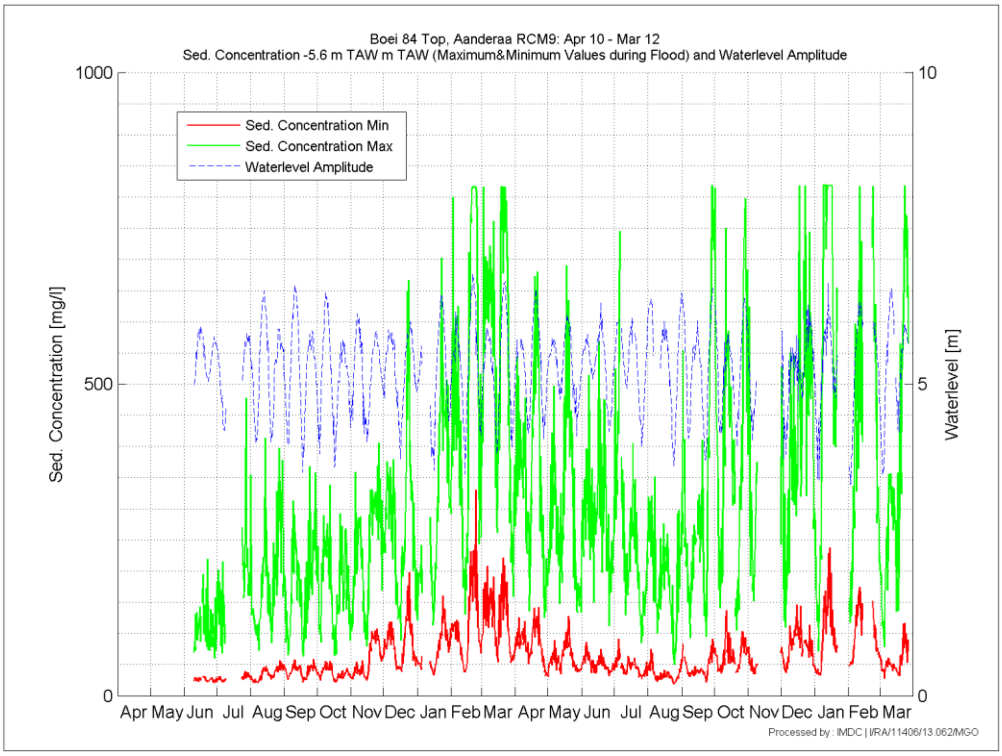
Lower Sea Scheldt

I/RA/11406/13.143/MGO

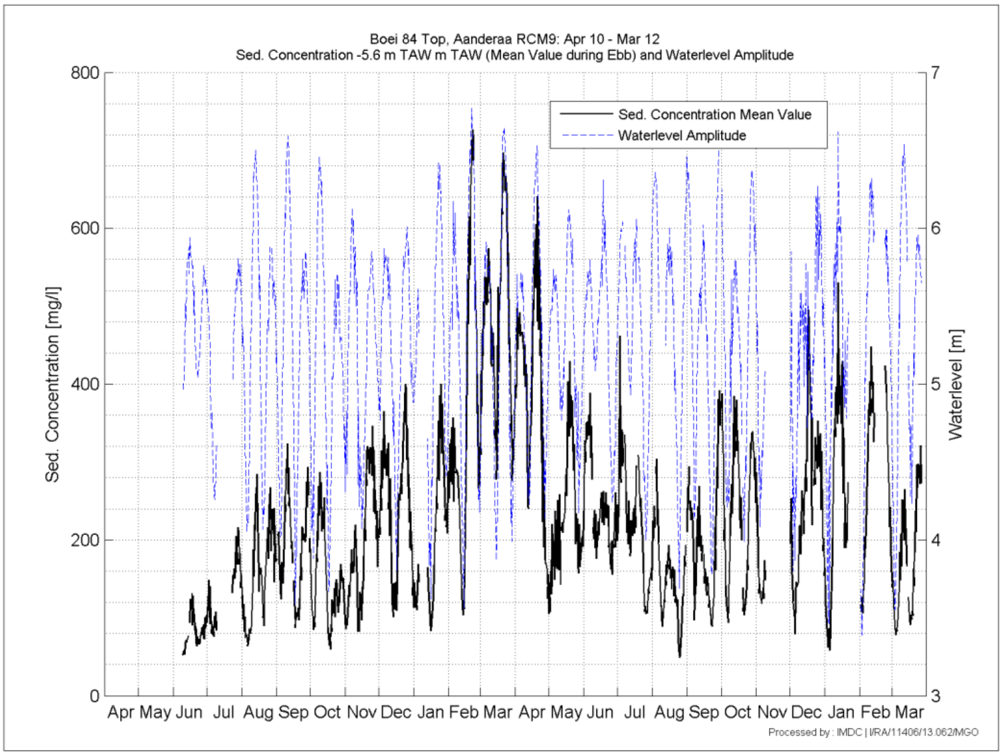
Annex-Figure E-19: Time series if monthly moving average of temperature at Prosperpolder, Buoy84, (Buoy97), Liefkenshoek and Oosetrweel measurement stations.

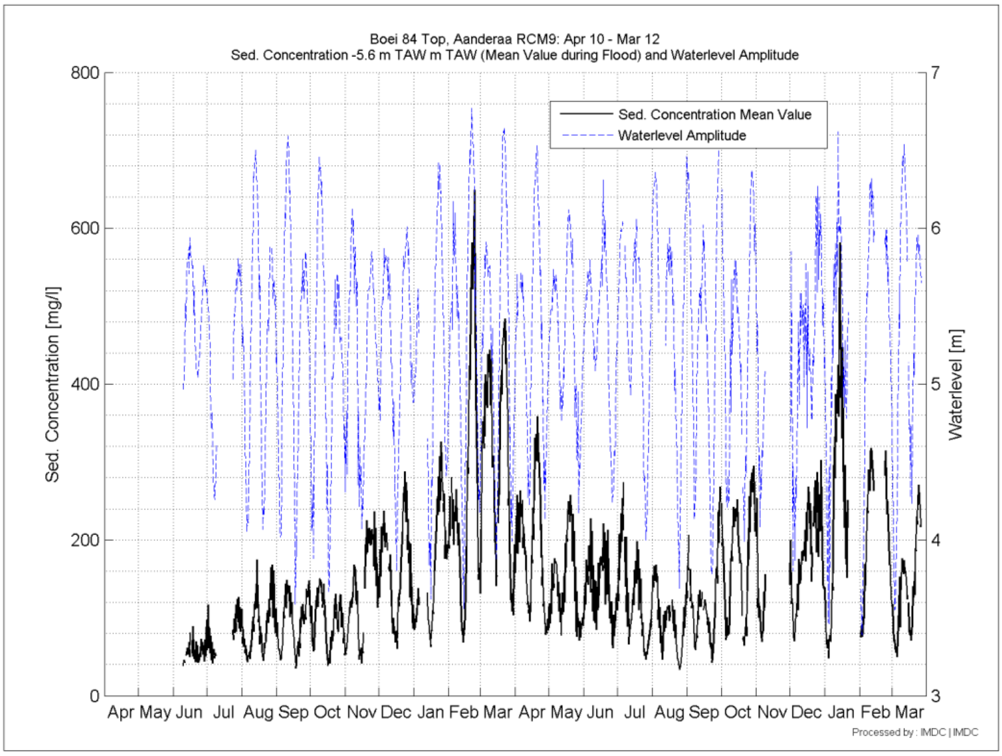
Annex F Figures for suspended sediment concentration



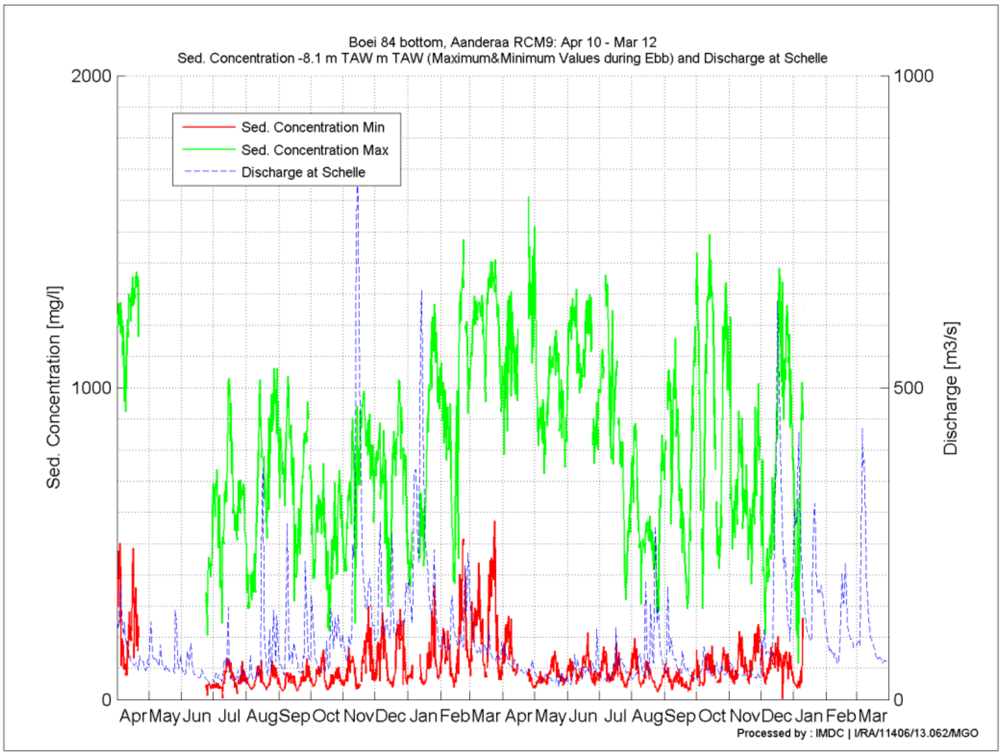


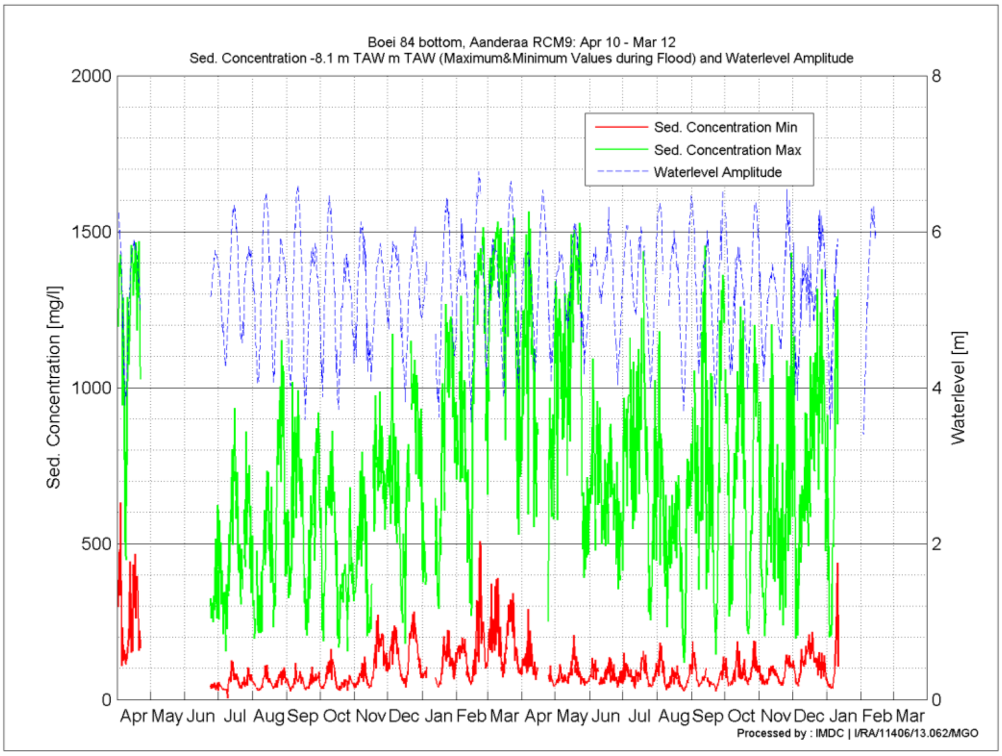
Annex-Figure F-1: Buoy 84 (-5.6m TAW), April 2010 – March 2012, minimal & maximal (a) ebb phase (and Scheldt discharge) and (b) flood phase (and tidal amplitude) suspended sediment concentration.



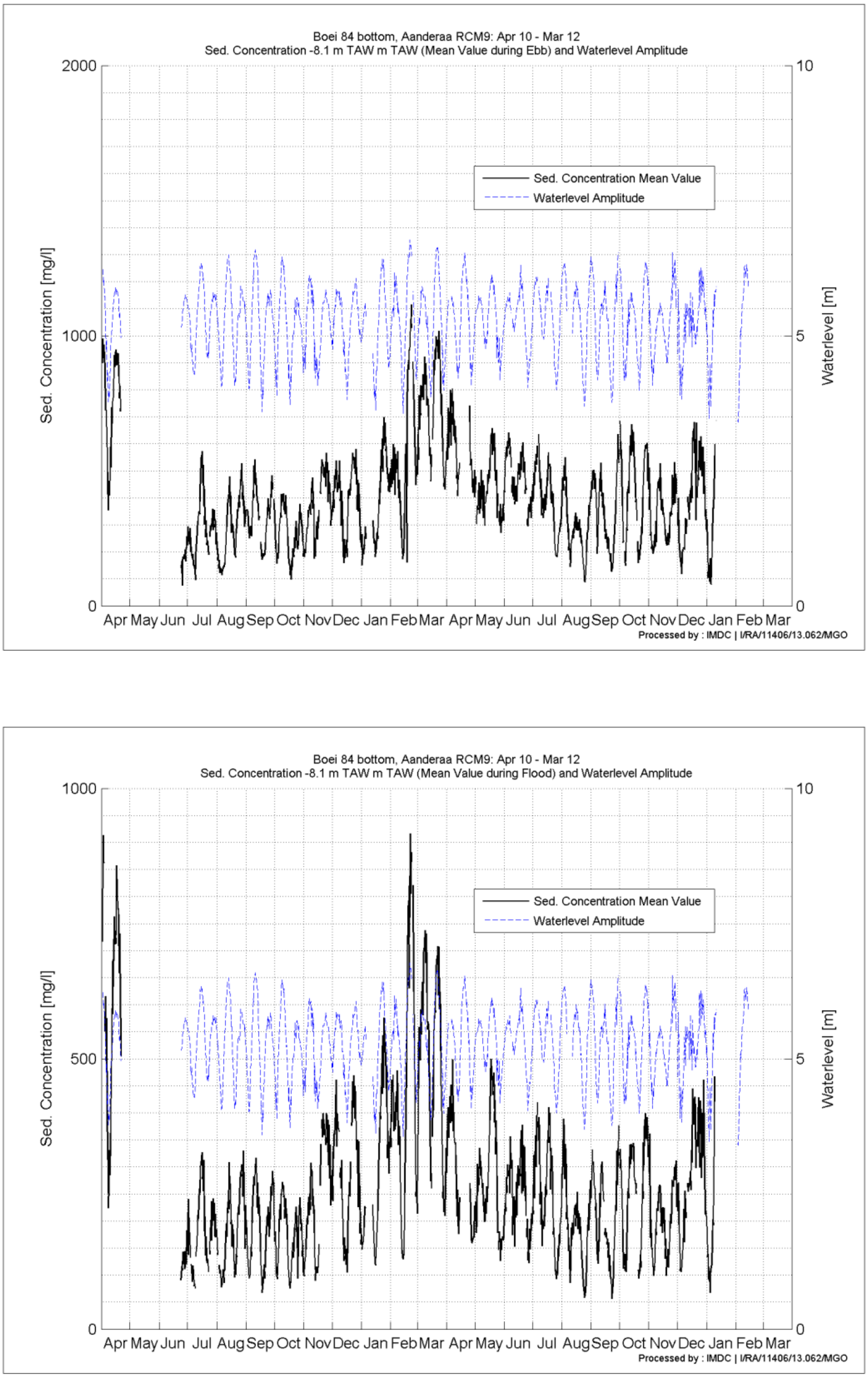


Annex-Figure F-2: Buoy 84 (-5.6m TAW), April 2010 – March 2012, average (a) ebb phase and (b) flood phase suspended sediment concentration and tidal amplitude.

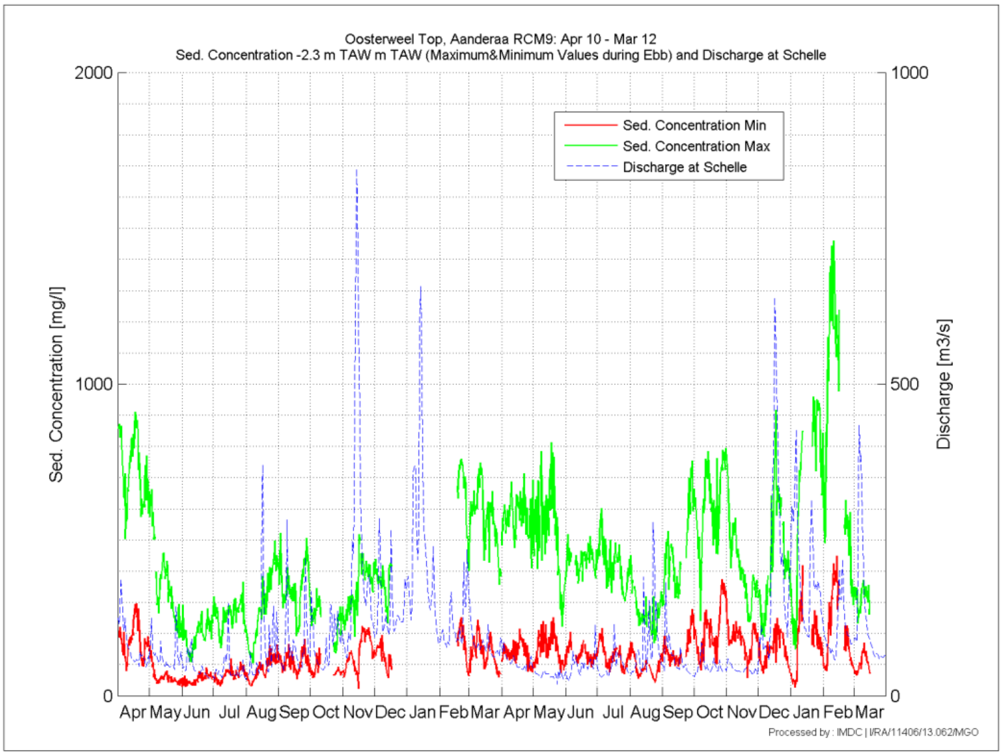


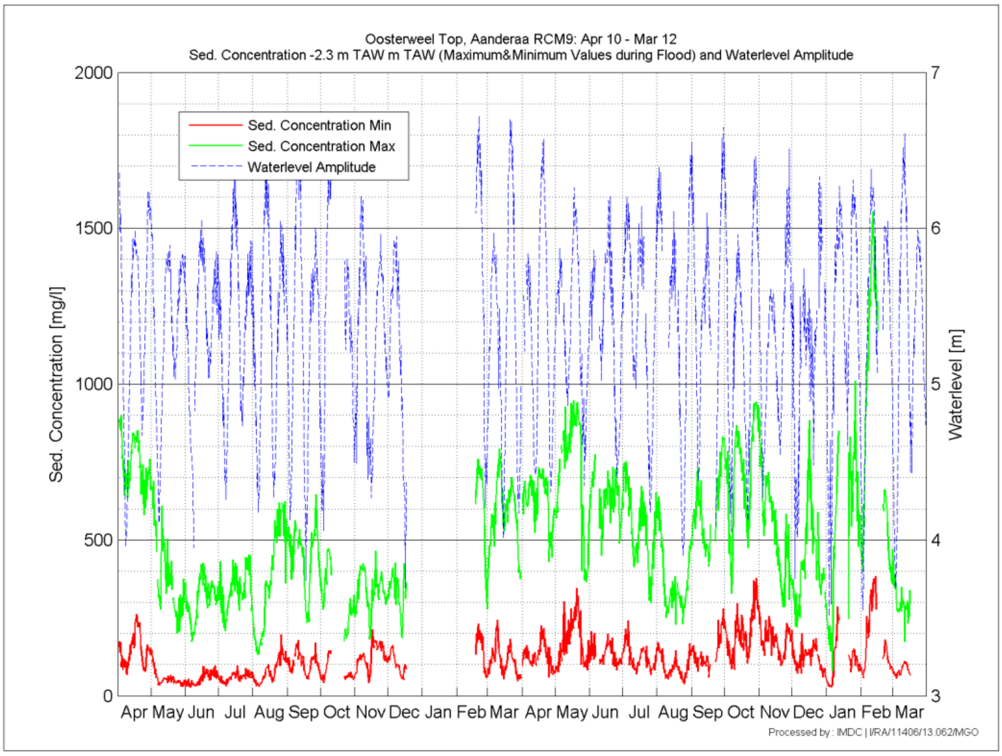


Annex-Figure F-3: Buoy 84 (-8.1m TAW), April 2010 – March 2012, minimal & maximal (a) ebb phase (and Scheldt discharge) and (b) flood phase (and tidal amplitude) suspended sediment concentration.

