ENVIRONMENTAL OBSERVATIONS

MANUAL

WAVE BUOY

Revision 6 – October 2021

These operating instructions (rev. 6) describe functionality according to firmware version 3.4 used in equipment manufactured as of June 2021.

We reserve the right to make technical changes and improvements without notice.

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NOTICE: When opening the Wave Buoy housing, ALWAYS ensure that the instrument is completely dry, and no water can enter the housing! Opening the housing and working with the control panel may only be done in a dry and clean environment. When handling the Wave Buoy in an offshore environment, never open the housing on deck!

NOTICE: The data display on the Obscape Data Portal is sourced directly from automatic monitoring equipment (i.e a Obscape Wave Buoy). It is not reviewed or passed through quality control. You should not rely on the raw information/data for any purpose whatsoever. NOT FOR NAVIGATION. Please refer to our Legal Section.

THE OBSCAPE WAVE BUOY IS A PRODUCT OF OBSCAPE B.V.

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OBSCAPE WAVE BUOY
Setting a new standard for wave measurements

Ocean wave measurements are an indispensable part of any MetOcean project. The Obscape Wave Buoy is based on recent advances in sensor and data technology, ensuring a light-weight, flexible, reliable and affordable wave buoy.

The Wave Buoy will suit your wave observation needs on any project, regardless of location and budget. Accurate wave data makes its way to your desktop in real-time through a robust telemetry solution. The Wave Buoy was designed to make your life easy: no receiver station needed, solar-powered, a simple mooring solution, deployable by hand and transportable as check-in luggage.

This manual describes all functions of the Obscape Wave Buoy in full detail. For any questions or suggestions that remain after reading this manual, do not hesitate to contact us at **support@obscape.com**.

1. SPECIFICATIONS

DATA SPECIFICATIONS	
WAVE SPECTRUM	Fully directional (Maximum Entropy Method)
BULK WAVE PARAMETERS	H_{m0}, H_{max}, T_p, T_{m01}, T_{m02}, T_{m-10}, T_{max}, Dir_p, Dir_m, σ_p, σ_m
DIAGNOSTIC PARAMETERS	Latitude, Longitude, Battery voltage, Solar panel voltage, Internal temperature, Signal strength
SAMPLE FREQUENCY	6.25 Hz
FILTERED FREQUENCY RANGE	0.05 Hz – 1.00 Hz (20 sec – 1 sec)
BURST DURATION	30 minutes
STORAGE	Data Portal & on-board micro SD card

WEB-PORTAL SPECIFICATIONS	
ONLINE GRAPHS	Bulk wave parameters & diagnostic parameters
DOWNLOADS	Bulk wave parameters, diagnostic parameters, 1D wave spectra, directional wave spectra (text files, png or pdf report)
FORWARDERS	JSON API or HTTP post
STATUS NOTIFICATION EMAILS	Online/offline, GPS watch circle, battery level, wave height threshold

PHYSICAL CHARACTERISTICS	
BUOY DIAMETER	500 mm
BUOY HEIGHT	350 mm
MOORING EYE INNER DIAMETER	15 mm
WEIGHT	17 kg
SAFETY SYSTEMS	Navigation light, GPS watch circle

FACTORS ADVERSELY AFFECTING OPERATION	
BREAKING WAVES	Reduced accuracy
STRONG CURRENTS > 0.5 M/S	Reduced accuracy
WATER DEPTH < 4 M	Reduced accuracy, risk of excessive mooring wear

ELECTRICAL CHARACTERISTICS	
SOLAR PANEL CAPACITY	6 W
BATTERY	18650 lithium battery
NOMINAL VOLTAGE	3.7 V

TELEMETRY SPECIFICATIONS	
COMMUNICATION MODES	Cellular (4G with 2G/3G fallback), Satellite (Iridium), Hybrid (Cellular with Satellite fallback)
REAL-TIME DATA INTERVAL	30 minutes – 24 hours (user selectable)
REAL-TIME WAVE DATA	Bulk wave parameters, compressed directional wave spectrum
CELLULAR DATA LOAD	10 kB per message (bulk parameters only) or 12 kB per message (bulk parameters & spectra)
SATELLITE DATA LOAD	1 credit per message (bulk parameters only) or 6 credits per message (bulk parameters & compressed spectra)

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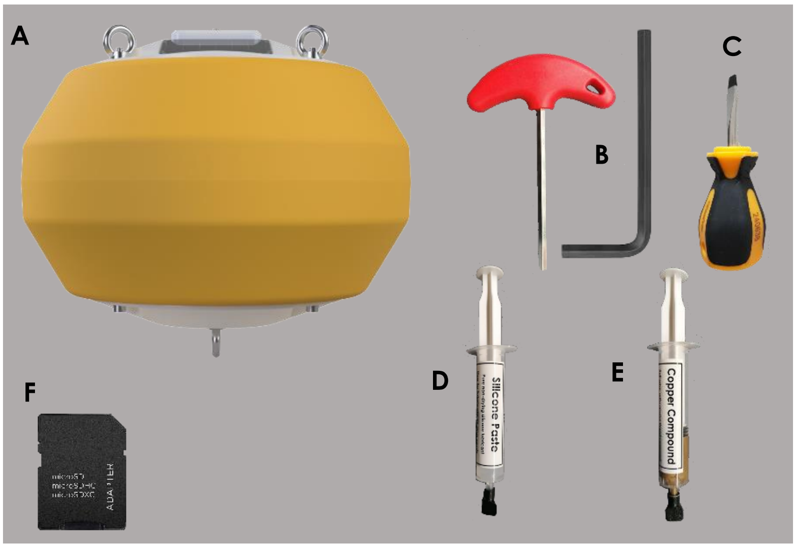
2. PARTS AND COMPONENTS

The following parts and components are included in the box (not to scale):



A. **Wave Buoy (with SD card and battery included inside)**
B. **Allen keys #5 and #8**
C. **Flat screw driver**
D. **Silicone paste**
E. **Copper compound**
F. **Adapter for micro SD card**

NOT INCLUDED (to be sourced by user):

- **SIM card**

3. WORKING PRINCIPLE

The Obscape Wave Buoy determines the directional wave spectrum by measuring its own three-dimensional displacements with the wave orbital motion. An Inertial Measurement Unit with 9 degrees of freedom (9DOF IMU) samples the accelerations of the Wave Buoy in Upward, Northward and Eastward direction. Double integration and subsequent filtering of the accelerations yields the displacements of the buoy. Every 30 minutes (the 'sampling interval'), the directional wave spectrum is calculated from the three-dimensional displacement timeseries using Welch's method [1] and the Maximum Entropy Method[2]. Bulk wave parameters are calculated from the directional wave spectrum using the appropriate standard methods[3].

The measurement and telemetry cycle of the Wave Buoy is visualised in Figure 1. The data sent to the server are the bulk wave parameters and (optionally) the directional wave spectrum. The

[1] Welch, P.D. (1967). The Use of Fast Fourier Transform for the Estimation of Power Spectra: A Method Based on Time Averaging Over Short, Modified Periodograms. *IEEE Transactions on Audio and Electroacoustics*, Vol. AU-15, No. 2, pp 70-73.
[2] Lygre, A. and Krogstad, H.E. (1986). Maximum Entropy Estimation of the Directional Distribution in Ocean Wave Spectra. *Journal of Physical Oceanography*, Vol. 16, No. 12, pp 2052-2060.
[3] Holthuijsen, L.H. (2007). Waves in Oceanic and Coastal Waters. *Cambridge University Press*. ISBN 9780511618536.

communication interval can be set by the user on the Data Portal (cellular communication mode, refer to Section 6.4) or in the SD settings file (satellite communication mode, refer to Section 6.6).

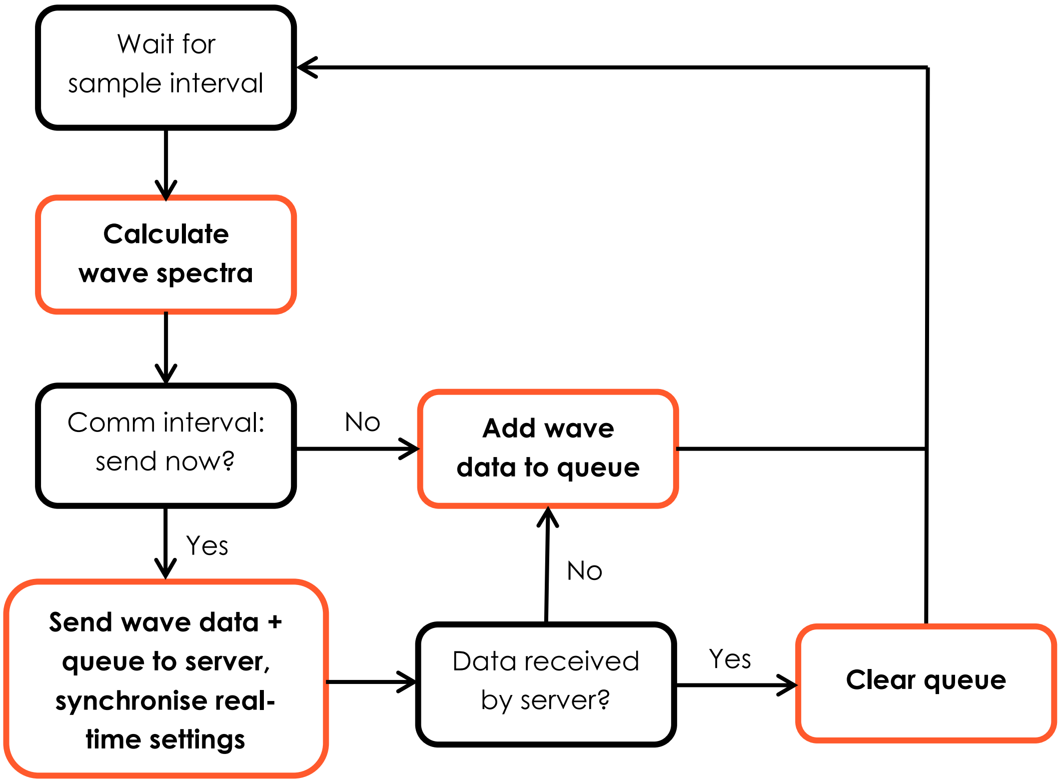


Figure 1: Measurement and telemetry cycle

4. COMMUNICATION MODES

The Wave Buoy is equipped with a cellular modem and a satellite modem. Based on these telemetry options, three different communication modes are supported: cellular communication, satellite communication and hybrid communication. These modes are explained in more detail in the next sections.

4.1. CELLULAR COMMUNICATION

The cellular modem inside the Wave Buoy communicates on the 4G, 3G and 2G cellular networks. The cellular connection is managed and paid for by the user. It is up to the user to arrange a valid SIM card with sufficient credit throughout the measurement period.

The Wave Buoy will only be able to use cellular communication if it is deployed within range of a cellular network. Since cell towers are usually only placed on land, this means that cellular communication is only viable if the Wave Buoy is deployed within several kilometres from the shore. Most cellular network providers publish approximate coverage maps on their website, which enables you to check network coverage at the deployment location prior to the deployment itself.

Periodic costs for cellular communication are significantly lower than periodic costs for satellite communication. The actual costs will depend on the rates used by your selected provider. When sending real-time wave spectra, the Wave Buoy will consume approximately 15 MB/month. Without real-time spectra, the data rate will be approximately 12 MB/month.

4.2. SATELLITE COMMUNICATION

The satellite modem inside the Wave Buoy connects to the Iridium network. This connection is managed by Obscape. You will receive quarterly invoices from Obscape based on your actual satellite data usage over the preceding quarter.

The Iridium network provides global coverage, which means that your Wave Buoy will be able to send its data in real-time from anywhere around the world. This global connectivity comes at a price. Satellite communication costs are split into two parts: line rental and data transmission costs. Line rental can be purchased at the Obscape Data Portal at a rate of €14 per month. Data transmission costs are charged at a rate of €0.05 per credit. Each transmission of bulk wave parameters consumes 1 credit, while transmission of (compressed) wave spectra consumes another 5 credits.

At a 30-minute communication interval, the Wave Buoy will therefore consume 1 credit (bulk parameters only) or 6 credits (bulk parameters and real-time spectra) per 30 minutes. For a period of 1 month (30 days), this totals to €14 + 30 days x 24 hours/day x 2 credits/hour x €0.05 per credit = €86 per month if no real-time spectra are sent. Including real-time spectra, the monthly costs are €14 + 30 days x 24 hours/day x 12 credits/hour x €0.05 per credit = €446 per month.

Real-time wave spectra transmitted over satellite communication are compressed to 25 frequency bins. The nature of the Iridium network does not allow for the transmission of higher resolution spectra.

4.3. HYBRID COMMUNICATION

Since cellular communication and satellite communication each have their advantages and disadvantages, the Wave Buoy has been equipped with a hybrid communication mode that combines the best of both worlds. It first tries to send out the wave data using the cellular modem, but switches to the satellite modem if it cannot connect to the cellular network. The hybrid communication mode will use the cellular network whenever possible, but uses satellite transmission as a backup to avoid having no real-time data at all.

Despite combining the best of both worlds, the hybrid communication mode also comes with two minor disadvantages:

- It is difficult to estimate data transmission costs in advance, since they will strongly depend on cellular network connectivity at the deployment location. In case cellular connectivity turns out to be largely absent, data transmission costs will be equal to exclusive satellite communication.
- Sending real-time wave spectra potentially becomes very expensive. Over cellular communication, the additional costs of real-time wave spectra are very small, but if the buoy needs to fall back to satellite communication regularly, high satellite transmission costs will be charged. Furthermore, real-time wave spectra are compressed to 25 frequency bins in hybrid communication mode, regardless of the a data burst being sent over cellular or satellite communication.

4.4. OVERVIEW

The overview in Table 1 lists the advantages and disadvantages of the three communication modes.