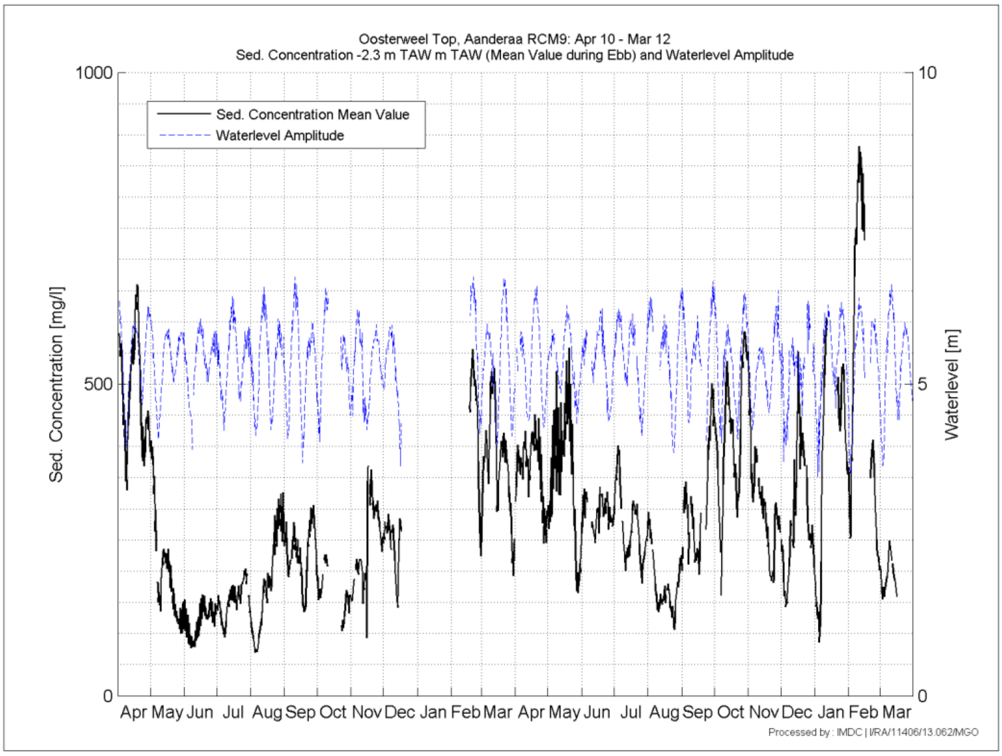


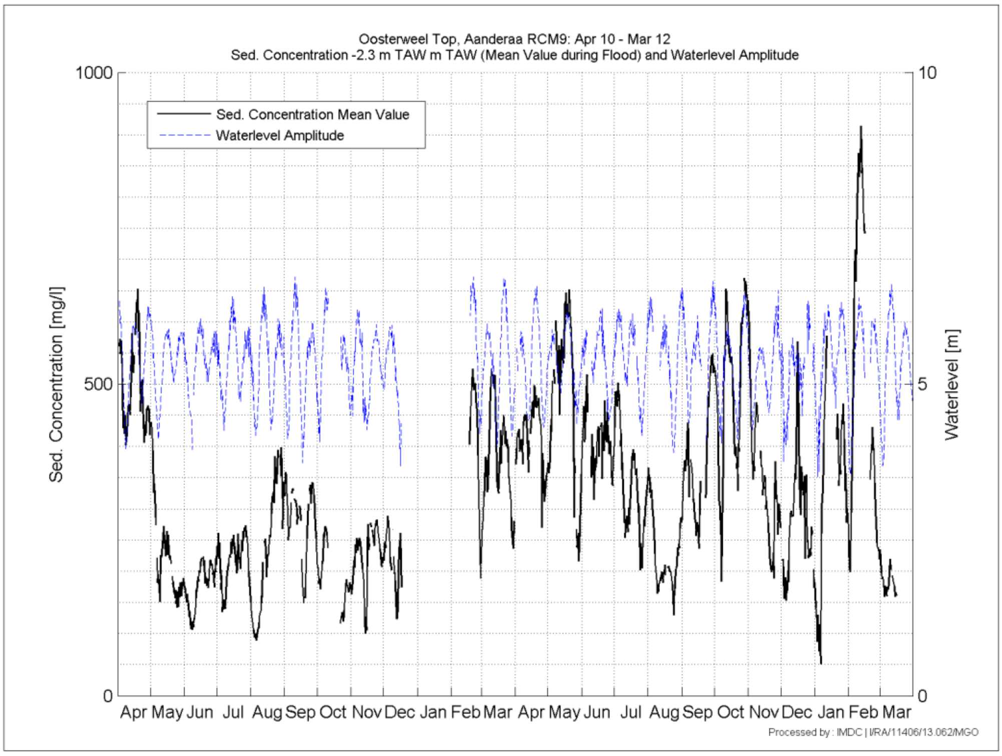
Annex-Figure F-4: Buoy 84 (-8.1m TAW), April 2010 – March 2012, average (a) ebb phase and (b) flood phase suspended sediment concentration and tidal amplitude.



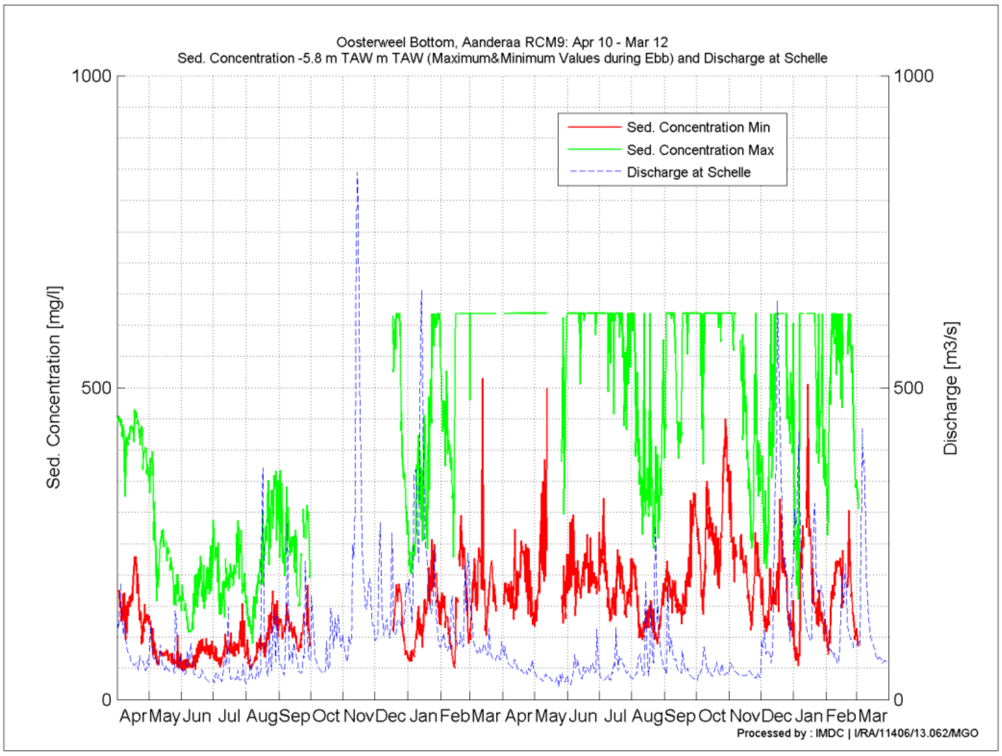


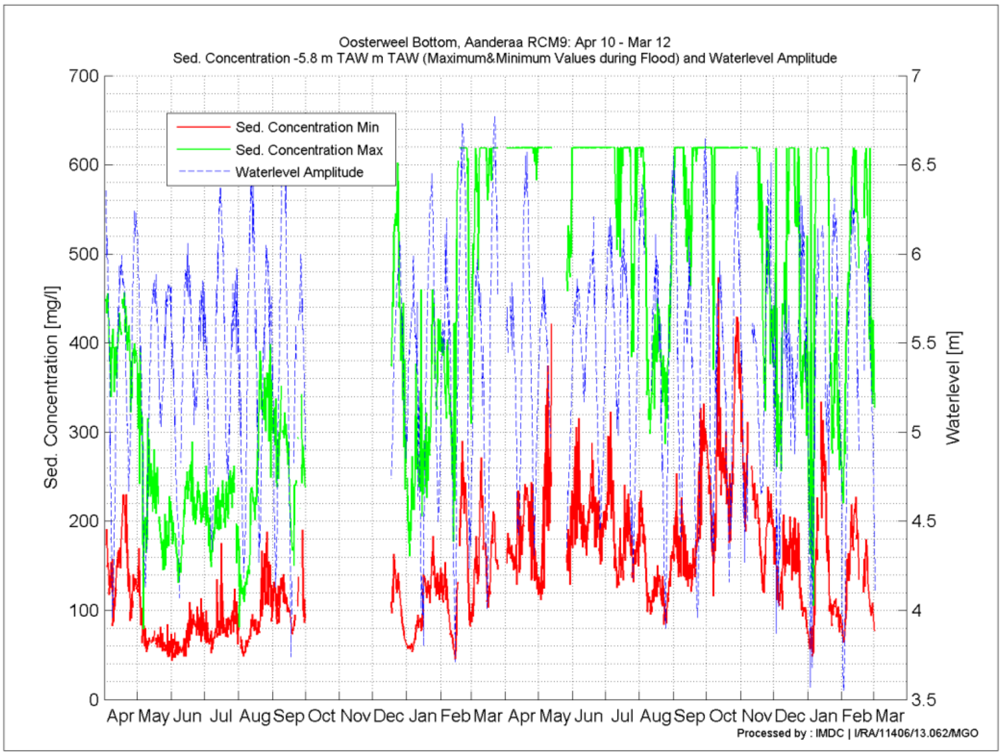
Annex-Figure F-5: Oosterweel (-2.3m TAW), April 2010 – March 2012, minimal & maximal (a) ebb phase (and Scheldt discharge) and (b) flood phase (and tidal amplitude) suspended sediment concentration.



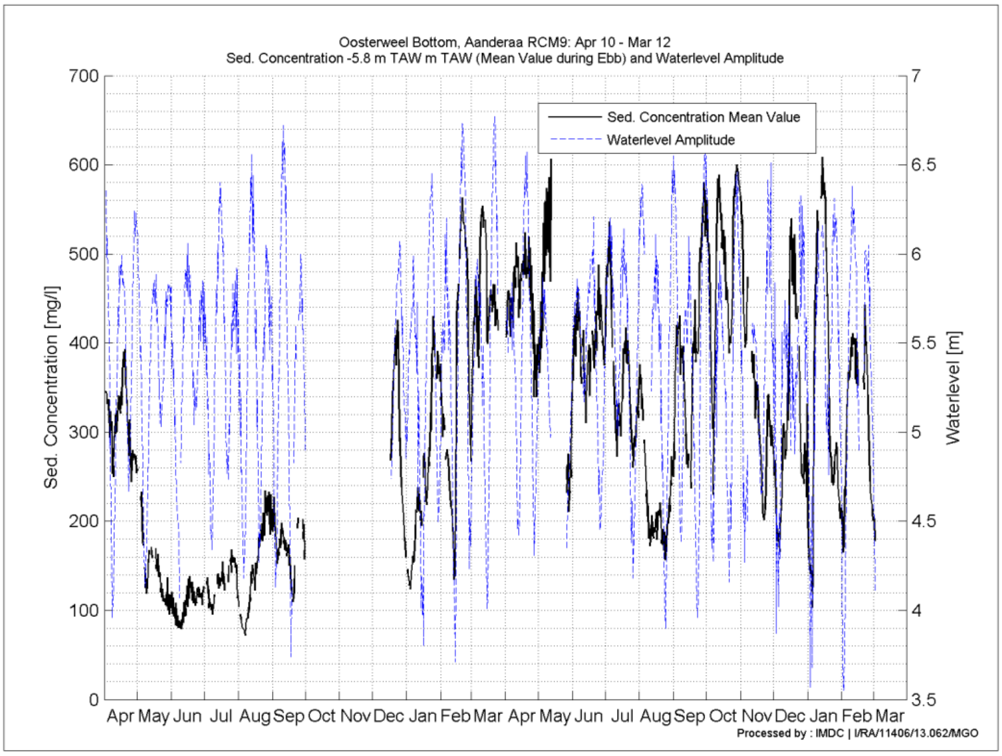


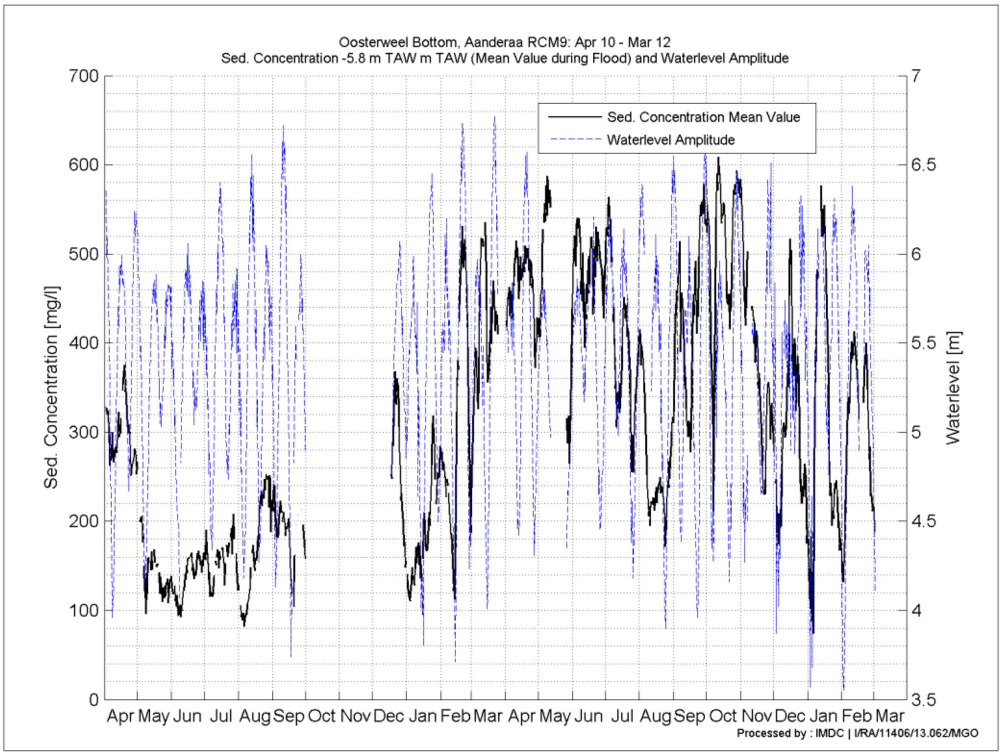
Annex-Figure F-6: Oosterweel (-2.3m TAW), April 2010 – March 2012, average (a) ebb phase and (b) flood phase suspended sediment concentration and tidal amplitude.



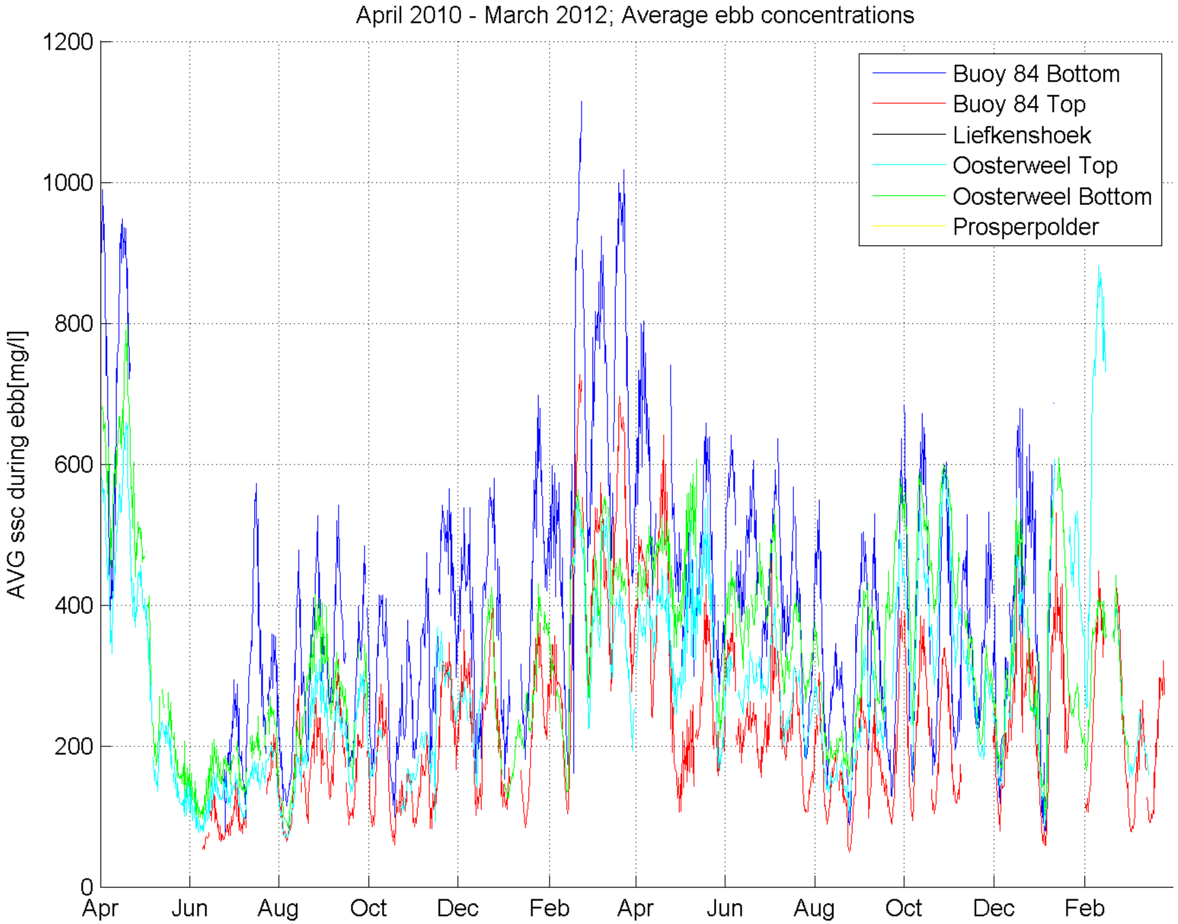


Annex-Figure F-7: Oosterweel (-5.8m TAW), April 2010 – March 2012, minimal & maximal (a) ebb phase (and Scheldt discharge) and (b) flood phase (and tidal amplitude) suspended sediment concentration.

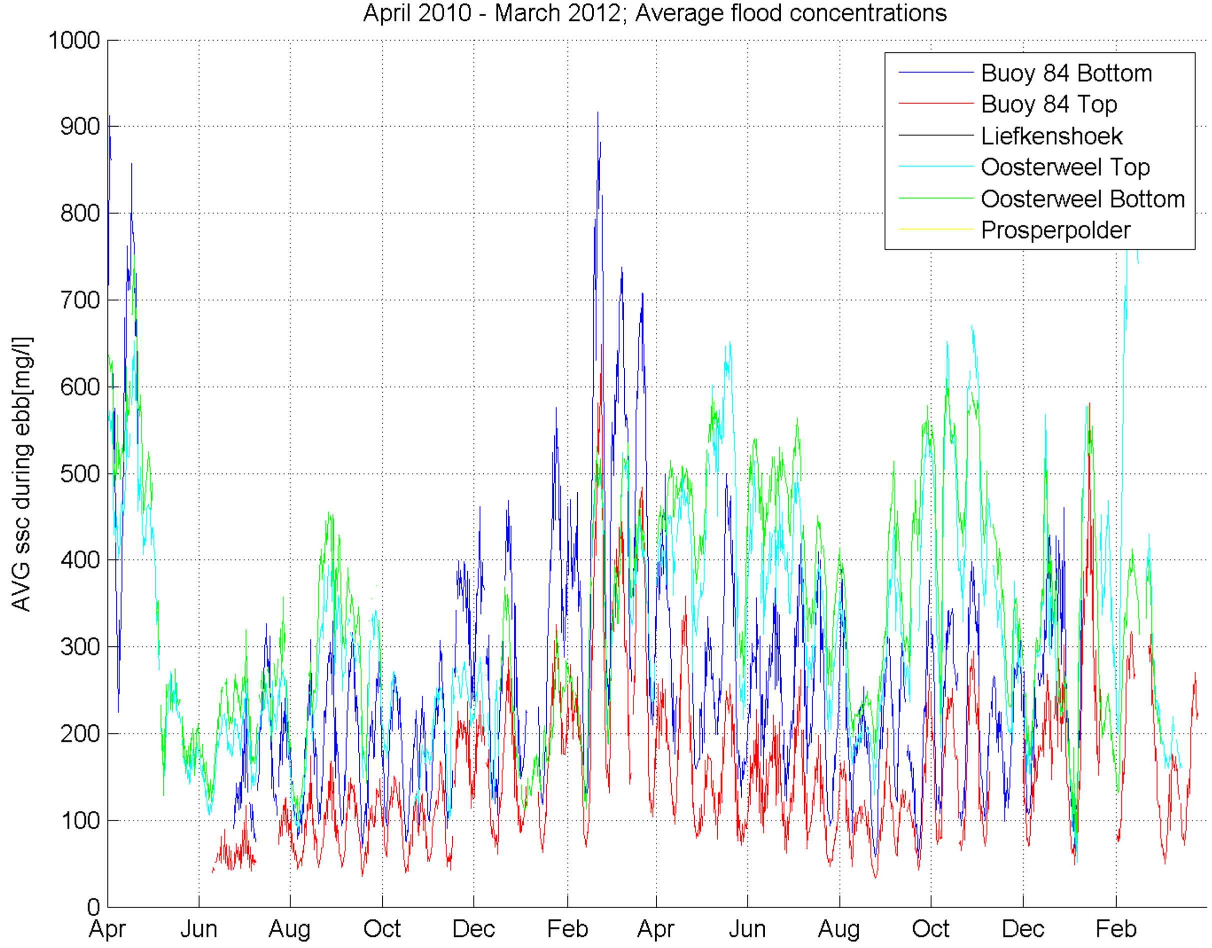




Annex-Figure F-8: Oosterweel (-5.8m TAW), April 2010 – March 2012, average (a) ebb phase and (b) flood phase suspended sediment concentration and tidal amplitude.



Annex-Figure F-9: Tidally-averaged sediment concentrations during Ebb in all measurement stations. April 2010 to March 2012.



Annex-Figure F-10: Tidally-averaged sediment concentrations during Flood in all measurement stations. April 2010 to March 2012.

Annex-Table F-1: Averaged-ebb phase suspended sediment concentration, average value (C[mg/l]), standard deviation (σ) and amount of ebb phases considered (N) during period considered (Summer: Apr–Sep, Winter: Oct–Mar, Year 1: Apr 2010 – Mar 2011. Total period April 2010 – March 2012).

			Apr-Jun			Jul-Sep			Oct-Dec			Jan-Mar			Summer			Winter			Apr-Mar			Total period		
			ΔS	σ	N	ΔS	σ	N	ΔS	σ	N	ΔS	σ	N	ΔS	σ	N	ΔS	σ	N	ΔS	σ	N	ΔS	σ	N
Buoy 84	-8.1 m TAW	Neap	477	94	8	204	63	44	232	82	46	404	146	47	246	118	54	307	139	110	293	141	145	279	136	266
		Avg	535	282	21	286	76	64	357	102	80	525	195	54	348	187	85	413	163	152	395	179	219	399	151	439
		Spring	695	335	23	388	85	64	417	97	49	760	213	56	469	229	87	569	233	125	541	244	192	519	197	350
		All	597	298	52	303	106	172	341	118	175	572	239	157	370	210	226	433	209	387	419	219	556	409	188	1055
	-5.6 m TAW	Neap	-	-	-1	113	37	42	124	46	48	248	117	49	114	36	44	179	102	115	164	99	139	153	83	280
		Avg	77	14	23	161	47	56	204	69	77	321	129	55	136	56	79	245	111	149	209	112	211	221	98	446
		Spring	93	21	16	218	47	46	250	78	51	495	155	55	186	69	62	355	169	126	307	172	168	307	137	373
		All	83	19	39	165	60	144	195	82	176	359	170	159	147	63	185	261	148	390	229	143	518	233	125	1099
Oosterweel	- 5.8 m TAW	Neap	322	195	32	201	82	45	249	77	3	310	110	42	251	152	77	293	101	61	272	140	122	293	128	262
		Avg	293	193	79	249	79	59	277	91	16	322	135	61	274	156	138	308	119	91	288	147	215	335	134	464
		Spring	382	233	51	248	69	47	352	64	8	399	112	52	318	186	98	374	105	73	346	165	158	374	141	342
		All	327	209	162	234	79	151	296	88	27	344	127	155	282	167	313	325	115	225	302	154	495	337	138	1068
	- 2.3 m TAW	Neap	254	144	33	149	52	49	202	69	36	301	76	24	191	110	84	229	81	78	213	104	142	232	100	282
		Avg	237	154	77	199	63	71	226	64	52	416	76	24	219	120	148	277	102	97	242	121	224	285	125	482
		Spring	310	196	60	201	54	51	226	54	33	434	63	31	260	158	111	311	111	81	285	148	175	337	161	367
		All	266	171	170	186	62	171	219	63	121	388	91	79	225	134	343	273	104	256	248	130	541	289	138	1131

Annex-Table F-2: Averaged-ebb phase suspended sediment concentration, average value (C[mg/l]), standard deviation (σ) and amount of ebb phases considered (N) during period considered (Summer: Apr–Sep, Winter: Oct–Mar, Year 2: Apr 2011–Mar 2012. Total period April 2010 – March 2012).

			Apr-Jun			**Jul-Sep**			**Oct-Dec**			**Jan-Mar**			**Summer**			**Winter**			**Year 2**			**Total period**		
			ΔS	**σ**	**N**	**ΔS**	**σ**	**N**	**ΔS**	**σ**	**N**	**ΔS**	**σ**	**N**	**ΔS**	**σ**	**N**	**ΔS**	**σ**	**N**	**ΔS**	**σ**	**N**	**ΔS**	**σ**	**N**
Buoy 84	**-8.1 m TAW**	Neap	420	107	35	192	69	34	218	50	43	127	47	9	308	146	69	205	66	67	263	128	121	279	136	266
		Avg	468	101	72	339	85	60	401	119	82	325	112	6	409	114	132	388	117	111	404	116	220	399	151	439
		Spring	565	107	43	428	95	65	509	83	47	572	130	3	485	121	110	491	98	67	492	111	158	519	197	350
		All	485	117	150	344	123	159	385	143	172	267	186	18	413	140	311	366	147	245	397	145	499	409	188	1055
	-5.6 m TAW	Neap	215	59	33	107	30	34	142	46	40	104	30	34	160	71	67	124	41	89	142	61	141	153	83	280
		Avg	261	92	84	183	41	58	250	80	56	212	77	37	229	84	142	227	77	115	231	83	235	221	98	446
		Spring	368	130	51	242	68	64	314	40	36	320	84	54	299	118	117	308	73	107	306	100	205	307	137	373
		All	284	116	168	191	73	156	235	91	132	229	114	125	240	108	326	225	99	311	236	105	581	233	125	1099
Oosterweel	**- 5.8 m TAW**	Neap	391	86	31	301	97	36	332	110	47	196	65	26	343	102	67	303	115	88	312	113	140	293	128	262
		Avg	429	74	74	309	87	58	386	111	80	347	115	37	376	100	132	371	109	139	375	106	249	335	134	464
		Spring	439	45	35	367	112	68	433	142	40	381	106	41	394	102	105	412	126	99	398	113	184	374	141	342
		All	423	73	140	332	104	162	382	123	167	323	125	104	375	102	304	365	123	326	367	115	573	337	138	1068
	- 2.3 m TAW	Neap	286	68	33	197	64	28	282	91	47	223	108	32	245	79	61	260	98	86	252	92	140	232	100	282
		Avg	334	67	83	243	64	58	334	93	82	399	211	35	297	80	141	343	135	137	322	115	258	285	125	482
		Spring	383	73	45	293	93	62	413	128	36	481	224	49	333	96	109	435	183	104	385	158	192	337	161	367
		All	338	76	161	255	85	148	336	110	165	385	220	116	299	91	311	350	158	327	326	135	590	289	138	1131

Annex-Table F-3: Averaged flood phase suspended sediment concentration, average value (C[mg/l]), standard deviation (σ) and amount of ebb phases considered (N) during period considered (Summer: Apr–Sep, Winter: Oct–Mar, Year 1: Apr 2010–Mar 2011. Total period April 2010 –March 2012).

			Apr-Jun			Jul-Sep			Oct-Dec			Jan-Mar			Summer			Winter			Year 1			Total period		
			ΔS	σ	N	ΔS	σ	N	ΔS	σ	N	ΔS	σ	N	ΔS	σ	N	ΔS	σ	N	ΔS	σ	N	ΔS	σ	N
Buoy 84	-8.1 m TAW	Neap	330	94	8	109	24	44	135	45	46	258	113	47	144	89	54	184	103	110	178	104	145	163	89	265
		Avg	421	240	21	179	46	64	253	84	77	393	146	53	239	162	85	295	130	151	282	149	215	262	118	433
		Spring	571	310	22	243	49	65	303	89	48	586	143	56	326	214	87	422	188	124	396	209	191	357	167	349
		All	471	271	51	185	68	173	235	100	171	422	191	156	250	185	226	304	172	385	294	184	551	268	150	1047
	-5.6 m TAW	Neap	-	-	1	57	14	43	73	26	47	145	63	48	60	17	45	101	58	113	93	56	138	89	45	280
		Avg	55	13	21	92	26	60	142	46	78	232	103	54	83	28	81	168	86	152	142	84	213	146	72	448
		Spring	61	13	15	116	24	47	168	52	50	367	110	56	103	32	62	249	134	126	210	135	168	211	107	372
		All	58	13	36	90	32	150	131	57	175	253	132	158	84	32	188	175	114	391	151	108	519	154	93	1100
Oosterweel	- 5.8 m TAW	Neap	325	180	32	245	98	45	216	59	3	243	106	41	278	143	77	258	101	59	265	131	121	303	133	264
		Avg	307	161	78	291	85	62	250	71	16	271	127	60	300	133	140	274	111	91	288	128	216	346	131	469
		Spring	391	192	48	295	79	43	317	40	8	358	116	51	345	157	91	352	100	71	348	140	150	386	131	333
		All	336	178	158	279	90	150	266	70	27	293	127	152	308	144	308	295	112	221	301	136	487	348	135	1066
	- 2.3 m TAW	Neap	286	147	33	201	76	47	183	45	37	317	87	23	236	117	82	236	86	76	236	107	140	262	110	282
		Avg	268	136	78	254	73	73	216	44	50	400	83	23	261	110	151	278	94	94	265	108	224	323	131	482
		Spring	340	164	58	259	63	46	232	44	36	427	54	32	304	135	104	322	99	83	312	126	172	377	159	365
		All	296	151	169	240	75	166	211	48	123	387	86	78	268	122	337	280	99	253	273	117	536	325	142	1129

Annex-Table F-4: Averaged flood phase suspended sediment concentration, average value (C[mg/l]), standard deviation (σ) and amount of considered ebb phases (N) during period considered (Summer Apr–Sep, Winter: Oct–Mar, Year 2: Apr 2011–Mar 2012. Total period April 2010 –March 2012).

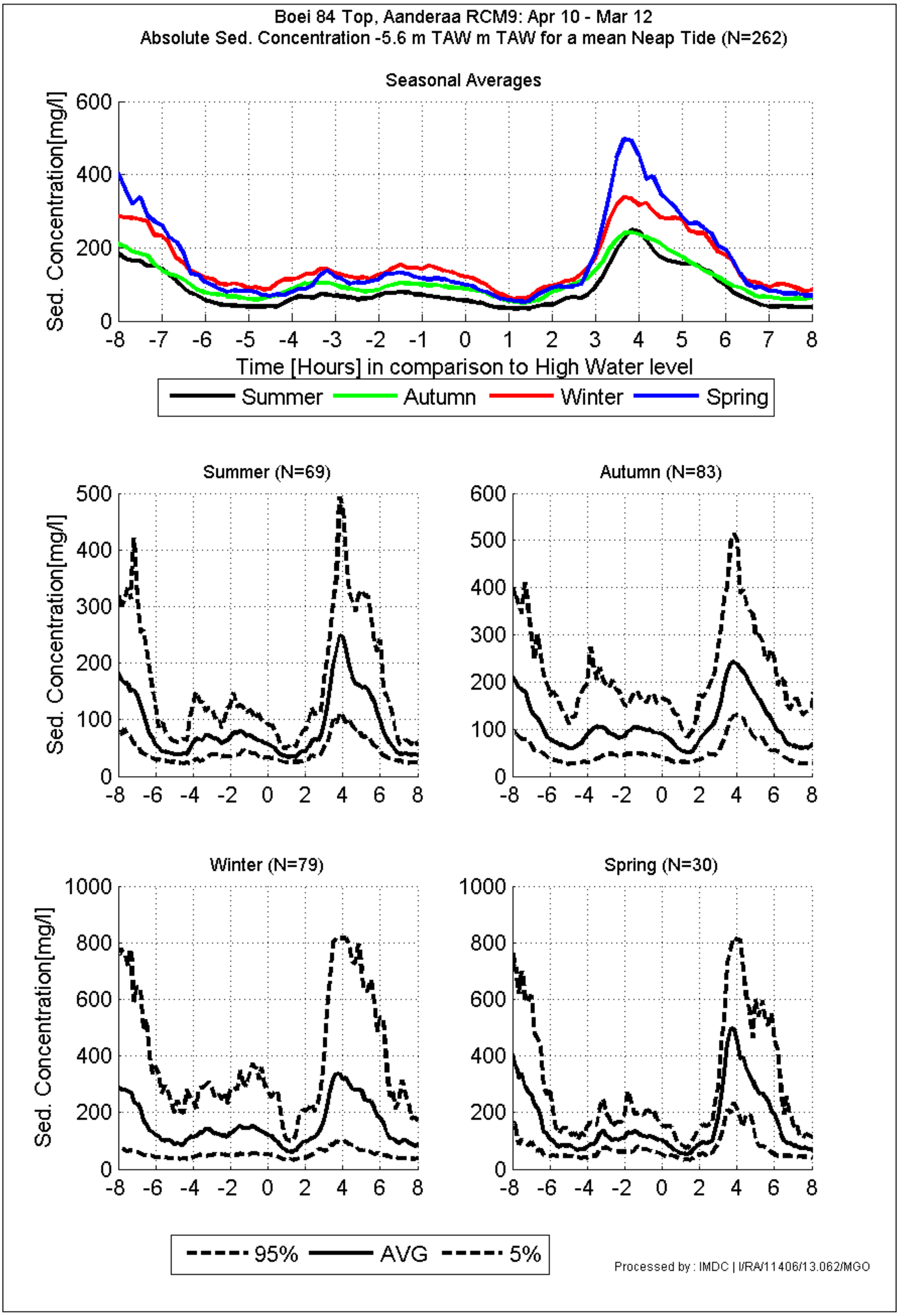
			Apr-Jun			Jul-Sep			Oct-Dec			Jan-Mar			Summer			Winter			Apr-Mar			Total period		
			∆S	σ	N	∆S	σ	N	∆S	σ	N	∆S	σ	N	∆S	σ	N	∆S	σ	N	∆S	σ	N	∆S	σ	N
Buoy 84	-8.1 m TAW	Neap	199	68	35	107	37	34	137	44	42	106	22	9	154	71	69	128	43	66	144	62	120	163	89	265
Buoy 84	-8.1 m TAW	Avg	256	69	72	202	50	59	260	76	81	205	88	6	232	66	131	246	77	110	241	72	218	262	118	433
Buoy 84	-8.1 m TAW	Spring	352	72	43	276	62	66	318	53	47	366	143	2	306	75	111	305	62	65	310	71	158	357	167	349
Buoy 84	-8.1 m TAW	All	270	90	150	213	83	159	245	92	170	172	107	17	241	91	311	230	93	241	240	93	496	268	150	1047
Buoy 84	-5.6 m TAW	Neap	98	21	34	59	17	34	102	39	40	82	25	34	79	28	68	89	33	89	86	32	142	89	45	280
Buoy 84	-5.6 m TAW	Avg	146	42	85	100	21	57	183	47	56	181	83	37	128	41	142	168	65	115	149	58	235	146	72	448
Buoy 84	-5.6 m TAW	Spring	220	57	50	151	41	65	233	34	36	264	96	53	182	59	117	237	80	106	212	77	204	211	107	372
Buoy 84	-5.6 m TAW	All	158	62	169	113	47	156	172	65	132	189	108	124	137	60	327	169	87	310	156	77	581	154	93	1100
Oosterweel	-5.8 m TAW	Neap	430	78	31	342	110	37	356	110	48	175	62	27	382	105	68	320	134	91	334	127	143	303	133	264
Oosterweel	-5.8 m TAW	Avg	476	56	77	345	88	58	394	116	81	311	112	37	420	97	135	373	116	141	396	111	253	346	131	469
Oosterweel	-5.8 m TAW	Spring	490	31	35	405	107	69	438	146	38	356	104	41	435	97	106	406	128	98	417	115	183	386	131	333
Oosterweel	-5.8 m TAW	All	470	60	143	369	105	164	393	124	167	294	121	105	417	101	309	368	129	330	387	120	579	348	135	1066
Oosterweel	-2.3 m TAW	Neap	361	71	33	255	88	29	315	101	48	199	86	32	311	95	62	279	111	88	287	106	142	262	110	282
Oosterweel	-2.3 m TAW	Avg	428	80	83	299	77	59	372	121	80	376	213	36	375	101	142	368	145	137	374	128	258	323	131	482
Oosterweel	-2.3 m TAW	Spring	488	88	45	365	102	63	463	167	35	456	233	50	418	114	110	451	193	105	435	163	193	377	159	365
Oosterweel	-2.3 m TAW	All	431	91	161	318	99	151	375	137	163	362	222	118	377	111	314	370	167	330	373	146	593	325	142	1129

Annex-Table F-5: Averaged-tide suspended sediment concentration, average value (C[mg/l]), standard deviation (σ) and amount of considered ebb phases (N) during considered period (Summer: Apr–Sep, Winter: Oct–Mar, Year 1: Apr 2010–Mar 2011. Total period April 2010 – March 2012).

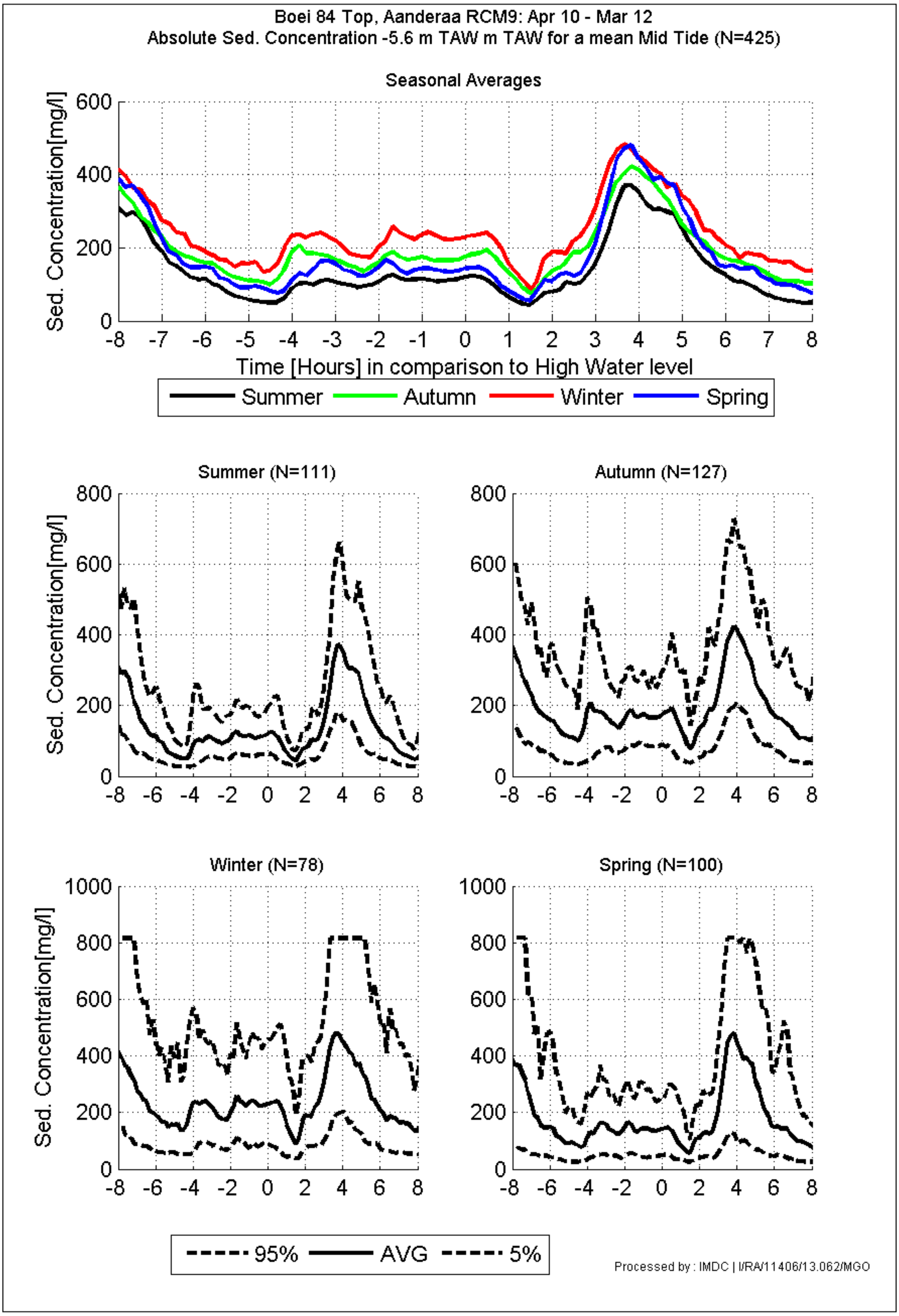
			Apr-Jun			Jul-Sep			Oct-Dec			Jan-Mar			Summer			Winter			Year 1			Total period		
			ΔS	σ	N	ΔS	σ	N	ΔS	σ	N	ΔS	σ	N	ΔS	σ	N	ΔS	σ	N	ΔS	σ	N	ΔS	σ	N
Buoy 84	-8.1 m TAW	Neap	399	92	8	154	39	44	182	58	46	327	124	47	192	100	54	242	116	110	232	118	145	217	107	266
		Avg	475	258	21	233	57	61	303	91	77	461	164	53	295	174	82	354	144	148	339	162	212	330	130	428
		Spring	629	324	22	316	65	64	359	90	48	675	173	56	396	219	86	497	208	124	469	224	190	437	179	345
		All	530	283	51	244	86	169	286	107	171	497	212	156	309	196	222	368	189	382	356	200	547	337	166	1039
	-5.6 m TAW	Neap	-	-	1	84	22	42	97	32	47	192	81	48	85	23	44	137	74	113	126	72	137	119	59	278
		Avg	66	13	21	126	34	56	174	56	77	277	108	54	110	40	77	208	94	148	177	95	208	184	81	441
		Spring	76	15	14	167	34	46	208	64	50	430	130	55	146	49	60	301	149	125	260	151	165	260	118	367
		All	70	15	35	127	45	144	163	68	174	305	147	157	116	46	181	217	128	386	190	123	510	193	106	1086
Oosterweel	-5.8 m TAW	Neap	323	186	32	224	91	44	233	68	3	275	104	41	266	147	76	276	94	59	268	132	120	298	128	260
		Avg	300	179	77	271	82	55	264	81	16	294	128	59	288	147	132	288	112	88	288	137	207	341	130	456
		Spring	388	215	47	271	74	42	335	52	8	384	110	50	333	174	89	367	99	70	350	152	147	382	134	327
		All	331	194	156	256	85	141	282	79	27	319	124	150	296	157	297	310	110	217	302	144	474	343	135	1043
	-2.3 m TAW	Neap	270	144	33	174	64	47	193	53	36	310	80	23	213	113	82	233	81	75	224	104	139	247	102	278
		Avg	253	145	77	226	68	70	219	53	49	407	78	23	240	116	147	276	97	92	253	114	219	303	125	471
		Spring	324	180	58	227	59	45	230	48	32	431	57	31	282	148	103	320	105	77	300	138	166	358	158	356
		All	280	160	168	211	68	162	214	53	117	388	87	77	246	128	332	277	101	244	260	123	524	307	138	1105

Annex-Table F-6: Averaged tide suspended sediment concentration, average value (C[mg/l]), standard deviation (σ) and amount of ebb phases considered (N) during period considered (Summer: Apr–Sep, Winter: Oct–Mar, Year 2: Apr 2011–Mar 2012. Total period April 2010 – March 2012).