Table 1: Overview of communication modes

Cellular communication	Satelllite communication	Hybrid communication
Low transmission costs	Global connectivity	Global connectivity
High-resolution wave spectra	Ready to use (managed through data portal)	Cellular when possible, satellite when needed
Only connects within range of cellular network	High transmission costs	Potentially high transmission costs
User needs to arrange SIM card	High additional costs for real-time spectra	Potentially high additional costs for real-time spectra
	Low-resolution wave spectra	Low-resolution wave spectra

5. QUICK START GUIDE

1. **Construct mooring** (refer to Chapter 8)
   Can alternatively be purchased at Obscape.
2. **Open the housing** (refer to Section 6.1)
   Unscrew the 3 eye bolts. Lift the white top disc and turn upside-down. Unscrew the 2 steel hexagonal bolts. Lift off the back panel.
3. **Create Data Portal account** (refer to Section 6.3)
   Click on the link in the account invitation email.
4. **Log onto Data Portal** (refer to Section 6.3)
   Navigate to https://www.obscape.com/portal and log in.
5. **Activate device** (refer to Section 6.3)
   Navigate to the Devices page and insert the activation code.
6. **Create station** (refer to Section 6.3 and the Obscape Data Portal manual)
   Create a new station on the Map page and couple the device. Check out the Quick Start Tutorial movie on the Support page for more detailed instructions.
7. **(Cellular communication only) Real-time settings** (refer to Section 6.4)
   Review and adjust real-time device settings on the Data Portal. On the Map page, click on the newly created station and then click the Settings button.
8. **(Satellite communication only) Activate satellite line rental** (refer to Section 6.5)
   Activate satellite line rental on the Satellite communication page.
9. **SD settings** (refer to Section 6.6)
   Review and adjust the settings file on the SD card.
10. **(Cellular communication only) Insert SIM card** (refer to Section 6.7)
    Insert a micro SIM card into the SIM slot. Ensure the SIM card has internet access.
11. **Start measurement** (refer to Section 6.8)
    Press the power button and wait for the system test to complete successfully. For satellite communication, this must be done under open skies.
12. **Close the housing** (refer to Section 6.10)
    Lubricate the rubber O-ring, put the pack panel in place and apply the 2 bolts. Place the white top disc onto the yellow float and tighten the eye bolts. Apply the split pins. Flip the bottom disc of the buoy in case it was mounted upside-down for transportation.
13. **Monitor data connection** (refer to Section 6.8)
    Keep the Wave Buoy running overnight to verify stable data transmission.
14. **Deploy your Wave Buoy** (refer to Section 6.11)
    Connect the mooring to the buoy and deploy it at your preferred location.

6. GETTING READY TO MEASURE

This chapter describes the steps required to get the Wave Buoy ready to measure.

6.1. OPENING THE HOUSING

NOTICE: Before opening the housing, ensure that the housing is dry and there is no risk of water or dirt entering the opened housing. Water or dirt can cause severe damage to the Wave Buoy electronics!

NOTICE: Do not remove the three steel star screws in the triangular centre part of the top cap!

Remove the split pins from the three steel eye bolts on the top side of the buoy. Then, unscrew the eye bolts (e.g. by using the flat screw driver from the tool kit as a lever arm). Lift the white top disk out of the buoy. Now, unscrew the two steel hexagonal bolts using the #5 allen key from the tool kit (Figure 2, left). Finally, insert the flat screw driver from the tool kit into the grooves on both side edges of the back panel and rotate the screw driver b 90 degrees. Once the back panel has lifted a bit, it can be taken off by hand (Figure 2, right). Alternatively, in case the back panel has 2 blind bolt holes, you can insert the steel hexagonal bolts into these blind bolt holes in order to jack up the back panel and then remove it by hand.

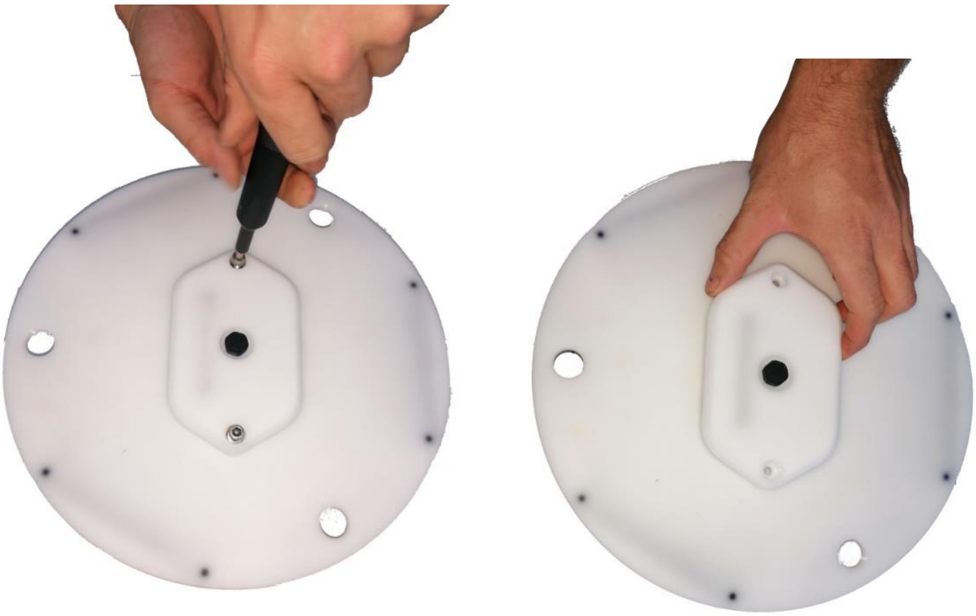


Figure 2: Unscrewing steel bolts (left), removing back panel (right).

Once the back panel has been removed, the control panel of the Wave Buoy is revealed (Figure 3).

A. Power button
B. Status LED
C. SIM card slot
D. SD card slot
E. OLED display
F. Lithium-ion battery
G. USB socket (do not use)

Figure 3: Control panel

6.2. INSERTING AND CHARGING THE BATTERY

The Wave Buoy is powered by 3 solar panels with a total capacity of 6W and a single lithium-ion 18650 rechargeable battery. If your Wave Buoy did not come with the battery included, it must be sourced by you. The battery should fulfil the following requirements:

- 18650 lithium-ion battery
- Minimum capacity 2500 mAh
- Button-top (i.e. with the metal 'button' on the positive battery terminal, as opposed to a flat-top battery that has 2 flat terminals)

To insert the battery, place it into the holder, acknowledging the battery polarity indicated on the device (positive battery terminal pointing towards the top side of the control panel). **Inserting the battery in the wrong orientation may result in the battery catching fire or exploding!**

Figure 4: Button-top 18650 lithium-ion battery

Most likely, the battery is not fully charged yet. The Wave Buoy requires a battery voltage of 3.8V or higher in order to complete its start-up sequence (Section 6.8). You can easily check if the battery voltage is below 3.8V, either with a multimeter or by powering up the device and seeing if the 'Battery voltage too low' error code is issued. If the battery voltage is below 3.8V, the battery must first be charged by placing the device with inserted battery in direct sunlight. In order to charge, the device can remain powered off. The charging circuit will always remain active. A drained battery is expected to charge to 3.8V within 2 to 3 hours, provided that the device receives direct sunlight.

6.3. ACTIVATING THE DEVICE ON THE OBSCAPE DATA PORTAL

The Wave Buoy sends its real-time data straight to the Obscape Data Portal. This online environment allows you to view, analyse, and download real-time data from all your Obscape devices. Furthermore, the devices and their real-time settings can be managed from the portal. All functions of the Data Portal are described in full detail in the Data Portal manual. This Wave Buoy manual will only treat the steps that are necessary to get started.

Prior to receiving your Wave Buoy, you will have received an automated account creation email. Clicking the link in this email guides you to the account creation page. After filling out the requested details, click the **Create** button. You will be redirected to the login page of the Data Portal. Insert your newly chosen username and password and click the **Log in** button.