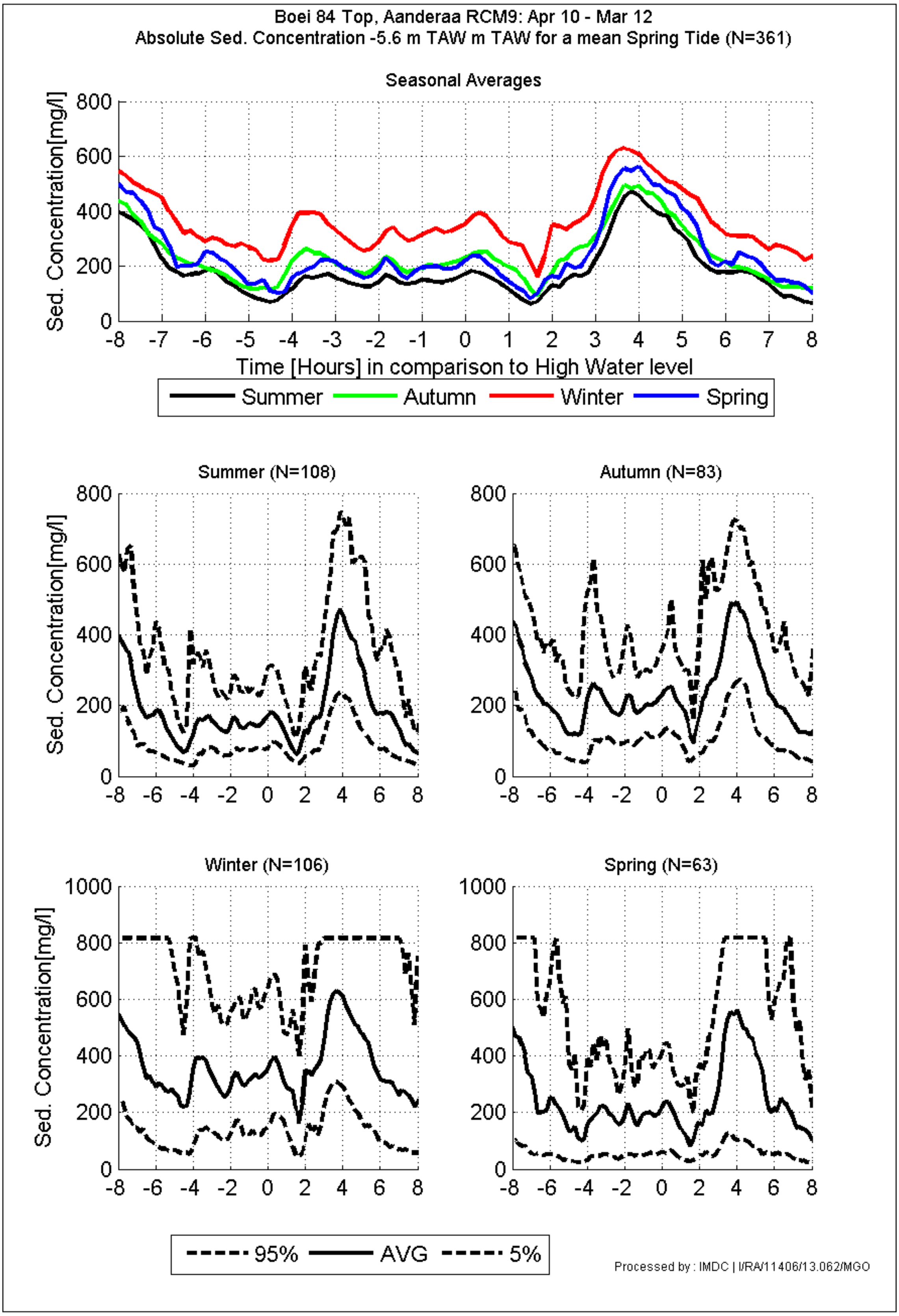
			Apr-Jun			Jul-Sep			Oct-Dec			Jan-Mar			Summer			Winter			Apr-Mar			Total period		
			ΔS	σ	N	ΔS	σ	N	ΔS	σ	N	ΔS	σ	N	ΔS	σ	N	ΔS	σ	N	ΔS	σ	N	ΔS	σ	N
Buoy 84	-8.1 m TAW	Neap	301	83	35	147	51	34	174	44	43	117	25	9	225	104	69	164	50	67	199	89	121	217	107	266
		Avg	358	76	70	269	64	59	328	93	81	262	97	6	317	83	129	315	93	110	320	88	216	330	130	428
		Spring	454	74	42	353	76	64	411	62	47	435	128	2	394	90	108	396	72	65	399	83	155	437	179	345
		All	372	96	147	277	102	157	312	115	171	205	128	17	324	110	306	295	117	242	315	114	492	337	166	1039
	-5.6 m TAW	Neap	153	36	33	82	23	34	121	42	40	93	27	34	117	46	67	106	36	89	112	42	141	119	59	278
		Avg	202	61	83	141	28	57	216	61	56	197	78	37	177	58	140	197	67	115	189	64	233	184	81	441
		Spring	293	90	50	198	52	63	273	31	36	291	87	53	241	85	115	272	73	106	259	82	202	260	118	367
		All	219	85	166	151	59	154	203	76	132	209	109	124	187	81	322	197	90	310	195	87	576	193	106	1086
Oosterweel	-5.8 m TAW	Neap	412	81	31	322	103	36	347	109	47	183	59	26	364	103	67	312	124	88	324	120	140	298	128	260
		Avg	453	61	75	326	87	57	391	111	80	330	110	37	398	97	132	373	109	139	386	106	249	341	130	456
		Spring	464	30	34	387	110	67	437	143	38	369	104	41	415	99	103	410	126	97	408	112	180	382	134	327
		All	447	63	140	350	105	160	389	122	165	309	122	104	396	100	302	368	124	324	378	116	569	343	135	1043
	-2.3 m TAW	Neap	323	66	32	224	73	28	299	94	47	211	96	32	277	85	60	269	101	86	269	96	139	247	102	278
		Avg	379	69	83	268	69	57	355	106	77	384	208	35	334	88	140	356	137	132	347	118	252	303	125	471
		Spring	434	75	45	329	98	61	435	146	35	468	229	49	376	102	108	443	187	103	409	157	190	358	158	356
		All	383	80	160	285	92	146	356	122	159	372	220	116	337	99	308	360	161	321	349	138	581	307	138	1105



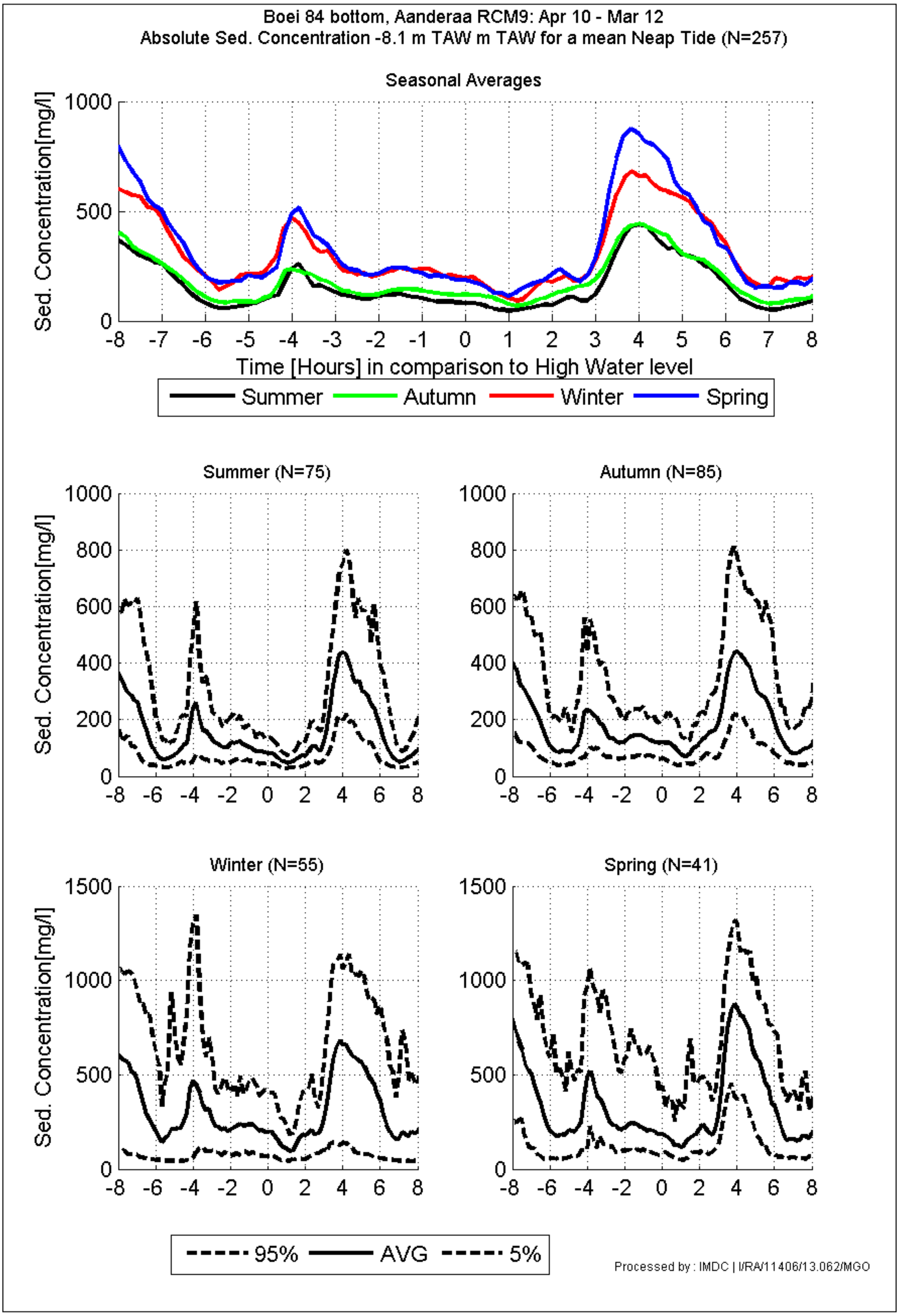
Annex-Figure F-11: Buoy 84 (-5.6m TAW), April 2010 – March 2012. Averaged-tidal curve of the suspended sediment concentration for an averaged neap tide.



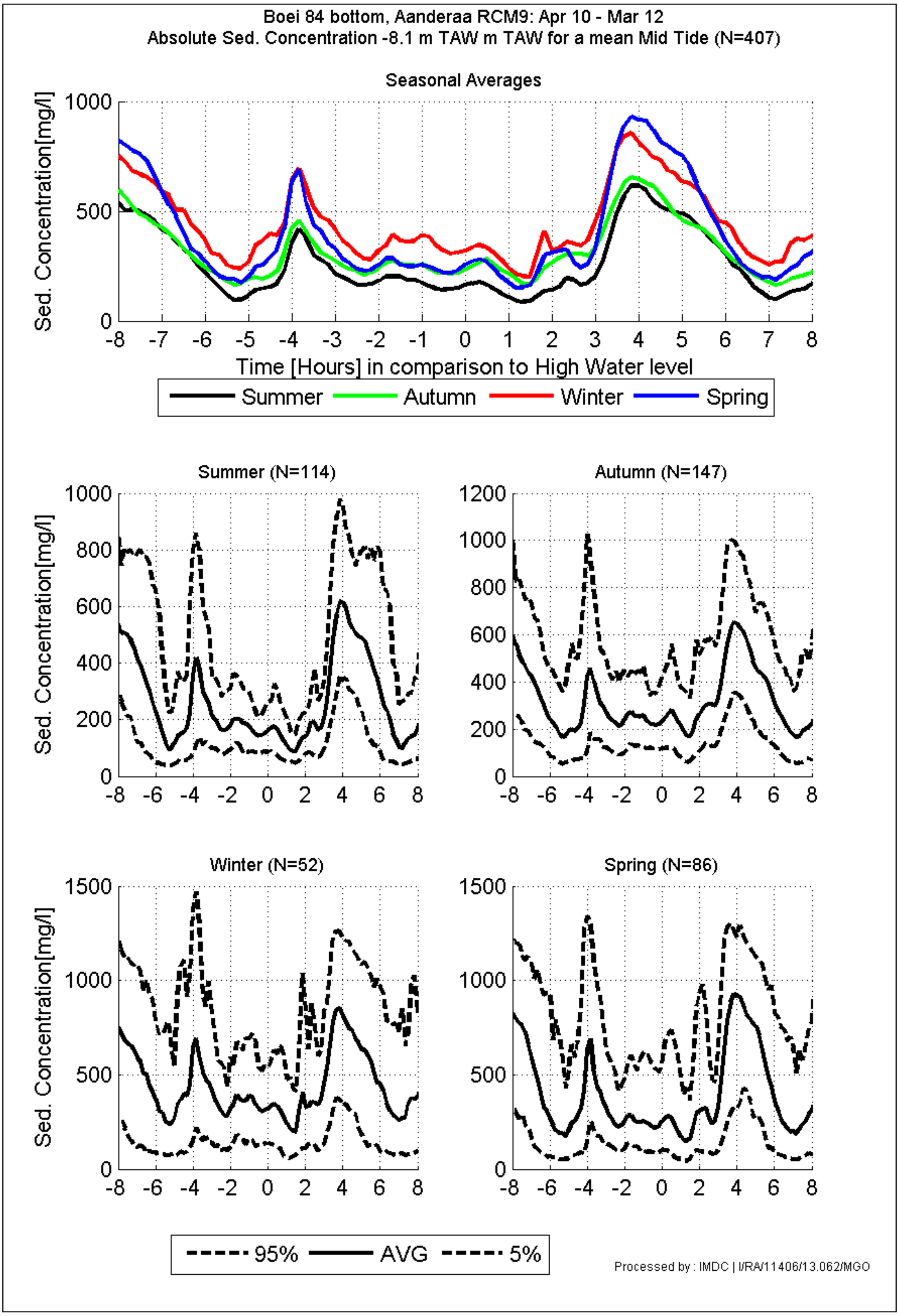
Annex-Figure F-12: Buoy 84 (-5.6m TAW), April 2010 – March 2012. Averaged tidal curve of the suspended sediment concentration for an averaged mean tide.



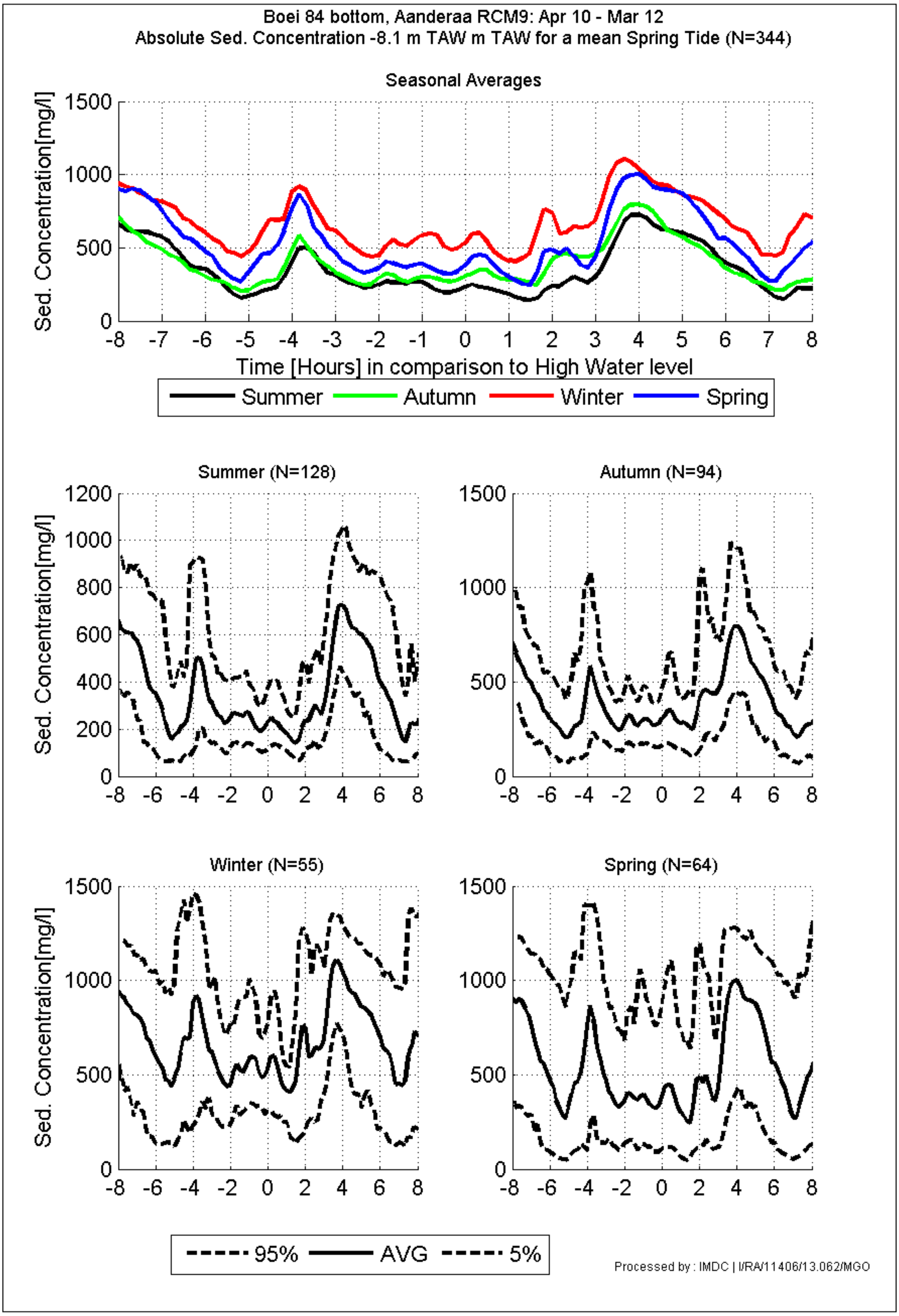
Annex-Figure F-13: Buoy 84 (-5.6m TAW), April 2010 – March 2012. Averaged-tidal curve of the suspended sediment concentration for an averaged spring tide.



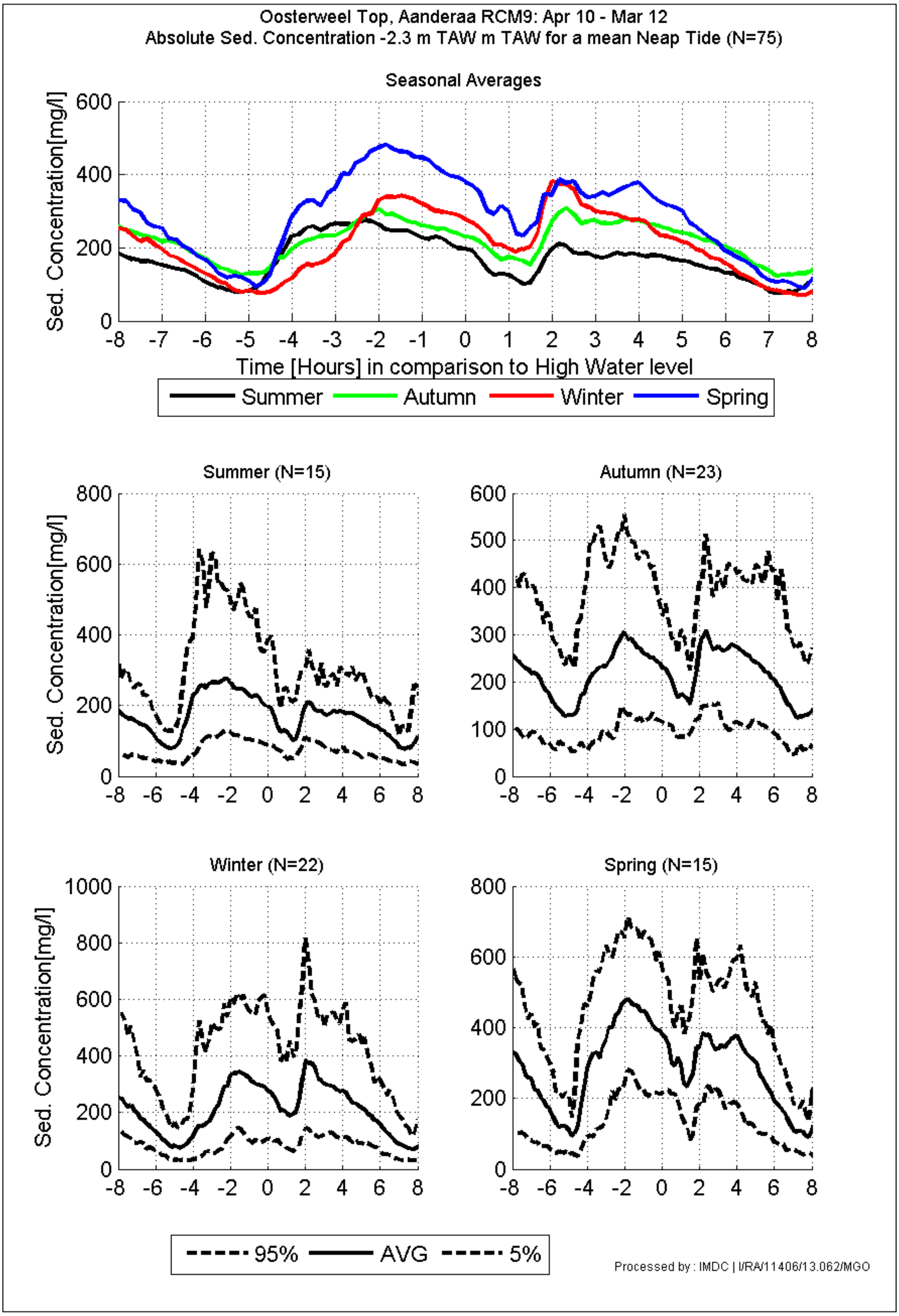
Annex-Figure F-14: Buoy 84 (-5.6m TAW), April 2010 – March 2012. Averaged tidal curve of the suspended sediment concentration for an averaged neap tide.



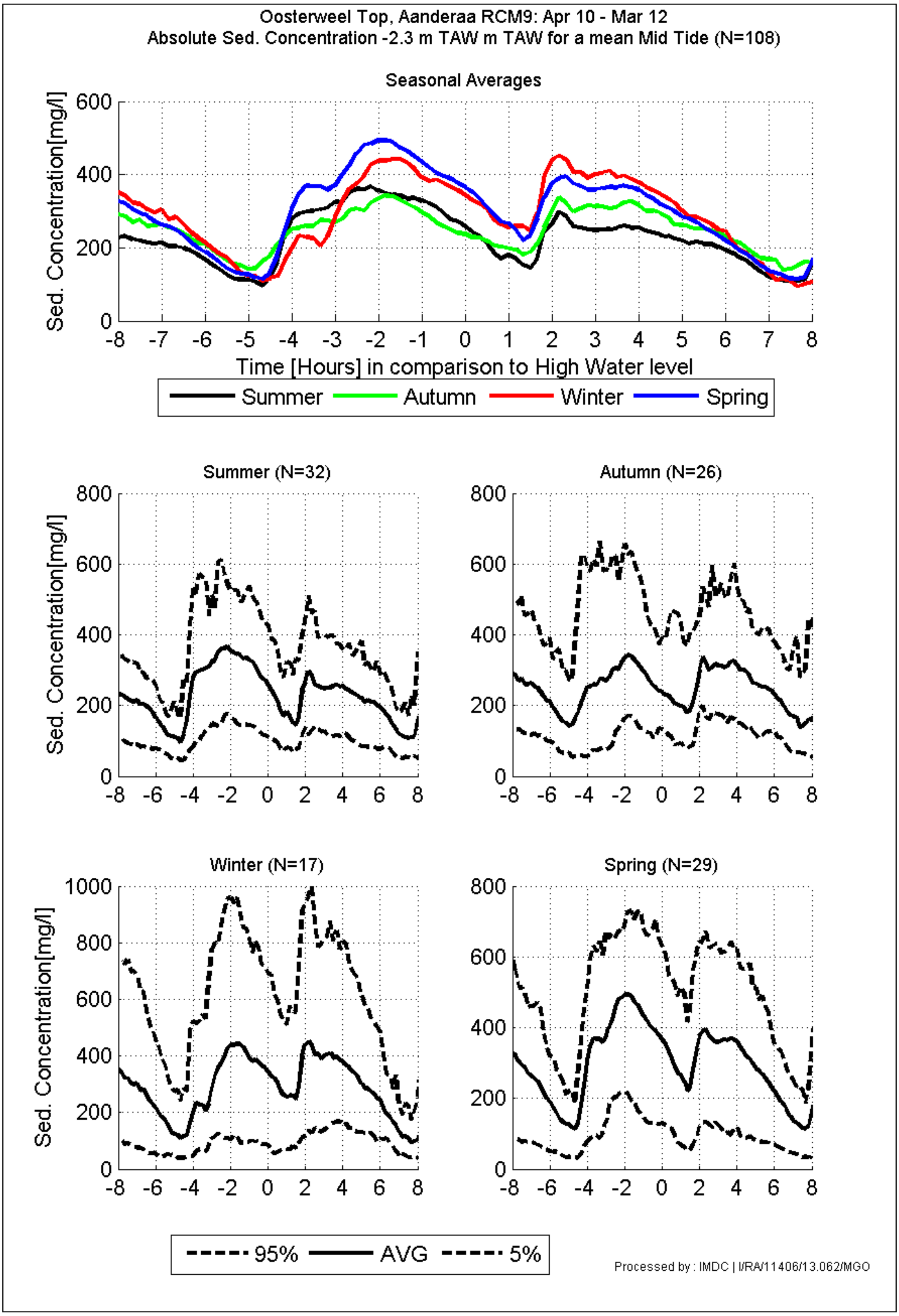
Annex-Figure F-15: Buoy 84 (-5.6m TAW), April 2010 – March 2012. Averaged-tidal curve of the suspended sediment concentration for an averaged mean tide.



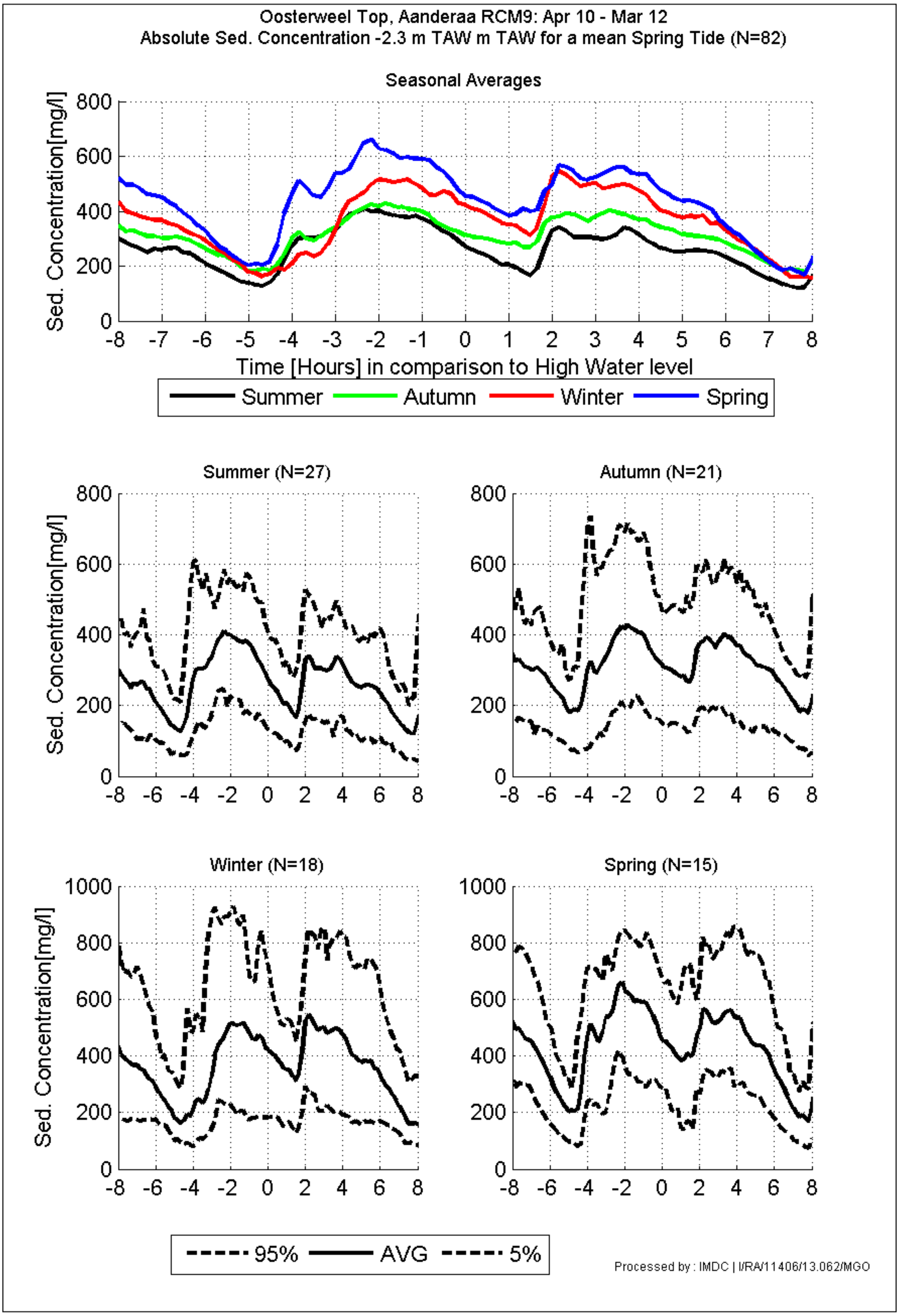
Annex-Figure F-16: Buoy 84 (-5.6m TAW), April 2010 – March 2012. Averaged-tidal curve of the suspended sediment concentration for an averaged spring tide.



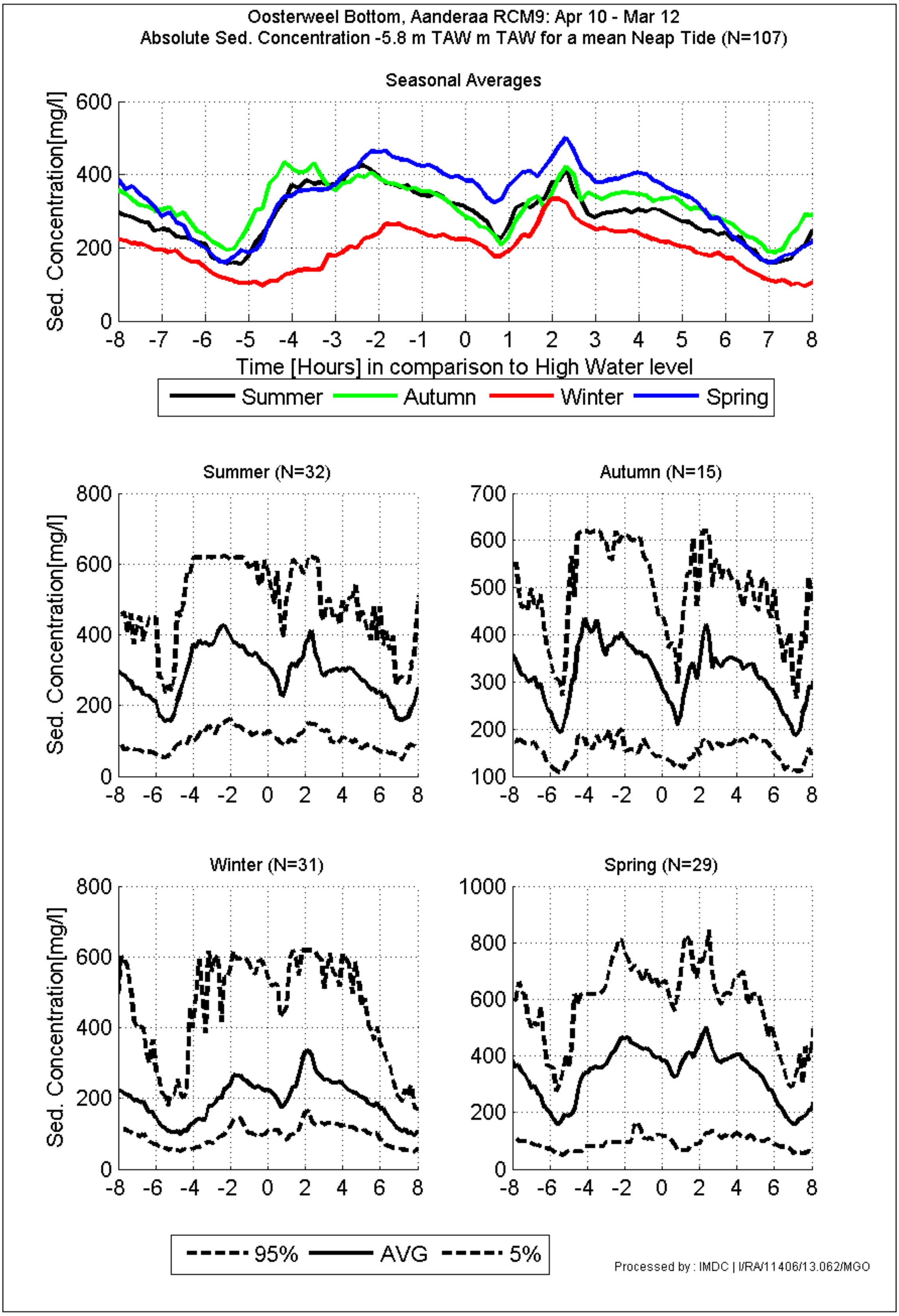
Annex-Figure F-17: Oosterweel (-2.3m TAW), April 2010 – March 2012, Averaged-tidal curve of the suspended sediment concentration for an averaged neap tide.



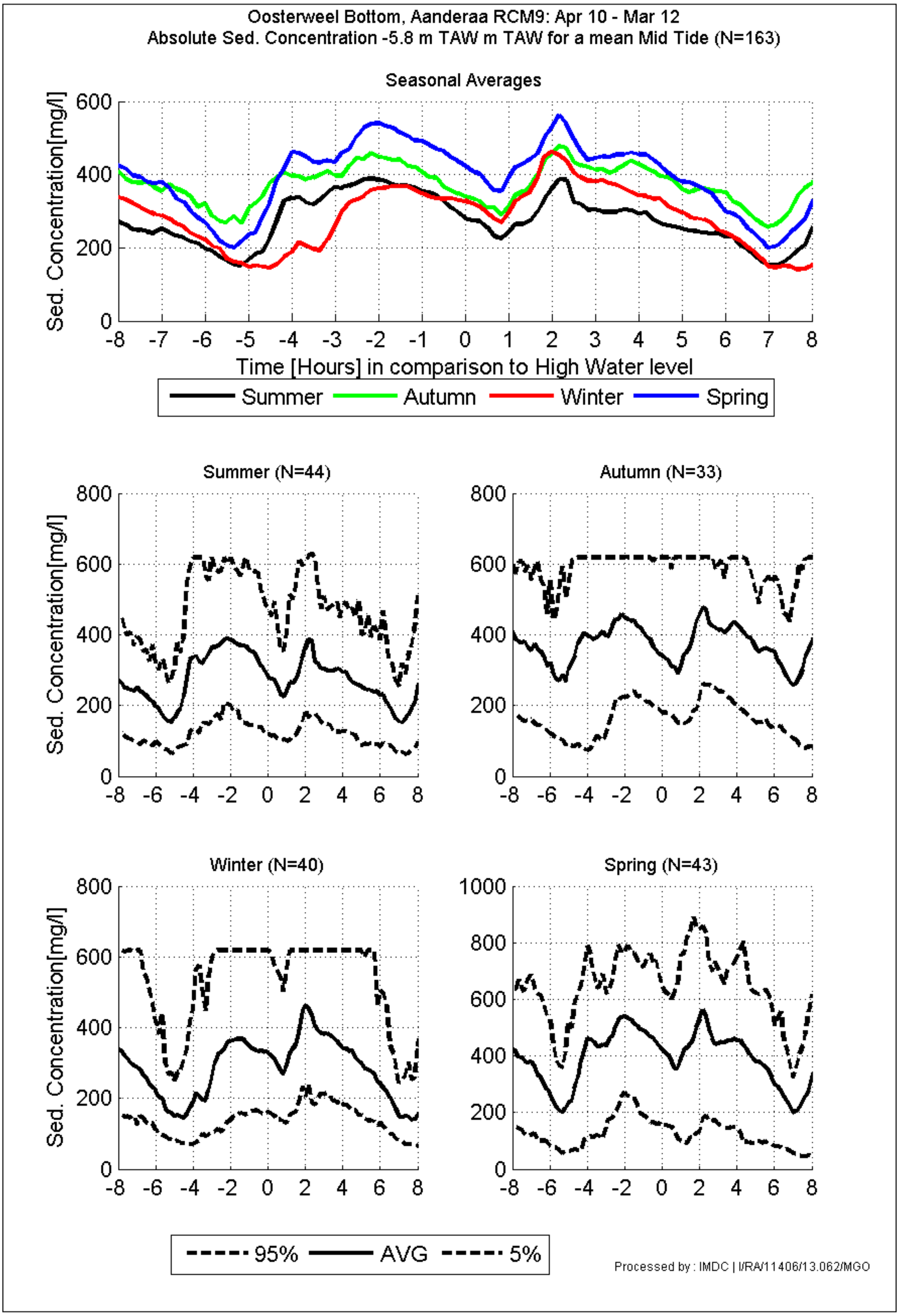
Annex-Figure F-18: Oosterweel (-2.3m TAW), April 2010 – March 2012. Averaged-tidal curve of the suspended sediment concentration for an averaged mean tide.



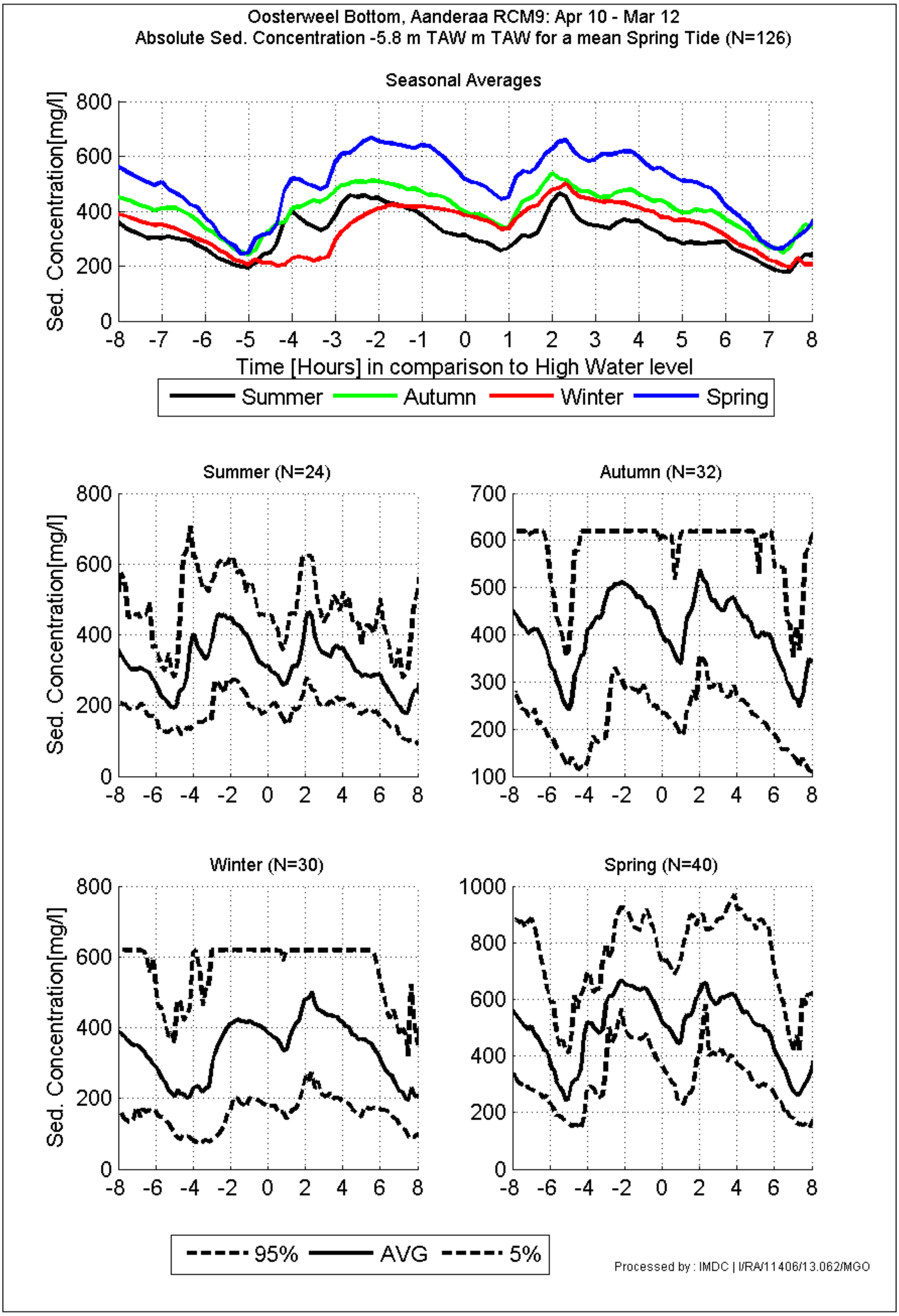
Annex-Figure F-19: Oosterweel (-2.3m TAW), April 2010 – March 2012. Averaged-tidal curve of the suspended sediment concentration for an averaged spring tide.



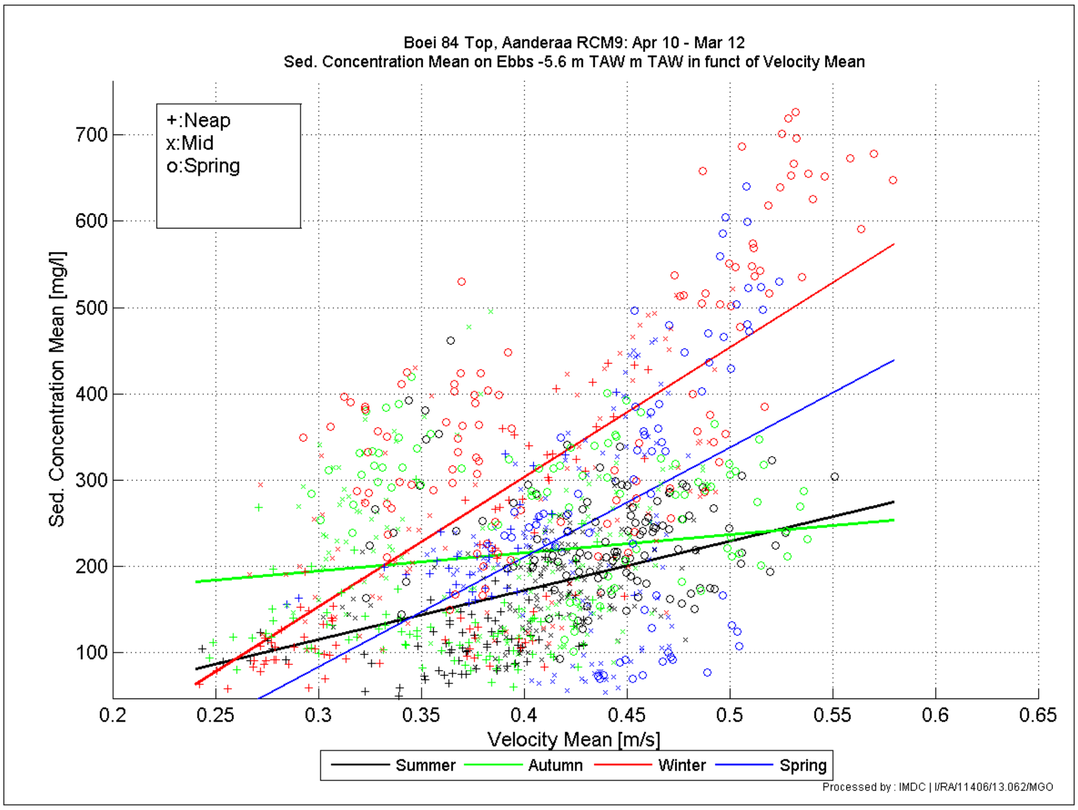
Annex-Figure F-20: Oosterweel (-5.8m TAW), April 2010 – March 2012. Averaged-tidal curve of the suspended sediment concentration for an averaged neap tide.