In order to work with your Wave Buoy in the Data Portal, the device needs to be activated prior to its first use. The device activation key can be found underneath the top cap. On the Data Portal, navigate to the **Devices** tab, enter the activation key in the corresponding field in the top-right corner of the page and click the **Add** button. The Wave Buoy will now appear in the list of devices.

6.4. REAL-TIME SETTINGS

The Wave Buoy has a number of user-configurable settings. Most of these settings are controlled through the Obscape Data Portal and will be synchronised by the device when it contacts the server over the cellular modem or satellite modem. These settings are termed 'real-time settings' and will be described in this section. In addition, some settings are controlled through a settings file on the SD card of the device (termed 'SD settings') and will be described in Section 6.6.

An overview of available real-time settings is presented in Table 2. The real-time settings can be viewed and changed from the Data Portal. Navigate to the **Devices** page, click on the device in the list and choose **Menu** → **Settings**. In case you have coupled the device to a station already, you can alternatively access the real-time settings from the **Map** page by clicking on the station and selecting **Menu** → **Edit devices** → **Settings** (refer to the Data Portal manual for detailed instructions).

Table 2: Real-time settings overview

Setting	Default value	Possible values	Description
Real-time spectra[4]	Unchecked	Unchecked	Do not send spectra.
		Checked	Send compressed directional wave spectra along with bulk wave parameters.
Real-time displacements[5]	Unchecked	Unchecked	Do not send displacements.
		Checked	Send displacement timeseries along with bulk wave parameters.
Communication mode	Cellular	Cellular	Real-time communication via cellular network (requires SIM card)
		Satellite	Real-time communication via satellite (requires line rental activation)
		Hybrid	Real-time communication via cellular when available, otherwise via satellite otherwise (requires SIM card and line rental activation)
Communication interval[6]	30	30, 60, 120, 180, 240, 360, 480, 720 or 1440	Communication interval in minutes. Can be a multiple of the 30-minute sampling interval in order to save power.

PLEASE NOTE

While it is possible to put the Wave Buoy in satellite communication mode using the real-time settings interface at the Data Portal, this will require the Wave Buoy to first power up and contact the server using cellular communication before it synchronises the communication mode change from the server.

Alternatively, it is possible to skip this step and power up the Wave Buoy in satellite communication mode straight away by specifying the communication mode in the settings file on the SD card (refer to Section 6.6). With this last option, the Wave Buoy will not require a SIM card to operate in satellite communication mode.

[4] The Wave Buoy measures the directional wave spectrum. Optionally, the wave spectrum can be sent to the server along with the bulk wave parameters. To limit the data size, spectra are compressed to 100 frequency bins when sending them over cellular communication. Full resolution spectra (513 bins) can be retrieved from the SD card after the buoy has been recovered from the field.
[5] Upward, northward and westward buoy displacement timeseries at 6.25 Hz can be sent to the server along with the bulk wave parameters.
[6] If the communication interval is chosen larger than 30 minutes, wave data will be added to the queue and transmitted to the server once the next communication interval has passed. Choosing a larger communication interval will save power, since the cellular modem will have to be powered up less often.

6.5. ACTIVATING SATELLITE LINE RENTAL

NOTICE: This section only applies to satellite communication. If you are using cellular communication, satellite line rental does not need to be activated. It is strongly recommended to read Chapter 4 before activating satellite line rental, so you are fully aware of the data transmission fees associated with satellite communication!

The satellite modem in the Wave Buoy connects to the Iridium satellite network. Next to the data transmission fee per wave data message that is sent out, the Iridium network comes with a monthly line rental fee that needs to be paid in order to keep the connection alive. Line rental can be activated from the Obscape Data Portal. Navigate to the **Satellite communication** page and click the **Extend** button associated with your Wave Buoy's serial number. Choose the number of months of line rental you would like to purchase, and click the **Buy** button.

Be aware that this operation cannot be reverted! Once bought, line rental cannot be cancelled and the associated fee cannot be refunded. The data portal will send automated reminder emails 7 days and 1 day prior to line rental expiry. These alerts can be configured from the **Project settings** page of the Data Portal.

6.6. SD SETTINGS FILE

The Wave Buoy will synchronise most of its settings in real-time from the Data Portal. However, some settings of the Wave Buoy are used to control the SIM card and cellular connection. Since the device might not be able to contact the server without these settings in place, they are controlled through a settings file on the SD card rather than through the data portal. Furthermore, in case you want to power up the buoy in satellite communication mode straight away, without having to communicate over the cellular modem first before switching to satellite communication, this can be controlled through the settings file on the SD card.

An overview of all available settings is provided in Table 2. The 'Default value' column indicates the value that is selected when a setting is not specified in the settings file. If you need to change any of the default settings, the following steps need to be taken. Eject the SD card by sliding the clip of the SD socket towards the bottom side of the control panel and lifting it up. The SD card can now be lifted out of the socket. Insert the SD card into a computer.

NOTICE: Never eject the SD card while the Wave Buoy is powered, as this may lead to loss or corruption of data!

On your computer, open the folder that corresponds with the SD card and look for the file named **settings.txt**. If no such file exists, create an empty plain-text file and name it 'settings.txt'. Settings can be adjusted by typing lines in the text file with the following format:

<keyword> = <value>

Where <keyword> corresponds with the 'Keyword' column in Table 3. The rightmost column in the table shows to which communication mode(s) each setting applies. Lines starting with a hash sign (#) are ignored and can be used for commenting. An example settings file is appended below for reference.

```
# This is a comment
simpin = 1234
apn = live.abcnetwork.com
```

Table 3: SD settings overview

Setting	Keyword	Default value	Possible values	Description	Comm. modes
Communication mode	`cmode`	1	1	Cellular	All
			2	Satellite	
			3	Hybrid	
SIM PIN code[7]	`simpin`	<No PIN specified>	Digits, maximum length is 9	PIN code of the SIM card	Cellular
APN for SIM provider[8]	`apn`	<No APN specified>	Any character, maximum length is 100 characters	APN of the network provider for the SIM card	Cellular

After editing the settings.txt file, save and close the file, eject the SD card from the computer and insert it back into the Wave Buoy. Be careful not to damage or unhinge the metal SD clip. The Wave Buoy checks the settings.txt file at power-up. Settings are stored in the volatile (RAM) memory of the device and will be lost after powering down the Wave Buoy. Therefore, the settings.txt file needs to remain in place if you want to reuse the same settings at the next power-up.

[7] By default, no SIM PIN code is specified. This is a valid choice in case the PIN code has been removed from the SIM card. If the SIM is protected by a PIN code, the PIN code must be specified in order for the Wave Buoy to function correctly. If you wish to remove the PIN code protection, insert the SIM card in a cellphone and disable the PIN code through the phone's settings menu.

[8] Every SIM provider has an Access Point Name (APN) associated with their cell network. Most providers will not require you to specify the APN, APN username and APN password in order to use their network, but some will. Google is the best source of APN information. Search for 'APN <your provider name> <your country name>'. It is advised to test the Wave Buoy first without any APN information specified. If the device issues the 'could not connect to server' error code (steady blue LED and 2 quick beeps every 2 seconds, refer to Section 6.8), APN information might be required to use the mobile network.

6.7. INSERTING THE SIM CARD

NOTICE: This section only applies to cellular communication. If you are using satellite communication, a SIM card is not needed. It is strongly recommended to read Chapter 4 before choosing your preferred communication mode.

The cellular modem inside the Wave Buoy communicates with the Obscape servers through a 4G internet connection (with 3G and 2G fallback). To that end, the user needs to add a valid SIM card to the device. When selecting the network provider and SIM card, the following requirements should be acknowledged:

- Network of choice has sufficient signal strength at the deployment location of the Wave Buoy. Most network providers offer network coverage maps on their websites.
- Network of choice supports 4G, 3G or 2G communication.
- Data consumption of the Wave Buoy is approximately 12 MB per month if real-time spectra are disabled, or 15 MB per month including real-time spectra.
- SIM format: micro SIM. This is the intermediate SIM size.

To insert the SIM card into the Wave Buoy, slide the clip of the SIM socket towards the bottom side of the control panel and lift it up. The SIM card can now be lifted out of the socket.

6.8. STARTING THE MEASUREMENT

NOTICE: When powering up using satellite communication (cmode = 2 specified in settings file), the Wave Buoy must be powered up outside and under open skies in order for the buoy to connect to the satellite network. If the buoy does not connect to the satellite network, the system test will fail and the buoy will return an error code (see below).

When the power button is pressed, the device will beep and the status LED will blink blue for 4 seconds before it turns solid blue and the device enters the start-up sequence. The OLED display will inform you about the progress of the device's system test. If it passes the system test, after 1 to 2 minutes the device will blink green and the buzzer will play the acknowledgement tune. If the Wave Buoy fails the system test, it will blink and beep until the user powers it down with the power button. The blinking and beeping signals indicate the error that occurred during the system test (Table 4). This information will also be visible on the OLED display.

Table 4: Error signals

LED	Sound	Error	Solution
Slow red blink every 2 seconds	Slow beep every 2 seconds	Battery voltage too low	Place the Wave Buoy in bright sunlight for 3 to 6 hours. Device will keep charging when powered down.
Two quick red blinks every 2 seconds	Two quick beeps every 2 seconds	SD card error	Check if SD card is present and inserted properly (Section 6.6).
Intermittent red and blue blinking	Slow beep synchronised with red LED	SIM card error	Check if SIM card is present and inserted properly (Section 6.7).
Intermittent red and blue blinking	Two quick beeps synchronised with blue blinking	SIM PIN error	Check if correct SIM PIN code is specified in the settings file (Section 6.6).
Steady red LED	Slow beep every 2 seconds	Network error	Check if network coverage is OK at current location (Section 6.7).
Steady red LED	Two quick beeps every 2 seconds	Could not connect to server	**Cellular communication:** Check if SIM card has been activated and has sufficient credit. Check if APN settings might be needed on the network (Section 6.6). **Satellite communication:** Does the Wave Buoy have a clear view of the sky? Have you activated line rental? Connectivity might depend on the present satellite constellation, which changes continuously. Try again a few minutes later. (Section 0)
Steady red LED	Three quick beeps every 2 seconds	General error	Check error.txt file on SD card and report contents to Obscape support team (**support@obscape.com**).

If the system test is successful, the Wave Buoy enters its operational mode. The Wave Buoy will align its sampling sequence with the clock: every new measurement burst is started at 15 or 45 minutes past the full hour. If the device passes its system test at 14h58, the first measurement will be started at 15h15. Each measurement burst lasts 30 minutes, after which the Wave Buoy calculates the spectra and bulk wave parameters and sends the processed data to the Data Portal. Calculation and telemetry typically consumes between 7 and 9 minutes. Therefore, in the example above, the first processed wave data are expected to appear in the Data Portal around 15h53.

Although passing the system test is a strong indication that the Wave Buoy is fully functional, it is advised to monitor the real-time data connection for a full day before deploying the device in the field. Log on to the Obscape Data Portal (**https://www.obscape.com/portal**) and check if the measurements of the device are being reported at the set communication interval. The Data Portal manual and tutorial video (check the **Support** tab on the Data Portal) contain further instructions on the usage of the Data Portal.

Ideally, the buoy should be placed in direct sunlight during pre-deployment testing in order to avoid the battery from running flat. If that is not possible, e.g. due to the lack of a private outdoor are for testing, limit the pre-deployment testing period to 24 hours. If you are using satellite communication, pre-deployment testing is only effective if the buoy has an unobstructed view of the sky.

6.9. POWER MANAGEMENT

With a fully charged battery, the Wave Buoy can operate for approximately 2 to 3 days without any solar input. When fully charged, the battery voltage will be just under 4.2V. In order to optimise device performance, the Wave Buoy has several power modes based on its battery level (refer to Table 5). When the battery level is dropping and it drops below the entry level of a certain power mode, the Wave Buoy enters that power mode. When the battery charges again and the battery voltage rises, there is a 0.1V hysteresis associated with each power mode. For example, if the battery level drops below 3.8V and the device enters into power saving mode, the Wave Buoy will only return to normal mode when the battery voltage is higher than 3.9V.

Table 5: Power modes

Power mode	Entry level	Description
Normal	-	-
Power saving	3.8V	Communication interval doubled.
Offline	3.7V	Communication interval set to 24 hours.
Hibernation	3.6V	No sampling, no real-time data transfer.

After around 2 years of operation, the battery might start showing signs of deterioration. This might be the case if the maximum battery voltage when fully charged drops below 4.1V. The lithium-ion battery can easily be replaced with a new one (Section 6.2).

6.10. CLOSING THE HOUSING

Once the measurement has been started and pre-deployment monitoring has commenced, the Wave Buoy housing can be closed. A rubber O-ring running around the side edges of the back panel ensures water tightness of the housing. The O-ring needs to be greased with silicone grease from the tool kit before every deployment and whenever maintenance takes place in the field. Remove any dirt and dust from the O-ring, apply some silicone grease to your finger and run it along the O-ring. Repeat the process until the entire O-ring has been greased.

Now the back panel can be placed into the housing again, paying attention to the orientation of the battery groove on the inside of the panel. Push the panel down into its position and apply the steel hexagonal screws with the #5 allen key from the tool kit.

NOTICE: Avoid overtightening of the bolts, as this might damage them. Water tightness of the housing is ensured by the rubber O-ring and does not rely on firm tightening of the bolts.

Then, place the white top disc back onto the yellow float, **with the 3 solar panels facing upwards**. Firmly tighten the eye bolts (e.g. by using the flat screw driver from the tool kit as a lever arm). Finally, insert the split pins and bend their legs outwards to prevent the eye bolts from loosening while the buoy is at sea (Figure 5).

Figure 5: Correctly inserted split pin.

At the bottom side of the Wave Buoy, the white bottom disc is mounted which contains the mooring eye. Typically, the Wave Buoy is shipped with the bottom disc mounted upside-down to save space inside the shipping box. If this is the case, the bottom disc needs to be flipped by first unscrewing the 3 steel bolts using the #8 allen key from the toolkit. Then, flip the bottom disc such that the mooring eye is located on the outside of the Wave Buoy housing. Finally, mount the bottom disc back onto the yellow float by applying the 3 steel bolts using the #8 allen key from the toolkit.

6.11. DEPLOYING IN THE FIELD

After having confirmed the stability of the real-time data connection, the Wave Buoy can be deployed in the field. Due to its relatively low weight and small size, the Obscape Wave Buoy can be deployed by hand from a small vessel (e.g. a RIB) without the necessity of using an on-board crane.