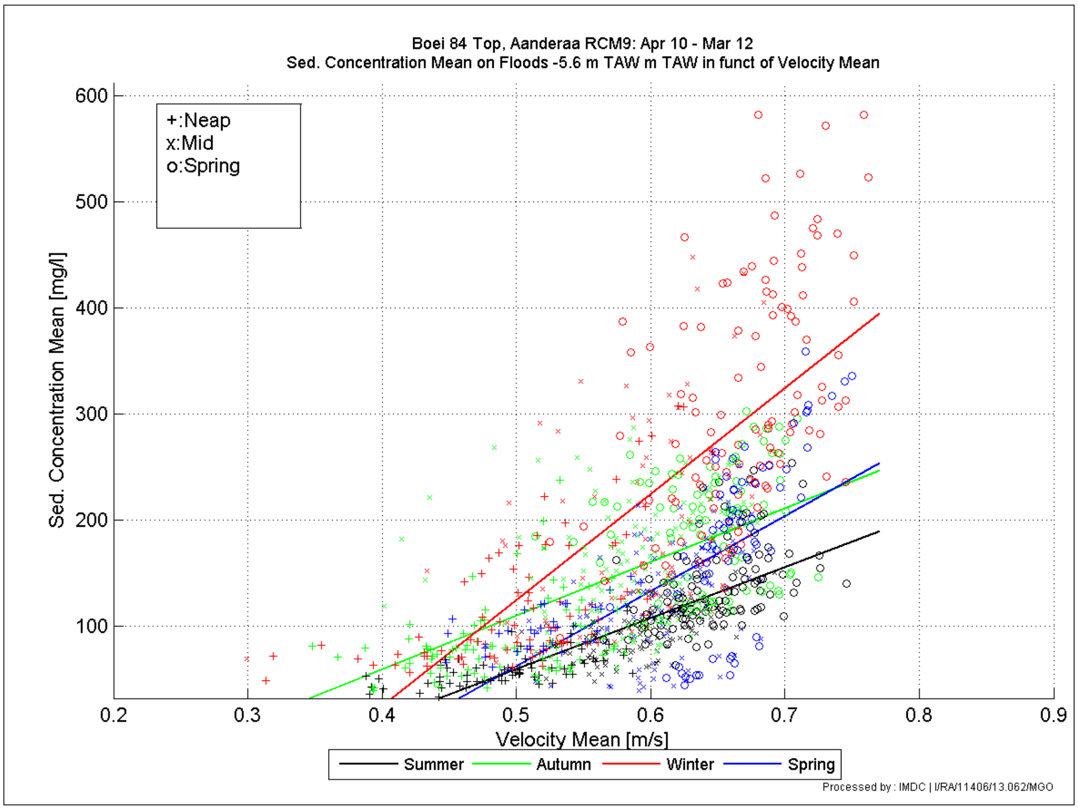


Annex-Figure F-21: Oosterweel (-5.8m TAW), April 2010 – March 2012. Averaged-tidal curve of the suspended sediment concentration for an averaged mean tide.

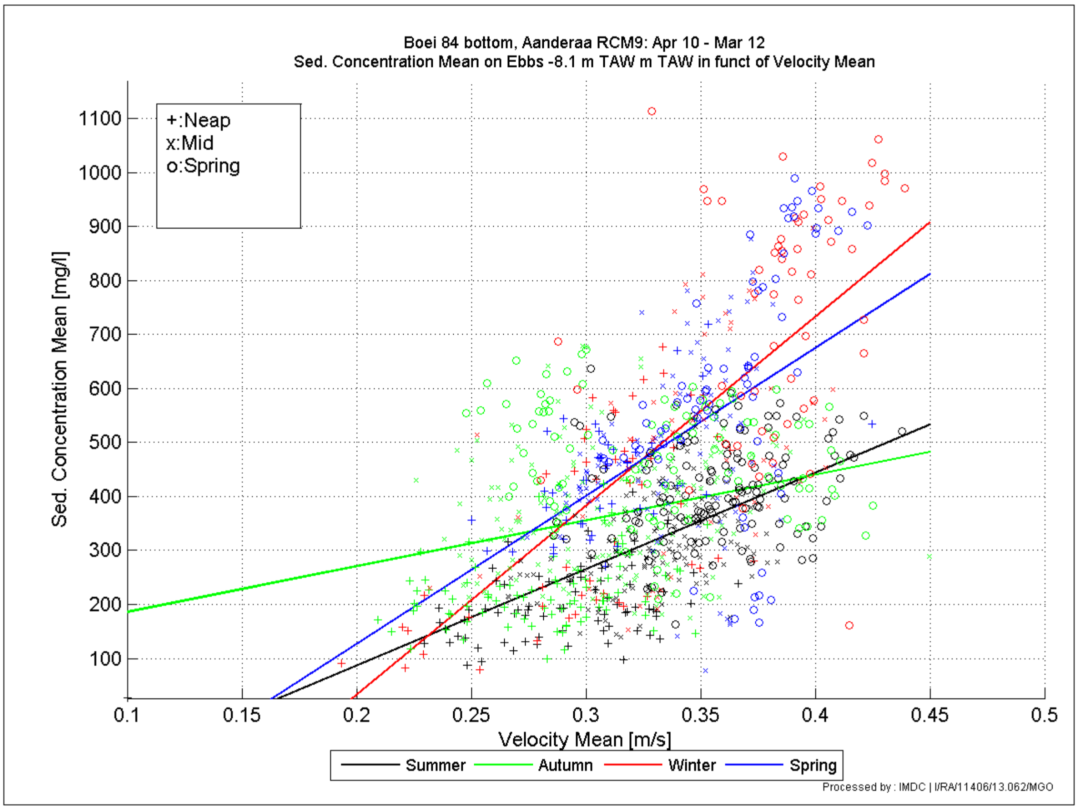


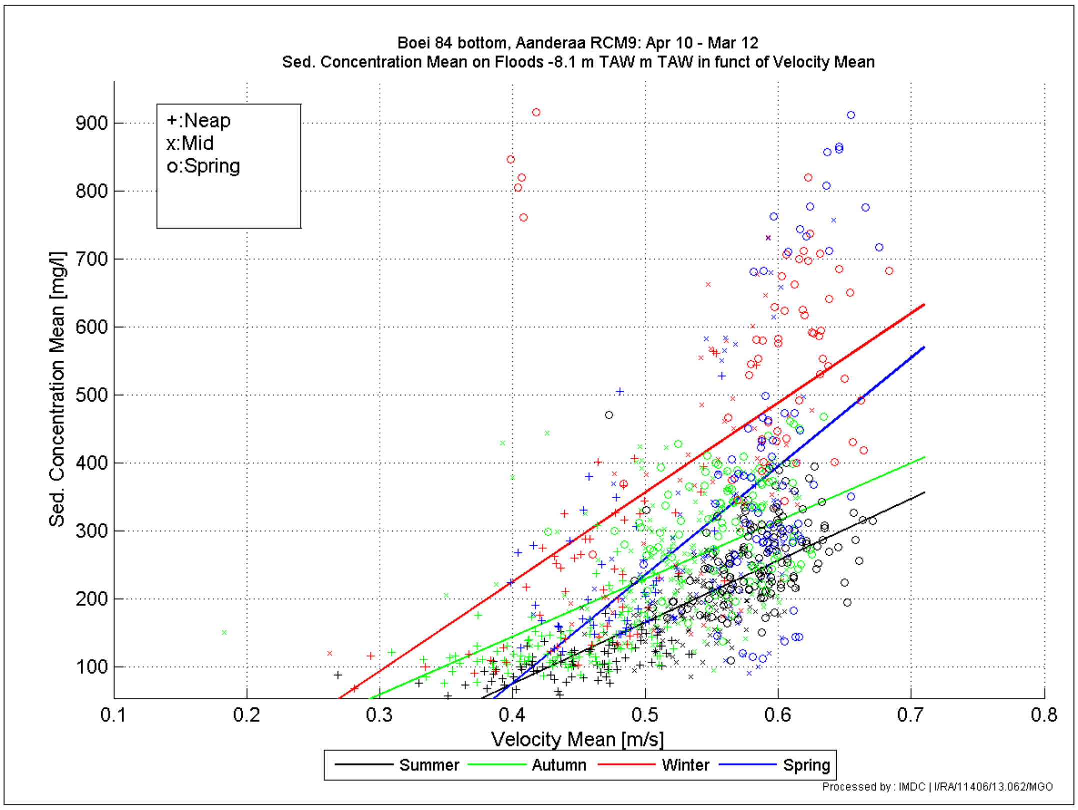
Annex-Figure F-22: Oosterweel (-5.8m TAW), April 2010 – March 2012. Averaged-tidal curve of the suspended sediment concentration for an averaged spring tide.



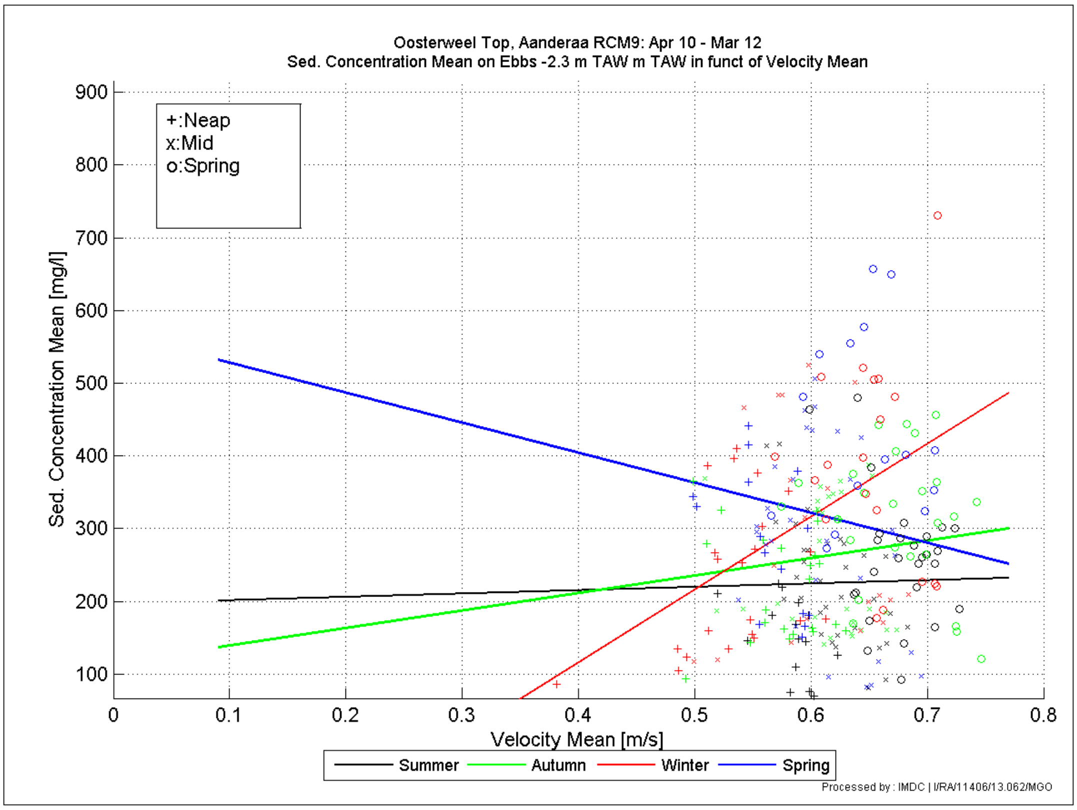


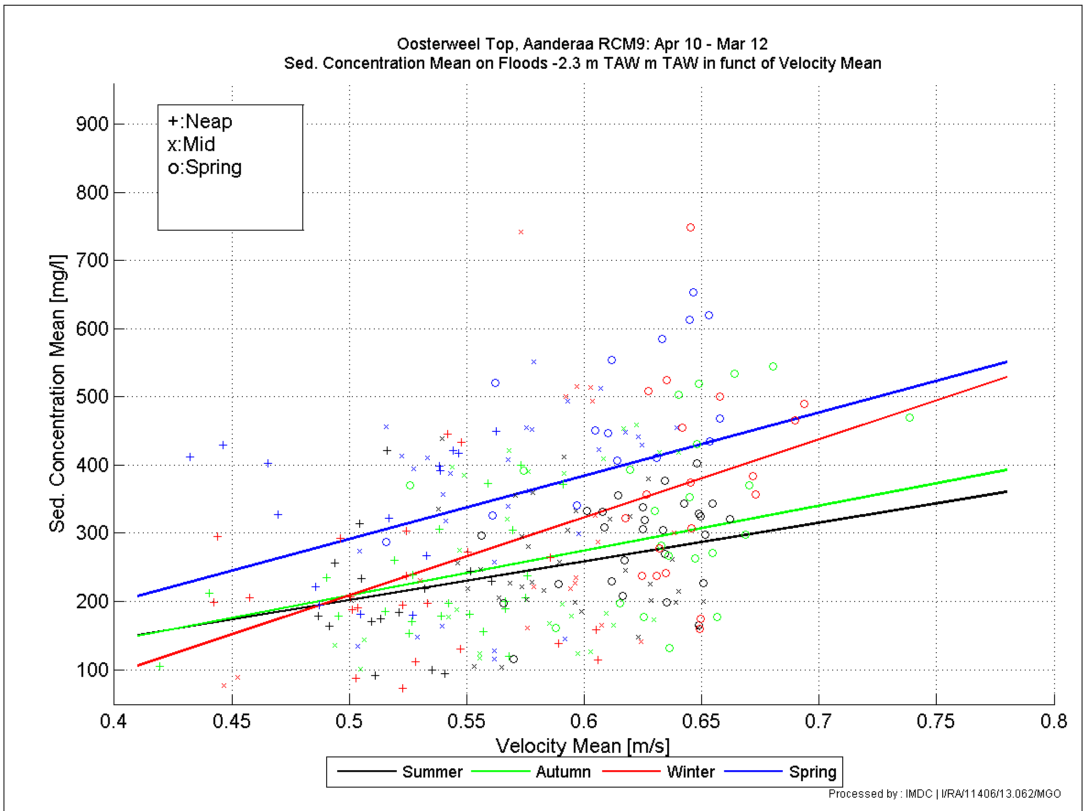
Annex-Figure F-23: Buoy 84 (-5.6m TAW). Ebb phase (R = 0.42; sig = 0.00; n = 1095) and flood phase (R = 0.59; sig = 0.00; n = 1094) average suspended sediment concentration vs. flow velocity.



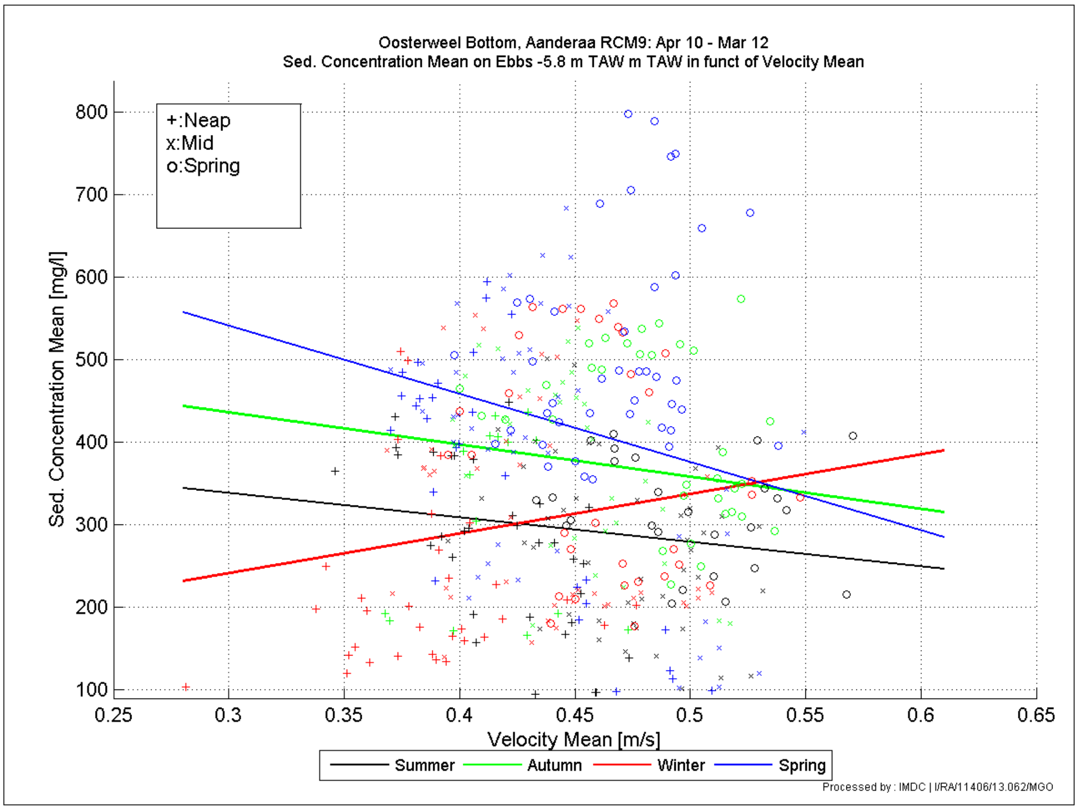


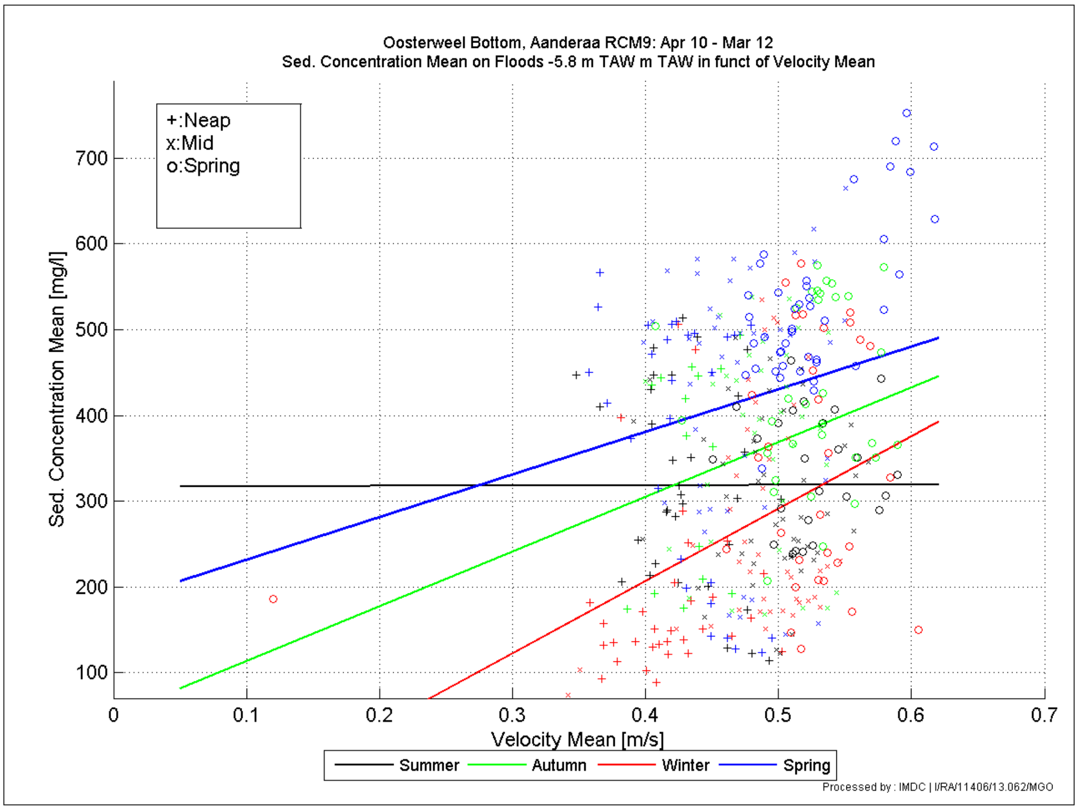
Annex-Figure F-24: Buoy 84 (-8.1m TAW). Ebb phase (R = 0.50; sig = 0.00; n = 1048) and flood 0phase (R = 0.51; sig = 0.00; n = 1045) average suspended sediment concentration vs. flow velocity.



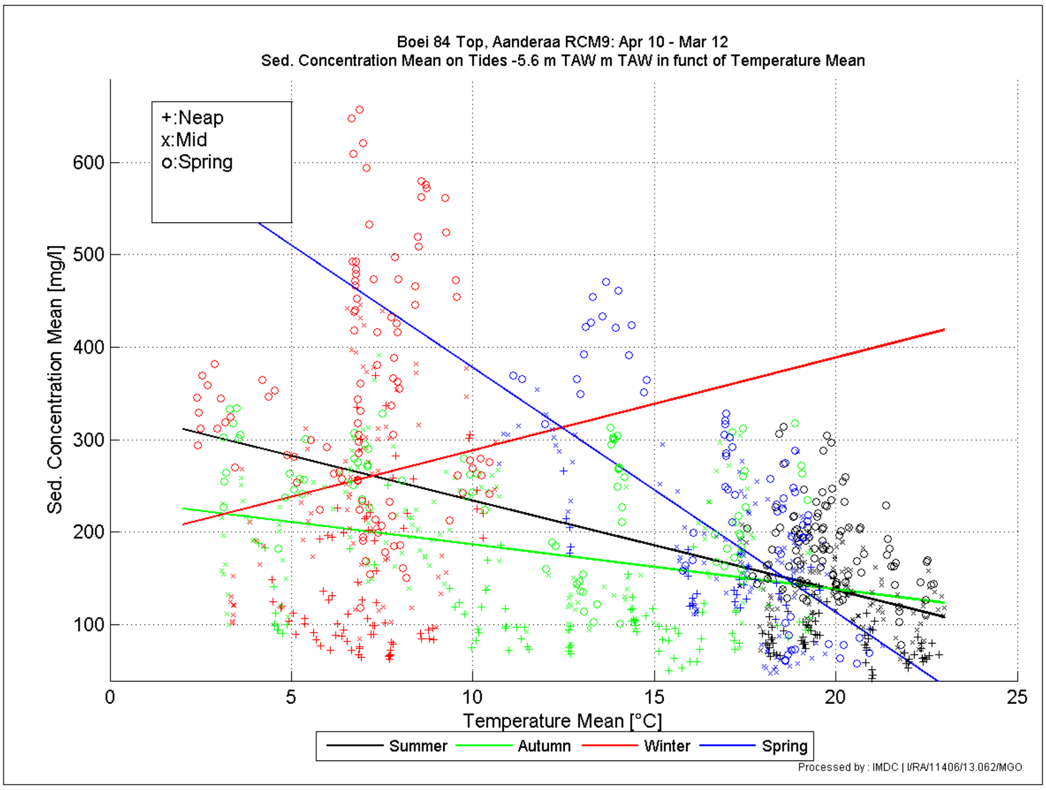


Annex-Figure F-25: Oosterweel (-2.3m TAW). Ebb phase (R = 0.08; sig = 0.09; n = 432) and flood phase (R = 0.31; sig = 0.00; n = 441) average suspended sediment concentration vs. flow velocity.

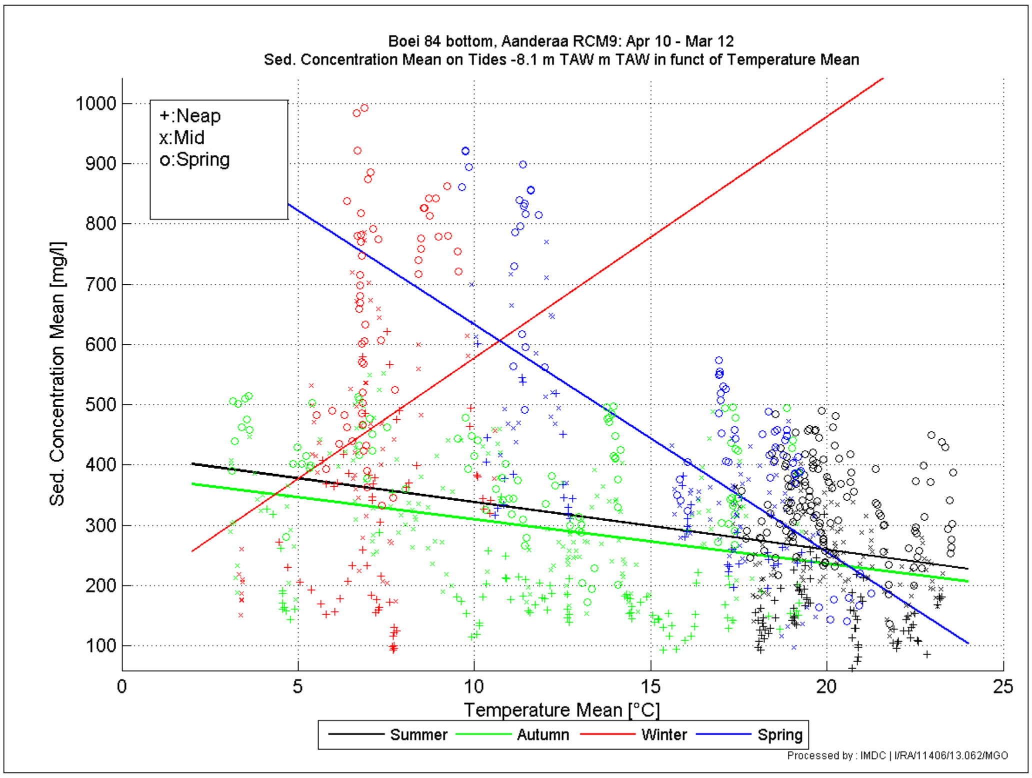




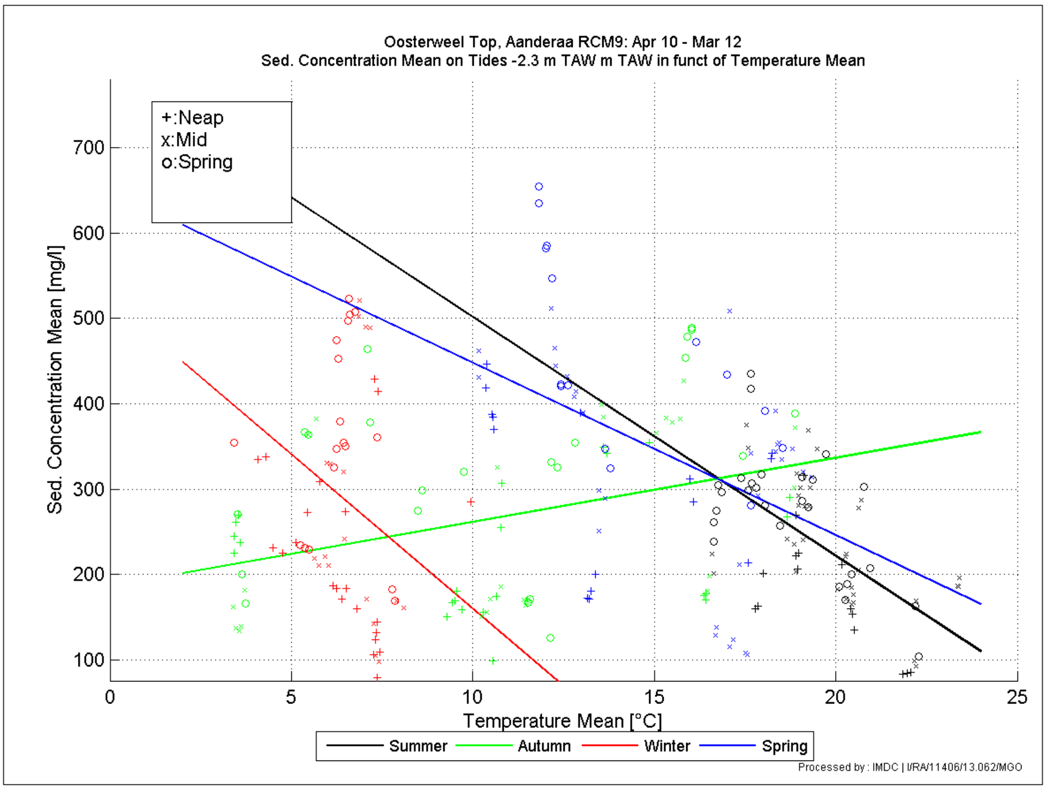
Annex-Figure F-26: Oosterweel (-5.8m TAW). Ebb phase (R = -0.08; sig = 0.08; n = 557) and flood phase (R = 0.21; sig = 0.00; n = 577) average suspended sediment concentration vs. flow velocity.



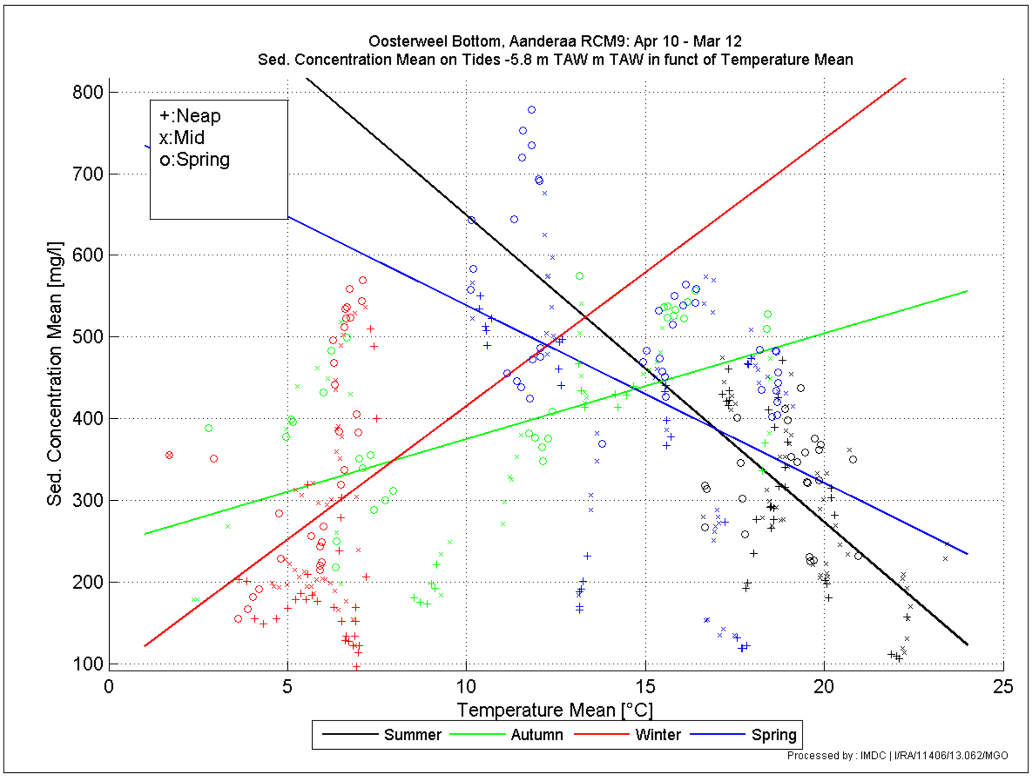
Annex-Figure F-27: Buoy 84 (-5.6m TAW) Tidal-average sediment concentration vs. temperature (R = -0.42; sig = 0.00; n = 1041).



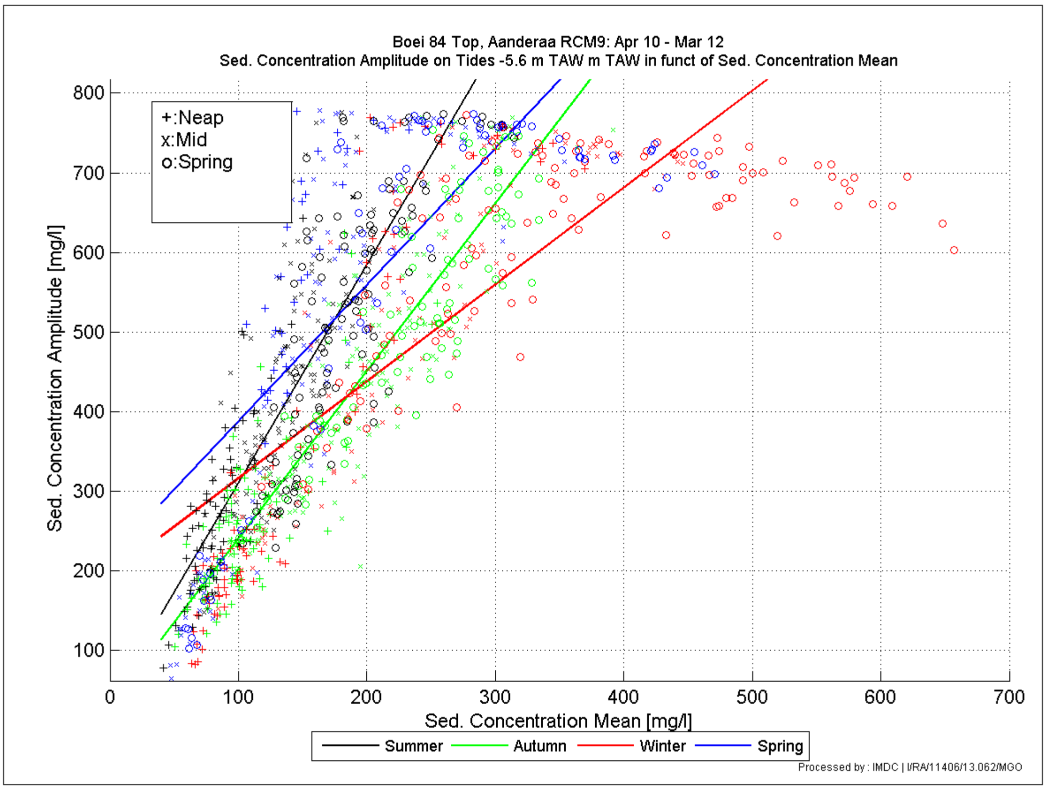
Annex-Figure F-28: Buoy 84 (-8.1m TAW). Tidal-average sediment concentration vs. temperature (R = -0.38; sig = 0.00; n = 1028).



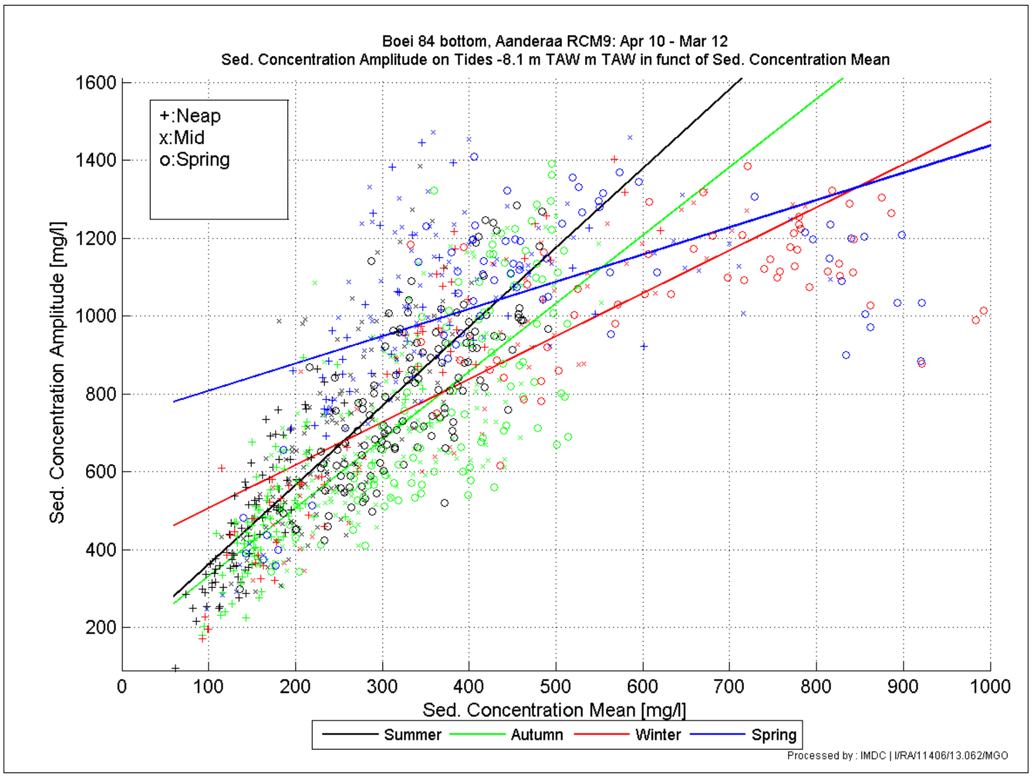
Annex-Figure F-29: Oosterweel (-2.3m TAW). Tidal average sediment concentration vs. temperature (R = -0.14; sig = 0.02; n = 275).



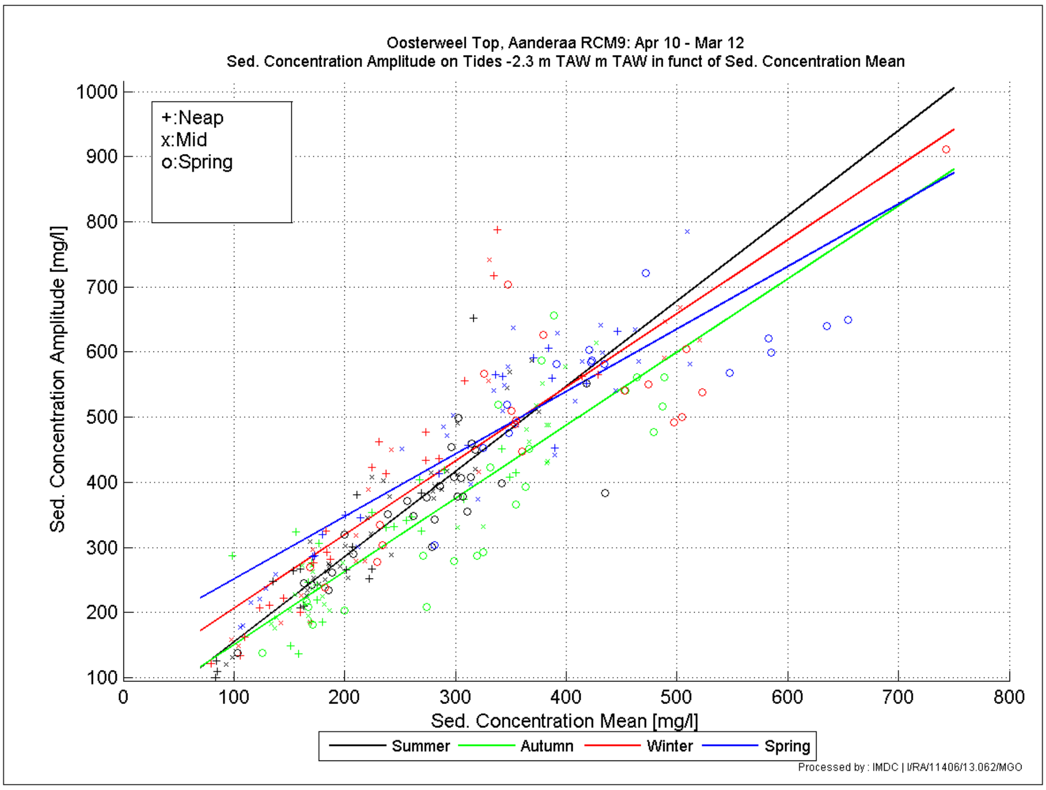
Annex-Figure F-30: Oosterweel (-5.8m TAW). Tidal average sediment concentration vs. temperature (R = 0.06; sig = 0.20; n = 414).



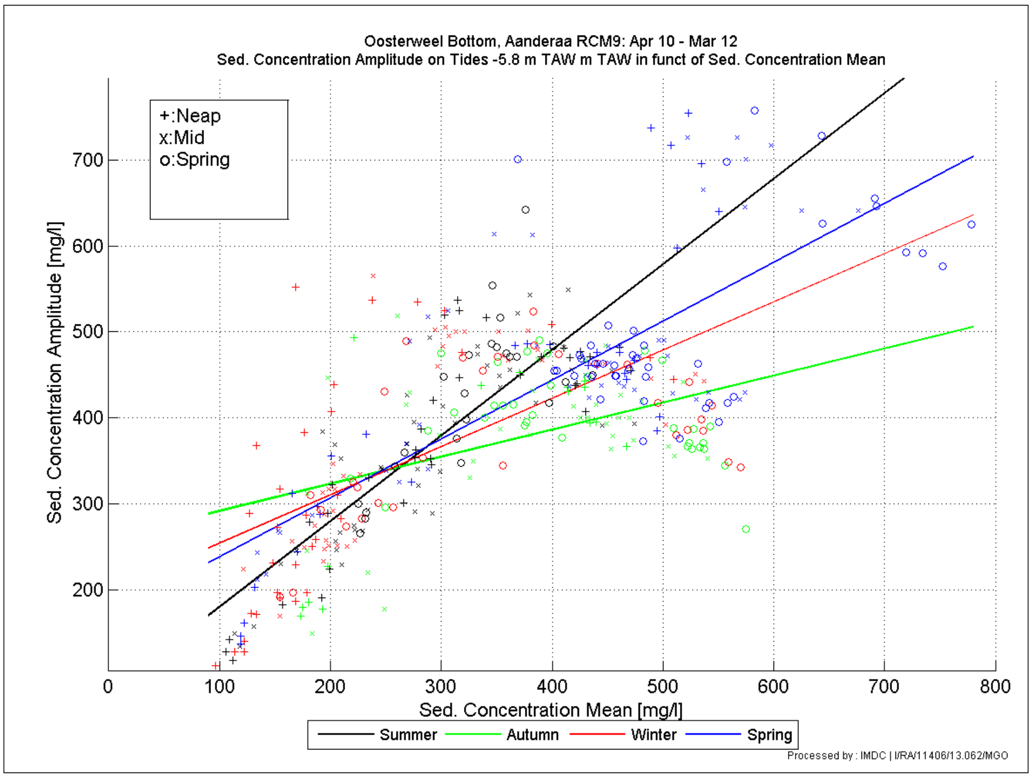
Annex-Figure F-31: Buoy 84 (-5.6m TAW). Sediment concentration amplitude vs. sediment concentration mean (R = 0.77; sig = 0.00; n = 1077).