Please be aware that in some countries or places, a permit is required to deploy a scientific measurement device. When placing the buoy in coastal waters, the local Hydrographic Service should always be informed so they are able to send out a Notice to Mariners.

Visibility of the Wave Buoy is ensured by its bright yellow colour and the three navigation lights on top. The flash pattern of the navigation lights is defined as follows: 4 flashes at 2-second intervals, with a 12-second interval after the 4th flash. The total duration of the flash pattern is 20 seconds.

6.12. MAINTENANCE

Maintenance of the Wave Buoy consists of three aspects:

- Removal of marine growth. The potential for marine growth differs strongly per geographic location. On average, it is recommended to clean the buoy every 6 months. Excessive marine growth may change the dynamics of the buoy, compromising the accuracy of your wave data.
- Mooring line inspection. The frequency of mooring line inspections depends on the robustness of the mooring line and the ferocity of waves and currents at the deployment location.
- Replacement of the battery. After around 2 years of operation, the battery might start to show signs of deterioration. This is the case if the maximum battery voltage when fully charged drops below 4.1V. New lithium-ion 18650 batteries can be ordered from many different web shops in almost any country. Refer to Section 6.2 for battery specifications.

7. RECOVERY FROM THE FIELD

This chapter describes the steps required to recover the Wave Buoy from the field.

7.1. LIFTING THE BUOY OUT OF THE WATER

When operating from a small vessel with a very small freeboard, it is possible to lift the buoy out of the water by hand with 1 or 2 persons. If the freeboard is higher, it is most convenient to use a boat hook. The Wave Buoy can be lifted easily at one of the three eye bolts.

7.2. STOPPING THE MEASUREMENT

NOTICE: Before opening the housing, ensure that the housing is dry and there is no risk of water or dirt entering the opened housing. Water or dirt can cause severe damage to the Wave Buoy electronics. When handling the Wave Buoy in an offshore environment, never open the top cap on deck.

Remove the split pins from the three steel eye bolts on the top side of the buoy. Then, unscrew the eye bolts (e.g. by using the flat screw driver from the tool kit as a lever arm). Lift the white top disk out of the buoy and turn it upside-down. Now, unscrew the two steel hexagonal bolts using the #5 allen key from the tool kit (Figure 2, left). Finally, insert the flat screw driver from the tool kit into the grooves on both side edges of the back panel and rotate the screw driver b 90 degrees. Once the top cap has lifted a bit, it can be taken off by hand (Figure 2, right).

Power down the Wave Buoy by pressing the power button. Since the Wave Buoy will not have any burning LEDs in its operational mode, there will be no sign to confirm that the device has been powered down.

7.3. RETRIEVING DATA FROM SD CARD

Although the Wave Buoy has a real-time data connection and sends its data to the Obscape Data Portal operationally, measured data are also stored to the on-board SD card. In order to retrieve these data, eject the SD card from the Wave Buoy.

NOTICE: Never eject the SD card while the Wave Buoy is powered! This might lead to loss or corruption of data files. Insert the SD card into a computer.

Copy all files from the SD card to a local folder, safely eject the SD card from your computer and insert the card back into the Wave Buoy.

Output files are stored on the SD card in subfolders per month, the name of the folder having the format yyyymm. In case the SD card runs out of available memory, the oldest folder will be automatically deleted (permanently).

The Wave Buoy produces several different file types on the SD card:

1. **Bulk data files**. Per UTC calendar day, the Wave Buoy will create a separate data file on the SD card in ASCII-format, containing the measured bulk wave parameters for that day. The file names of these data files correspond with their calendar day, having the format yyyymmdd.txt. Each line of the file has 18 columns, separated by a comma. These columns describe (1) epoch time in unix format, i.e. the number of seconds since 1 January 1970 00h00 UTC, (2) H_{m0} in metres, (3) H_{max} in metres, (4) T_p in seconds, (5) $T_{m0,1}$ in seconds, (6) $T_{m0,2}$ in seconds, (7) $T_{m-1,0}$ in seconds, (8) T_{avg} in seconds, (9) T_{max} in seconds, (10) Dir_p in degrees to **magnetic North**[9], (11) Dir_m in degrees to **magnetic North**, (12) Sig_p in degrees, (13) Sig_m in degrees, (14) Latitude in degrees, (15) Longitude in degrees, (16) the battery voltage in Volts, (17) the solar panel voltage in Volts and (18) the internal temperature in degrees Celsius. A complete definition of the bulk wave parameters is provided in Chapter 10.
2. **Wave spectrum files**. Per 30-minute measurement burst, one wave spectrum file is created on the SD card in ASCII-format. The file names of these files correspond with their unix epoch timestamp (i.e. the number of seconds since 1 January 1970 00h00 UTC), having the format <epoch time>_spec.txt. Each spectrum file has 6 columns delimited by a comma. The columns describe (1) frequency of the spectral bin in Hz, (2) variance-density of the 1D wave spectrum in

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[9] Note that all directions reported in the SD wave data files are given w.r.t. magnetic North! Conversion to geographic North through addition of the magnetic declination is only done automatically for the real-time data on the Data Portal (refer to Section 9.1). Wave directions on the SD card need to be corrected by adding the magnetic declination (www.magnetic-declination.com) to convert directions to geographic North. Let δ denote magnetic declination in degrees (can be positive or negative), subscript *mag* denote magnetic directions and subscript *geo* denote geographic directions, then: $Dir_{p,geo} = Dir_{p,mag} + \delta$ and $Dir_{m,geo} = Dir_{m,mag} + \delta$.

m^2/Hz, (3) Fourier coefficient[10] a1, (4) Fourier coefficient b1, (5) Fourier coefficient a2 and (6) Fourier coefficient b2. At the **Support** page of the Data Portal, you can find Python scripts to visualise the directional wave spectra based on the spectral data files on the SD card. Be aware that wave directions calculated based on the Fourier coefficients refer to magnetic North. Conversion to geographic North is done by adding the magnetic declination (www.magnetic-declination.com). This does not hold for real-time spectra downloaded from the Data Portal. The Data Portal is aware of magnetic declination and corrects for it after receiving the data from the Wave Buoy.

3. **Displacement files**. Per 30-minute measurement burst, one displacement timeseries file is created on the SD card in ASCII-format. The file names of these files correspond with their unix epoch timestamp (i.e. the number of seconds since 1 January 1970 00h00 UTC), having the format <epoch time>_disp.txt. Each displacement file has 3 columns delimited by a comma. The columns describe (1) upward displacement of the Wave Buoy in m, (2) westward displacement of the Wave Buoy in m and (3) northward displacement of the Wave Buoy in m. The frequency of the timeseries is equal to the sampling frequency of the Wave Buoy and amounts 6.25 Hz.

7.4. STORING THE WAVE BUOY

The battery should be removed from the battery holder in case the Wave Buoy is stored for a longer period of time. The ejected battery should be packed separately in such a way that the battery terminals cannot make contact with any conductive material (e.g. by wrapping it in a small plastic bag). Close the device again by placing the back panel into the housing, paying attention to the orientation of the battery groove on the inside of the panel. Push the panel down into its position and apply the steel hexagonal bolts using the #5 allen key from the tool kit. Avoid overtightening of the screws, as this might damage them. Then, place the white top disc back onto the yellow float and apply the three steel eye bolts.

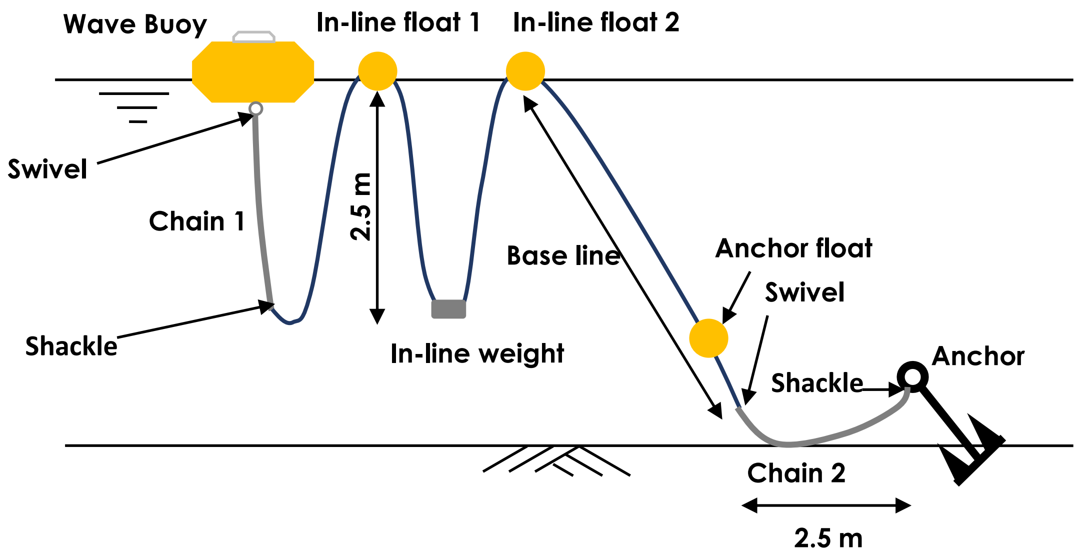
Place the Wave Buoy and its accessories back into their box to avoid damage to the device and store it in a dry place.

8. MOORING CONSTRUCTION GUIDELINE

NOTICE: The mooring design guideline is provided for reference and is based on the experience of Obscape staff. Obscape and its associated companies do not take responsibility for practical performance of mooring lines.

[10] Fourier coefficients of the directional distribution can be used to reconstruct the directional wave spectrum, for example using the Maximum Entropy Method (Lygre & Krogstad, 1986) or the Cosine-2s method (Kuik et al., 1988).

Waves and ambient currents will lead to tensile forces on the mooring line of any buoy. In order to allow the Obscape Wave Buoy to still move with the wave orbital motion, a system of in-line weights and floats is needed. The recommended general mooring design is shown in the figure below. The table gives the specifications of all components, partly depending on the expected maximum current speed and water depth.



Component	Specification		
Line[11]	Diameter: ≥ 16 mm Base length = 1.2 * Mean water depth + High Water level + Surge + 0.5 * maximum wave height Total line length = base length + 3 * 2.5 m For deep moorings, it is advised to increase the depth of the in-line weight and length of chain 1 from 2.5 m to 5 m (depth > 30 m) or 10 m (depth > 100 m).		
Anchor float	0.5 L		
Swivels & shackles	Stainless steel, min. 8 mm diameter		
	Currents max. 0.5 m/s	***Currents 0.5 – 1 m/s***[12]	***Currents 1 – 1.5 m/s***[3]
In-line float 1 and 2	≥ 5 L	≥ 10 L	≥ 10 L
In-line weight	1.5 kg	2 kg	3 kg
Anchor (< 30 m depth)	15 kg	20 kg	40 kg
Anchor (> 30 m depth)	30 kg	40 kg	80 kg
Anchor (> 100 m depth)	45 kg	60 kg	120 kg
Chain 1	1.5 kg/m	2.0 kg/m	2.5 kg/m
Chain 2	1.5 kg/m	2.0 kg/m	2.5 kg/m

[11] When determining the water depth from sea charts, be aware that these typically report water depth w.r.t. lowest astronomical tide rather than mean water depth.
[12] The Obscape Wave Buoy buoy functions optimally in currents < 0.5 m/s. Performance may be compromised at higher ambient flow velocities.

Please note:

- Chain 1 should not be replaced by a normal line, as it is important for optimal wave buoy dynamics.
- Chain 2 is needed to keep anchor forces as much as possible parallel to the sea bed. This will stimulate anchor burrowing.
- The anchor float is needed to prevent the line from dragging over the sea bed. This will prevent excessive wear of the line. The anchor float needs to be able to resist water pressure at sea bed level. Therefore, a solid anchor float (e.g. foam) is to be preferred over a hollow anchor float.
- The recommended anchor weights in the table are based on steel ship anchors in a sandy sea bed. For gravity anchors, significantly higher submerged weights are advised. For non-sandy substrates, it is advised to seek local experience and advice.
- For long-term deployments and/or energetic environments, it is advised to increase the mooring line diameter. Regular checks of the mooring line condition may help to prevent mooring line failure.

9. OBSCAPE DATA PORTAL

The Wave Buoy uses its real-time data connection to send the measured data to the Obscape Data Portal. The portal can be accessed through the Login button on the Obscape website, or directly through **https://www.obscape.com/portal**.

The **Support** tab of the Data Portal gives access to the Data Portal Manual, which contains all the information needed to use the portal to its full capability. The quick start tutorial video explains the most essential functions to get started.

9.1. SERVER-SIDE SETTINGS

Next to the real-time settings (Section 6.4) and SD settings (Section 6.6) that directly affect the Wave Buoy itself, there are a few device-specific settings that take effect only at the Data Portal. These so-called server-side settings can only be viewed and edited after the Wave Buoy has been coupled to a station on the Data Portal (refer to Section 6.2 and the Data Portal quick start tutorial movie). To this end, navigate to the **Map** page. Then, select the station of your Wave Buoy and click the **Settings** button corresponding with the Wave Buoy's serial number. The following server-side settings are available:

- **GPS radius**. The Data Portal monitors the GPS position of your Wave Buoy in real-time. When a new position is received, it is compared to the so-called GPS watch circle. This imaginary circle has its origin at the coordinates of the station the Wave Buoy is coupled to, while its radius is specified by the GPS radius server-side setting. If the Wave Buoy leaves or enters the GPS watch circle, an automated notification email is sent (further details provided in Section 9.2). The default GPS radius is 300 metres, which is the optimal choice for most applications in the coastal zone. When deploying at deeper water, the mooring line will have more slack and the Wave

Buoy will have more freedom to move around its anchor point. In that case, a larger GPS radius might be a good choice to prevent false GPS alerts.

- **Magnetic declination**. The Wave Buoy is equipped with an electronic compass, which references wave directions to the magnetic North. Most wave data applications will require the wave directions to be referenced to the geographic North (also known as 'true North'). The difference between magnetic and geographic North is called the magnetic declination (www.magnetic-declination.com), which changes with time and with geographic location. In some places the magnetic declination can be close to 0 degrees, while at other locations it can be more than 20 degrees. Magnetic declination can be both positive and negative. When coupling your Wave Buoy to a station on the Data Portal, the current magnetic declination at the station coordinates is automatically obtained from an online database and specified in the server-side settings of your Wave Buoy. There should be no need to modify this automatically specified magnetic declination, unless the true deployment location of the Wave Buoy is not the same as the coordinates of the station in the Data Portal. If the coordinates of a station are changed, the magnetic declination is automatically updated to the new station location.
- **Auto-update magnetic declination**. As stated above, magnetic declination changes slowly over time. The rate of change is typically less than 1 degree per year. In order to keep the magnetic declination of your Wave Buoy up to date, it will be updated automatically every month if this server-side setting is enabled.
- **Threshold alerts**. If you want to receive notification emails in case one of the bulk wave parameters exceeds a certain threshold (e.g. H_{m0} exceeds 2.0 m), you can add a threshold alert. Specify the parameter, the sign (≤ or ≥) and the threshold value and click the **Add** button.