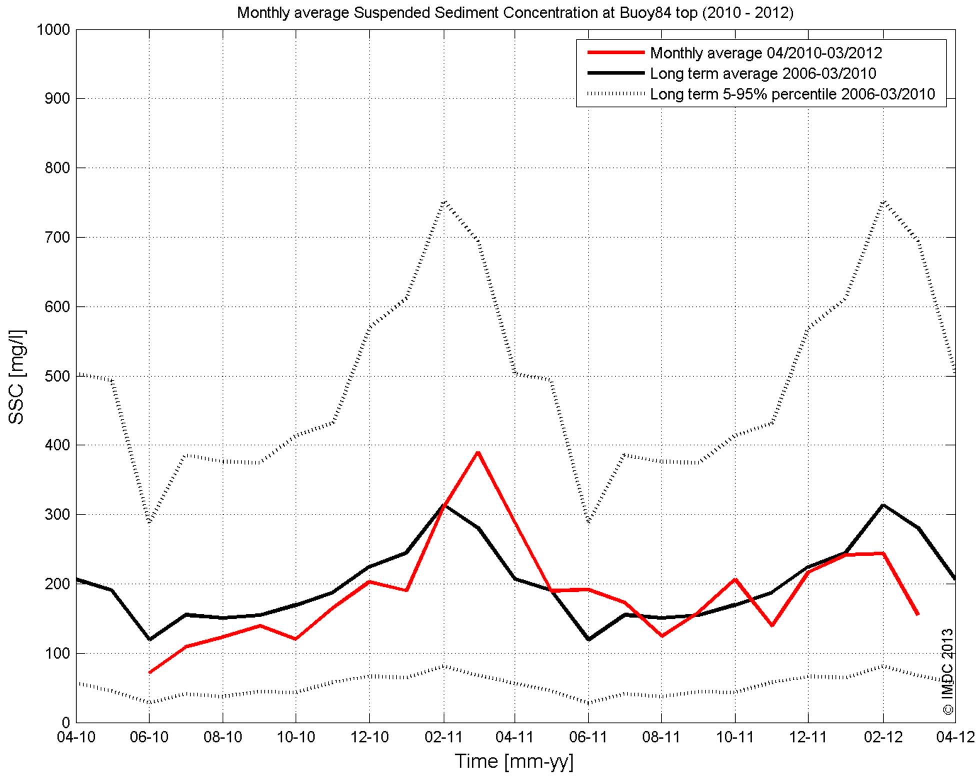
Annex-Figure F-32: Buoy 84 (-8.1m TAW). Sediment concentration amplitude vs. sediment concentration mean (R = 0.75; sig = 0.00; n = 1031).

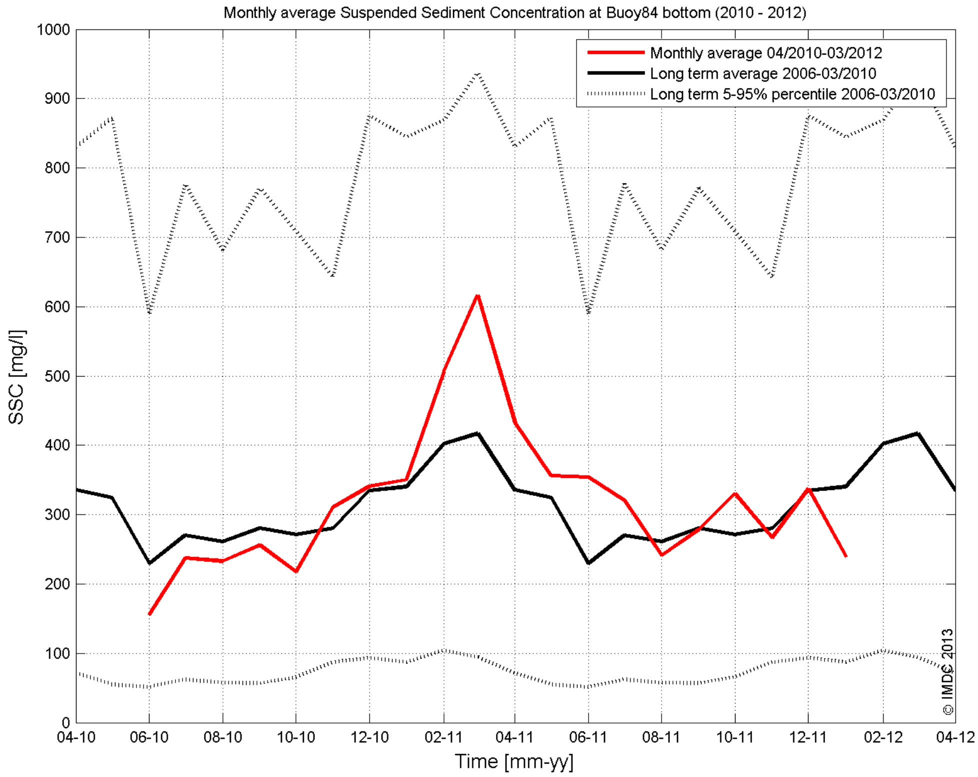


Annex-Figure F-33: Oosterweel (-2.3m TAW). Sediment concentration amplitude vs. sediment concentration mean (R = 0.88; sig = 0.00; n = 275).

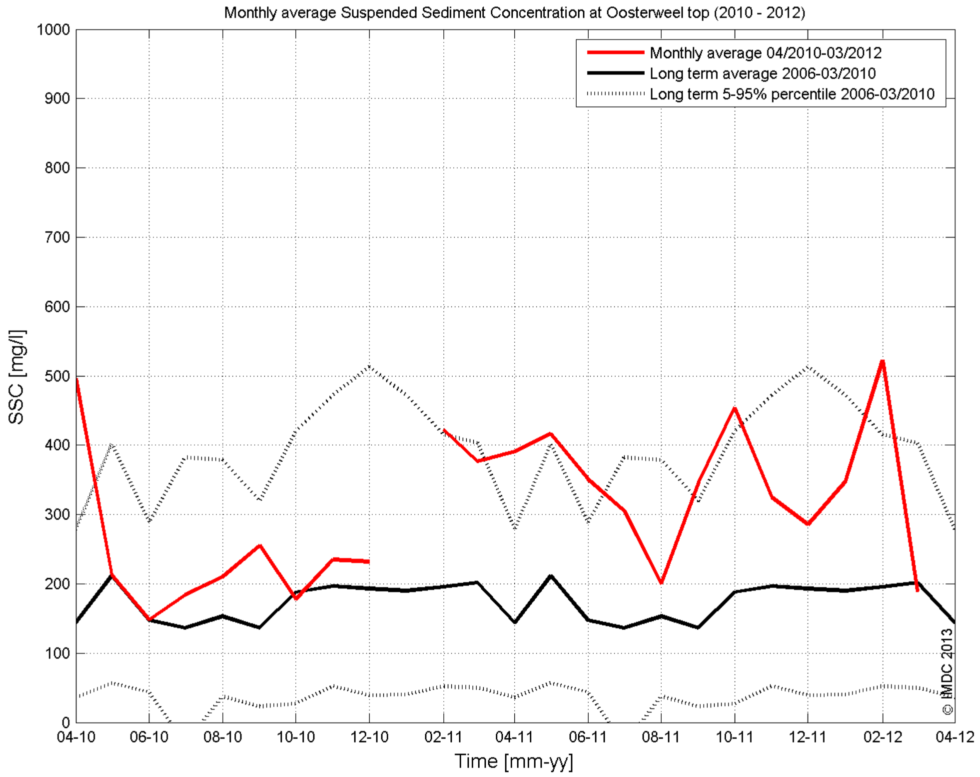


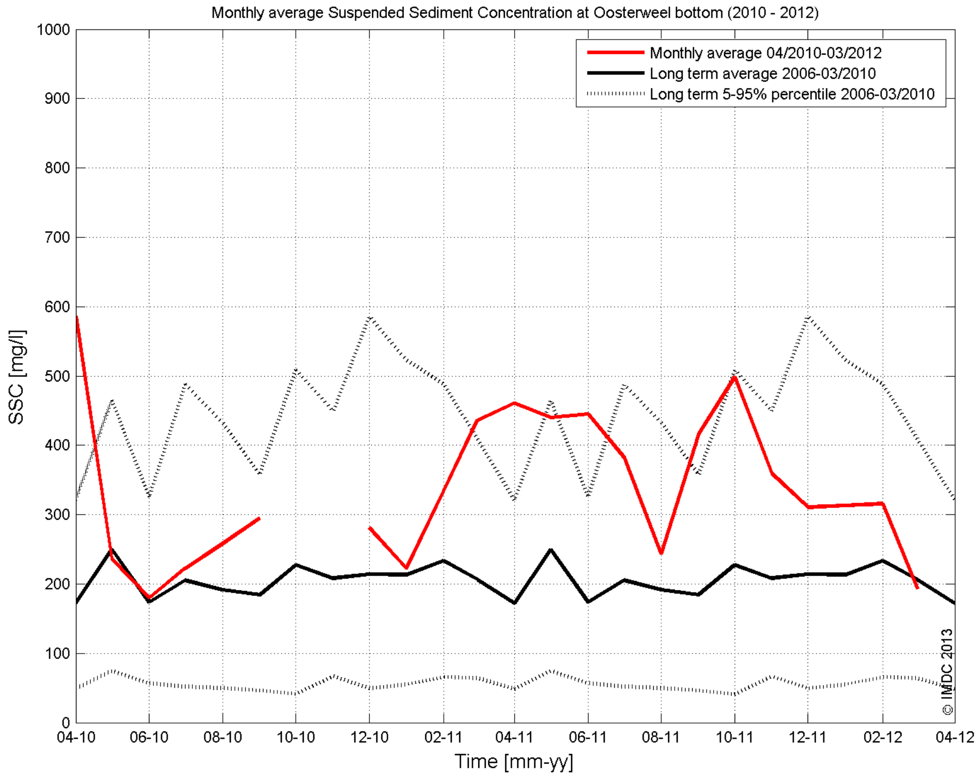
Annex-Figure F-34: Oosterweel (-5.8m TAW). Sediment concentration amplitude vs. sediment concentration mean (R = 0.71; sig = 0.00; n = 414).



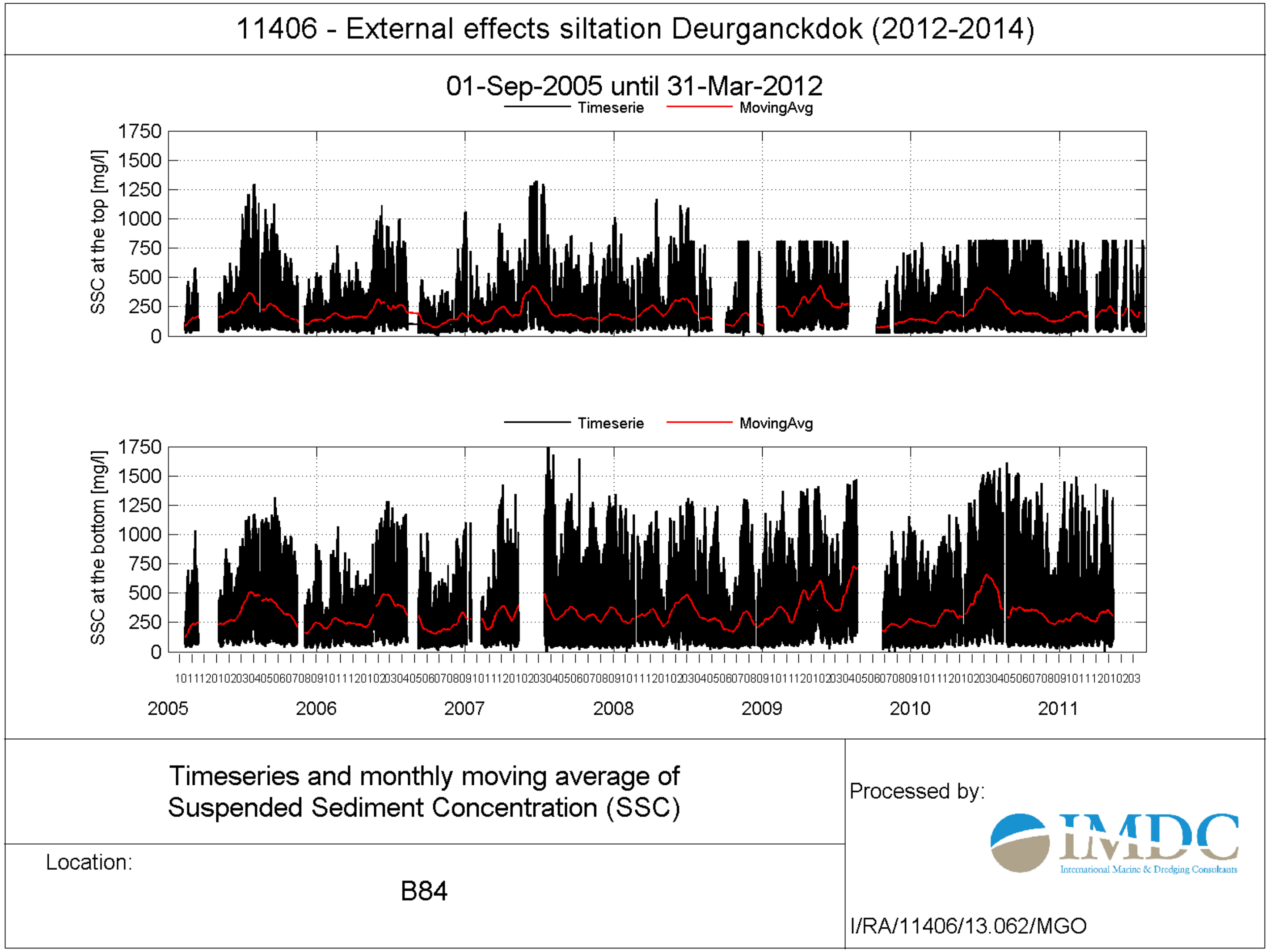


Annex-Figure F-35: The monthly average sediment concentration of Buoy 84 (a) top and (b) bottom between April 2010 – March 2012 and 2006 – March 2010 including the monthly 5/95%-percentiles for period 2006 – March 2010.

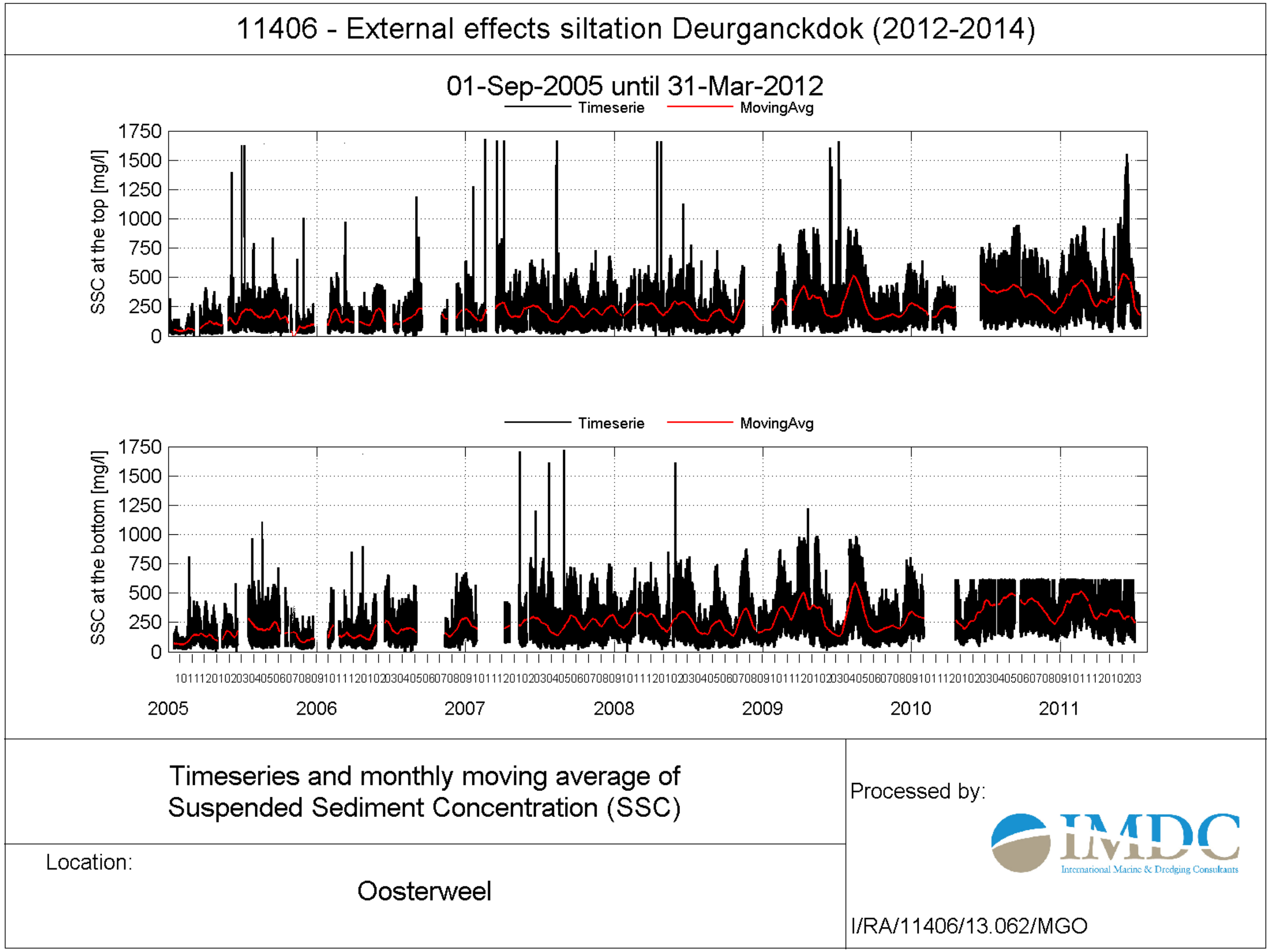




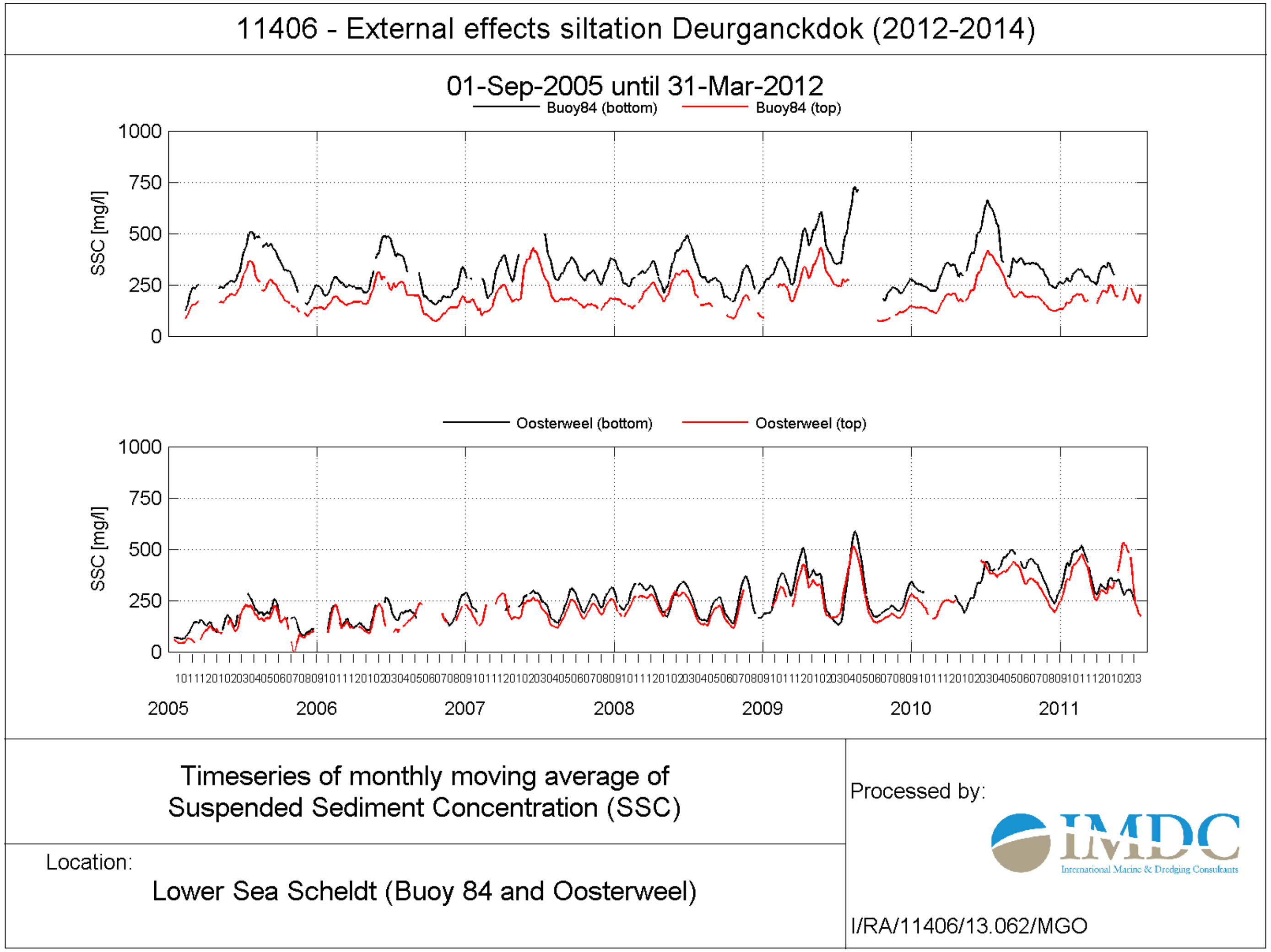
Annex-Figure F-36: The monthly average current velocity of Oosterweel (a) top and (b) bottom between April 2010 – March 2012 and 2006 – March 2010 including the monthly 5/95%-percentiles for period 2006 – March 2010.



Annex-Figure F-37: Time series and the monthly moving average of suspended sediment concentrations at both top and bottom sensor at buoy 84.



Annex-Figure F-38: Time series and monthly moving average of suspended sediment concentration at both top and bottom sensors at Oosterweel.



Annex-Figure F-39: Time series of monthly moving average of suspended sediment concentration at Buoy 84 and Oosterweel measurement locations.