9.2. STATUS MONITORING

The Data Portal performs continuous monitoring of your Wave Buoy's status variables. In case a status variable changes, an alert email is sent in accordance with your project's distribution list (see below) and a notification is added to the **Log** page of the Data Portal. The following status variables are monitored:

- **Online / offline**. If the Wave Buoy has contacted the server during the lasts 2.5 hours, the Wave Buoy is marked online, otherwise it is marked offline.
- **Battery level**. If the battery level of the Wave Buoy drops below 3.85 Volts, the battery level is marked low. If the battery level rises above 3.95 Volts, it is marked charged again.
- **GPS watch circle**. If the GPS position reported by the Wave Buoy moves outside the GPS watch circle, the Wave Buoy is marked out of position. If it moves into the GPS watch circle, it is marked in position.
- **Threshold status**. If a threshold value is exceeded (refer to Section 9.1), the threshold status is triggered.
- **Satcom line rental expiry**. If the satellite line rental of your Wave Buoy expires in 7 days or in 1 day, an alert will be sent.

The distribution list of your project on the Data Portal can be controlled from the **Project settings** page. Upon registering for the data portal, your email address is automatically added to the distribution list for all status notification emails.

9.3. REAL-TIME WAVE PARAMETERS

The following quantities are measured by the Wave Buoy and reported in real-time to the Data Portal:

- **Bulk wave parameters**
    - H_{m0} in metres
    - H_{max} in metres
    - T_p in seconds
    - $T_{m0,1}$ in seconds
    - $T_{m0,2}$ in seconds
    - $T_{m-1,0}$ in seconds
    - T_{avg} in seconds
    - T_{max} in seconds
    - Dir_p in degrees to geographic North
    - Dir_m in degrees to geographic North
    - Sig_p in degrees
    - Sig_m in degrees
- **Wave spectra** (if enabled, spectra are available for download from the **Station data** page)
    - 1D wave spectrum
    - Directional (2D) wave spectrum
- **Buoy displacements** (if enabled, displacements are available for download from the **Station data** page)
    - Upward displacement timeseries
    - Northward displacement timeseries
    - Westward displacement timeseries
- **Diagnostic parameters**
    - Latitude in degrees
    - Longitude in degrees
    - The battery voltage in Volts
    - The solar panel voltage in Volts
    - The internal temperature (i.e. inside the Wave Buoy housing) in degrees Celsius
    - The internal pressure (i.e. inside the Wave Buoy housing) in kPa
    - The internal relative humidity (i.e. inside the Wave Buoy housing) in %.
    - The cellular signal strength on a scale from 0 (no reception) to 32 (excellent reception).

A detailed description of all wave parameters is provided in Chapter 10.

10. DEFINITION OF WAVE PARAMETERS

Parameter	Description
Time [s]	Unix timestamp (seconds since 01-01-1970 00h00 UTC) of data point, situated in the middle of the 30 minute measurement burst
H_{m0} [m]	Significant wave height (also known as H_s). This is the most commonly used wave height statistic world-wide. It has been shown to closely match the visually estimated wave height by experienced human observers. Computed as 4 times the square-root of the 0^{th} order moment of the 1-dimensional wave spectrum.
H_{max} [m]	Maximum wave height. The wave height of the highest wave in one 30-minute record, based on a zero-crossing analysis.
T_p [s]	Peak wave period. The wave period that contains most energy in the 1-dimensional wave spectrum. The peak wave period is sometimes seen to alternate between different sea states (locally generated wind waves and distant swell).
$T_{m0,1}$ [s]	Average wave period. Computed by dividing the 0^{th} through the 1^{st} order moment of the 1-dimensional wave spectrum.
$T_{m0,2}$ [s]	Average wave period. Computed by dividing the 0^{th} through the 2^{nd} order moment of the 1-dimensional wave spectrum and taking the square root of the result.
$T_{m-1,0}$ [s]	Average wave period. Computed by dividing the minus 1^{st} through the 0^{th} order moment of the 1-dimensional wave spectrum.
T_{avg} [s]	Average wave period. Average period of all waves in one 30-minute record, based on a zero-crossing analysis.
T_{max} [s]	Maximum wave period. Wave period of the highest wave in one 30-minute record (the wave that defines H_{max}), based on a zero-crossing analysis.
Dir_p [deg]	Peak wave direction. Wave direction (coming-from convention) that contains the most energy in the 1-dimensional wave spectrum. The peak wave direction is sometimes seen to alternate between different sea states. Ranging from 0 (North) through 90 (East), 180 (South), 270 (West) and 0 again (North).

Dir_m [deg]	Mean wave direction. Average wave direction (coming-from convention) of all wave energy in the directional wave spectrum. Ranging from 0 (North) through 90 (East), 180 (South), 270 (West) and 0 again (North).
Sig_p [deg]	Peak directional spreading. Directional spreading of the frequency bin that contains most energy in the 1-dimensional wave spectrum. The peak directional spreading is sometimes seen to alternate between different sea states.
Sig_m [deg]	Mean directional spreading. Average directional spreading of all wave energy in the directional wave spectrum.
P_{UU} [m^2/Hz]	Variance-density of the 1-dimensional wave spectrum.
a1, b1, a2, b2 [-]	Fourier coefficients of the directional wave spectrum.

11. TROUBLESHOOTING

This chapter serves as a helping hand in case you are facing problems with your Wave Buoy. If you have not solved the problem after reading this chapter, do not hesitate to contact the Obscape support team (**support@obscape.com**).

11.1. FREQUENTLY ASKED QUESTIONS

- **The Wave Buoy does not work as intended, how can I fix it?** Try solving your problem with the flow diagram in Section 11.2.
- **I am trying to download wave spectra from the Data Portal, but they are not available. Where can I find the wave spectra?** Only if real-time wave spectra have been enabled, the Wave Buoy will send real-time wave spectra to the server. Otherwise, they will not be available for downloading. Sections 6.4 (cellular communication) and 6.6 (satellite communication) explain how to enable real-time spectra.
- **I am getting the 'low battery voltage' error code, even though the device has already been charging outside in the sun for more than 3 hours. How could that be possible?** If the solar intensity is relatively low at your current location or the battery was drained to a very low voltage initially, charging might take more than 3 hours. In order to gain more confidence, you could measure the battery voltage with a multimeter every once in a while to confirm that the voltage is increasing over time (i.e. the battery is charging).
- **I can't find APN information for my selected mobile provider. How to proceed?** It is advised to test the Wave Buoy first without any APN information specified, since most mobile network providers will not require APN information to be specified explicitly. If the device issues the

‘could not connect to server’ error code (steady red LED and 2 quick beeps every 2 seconds, refer to Section 6.8), APN information might be required to use the mobile network. Google is the best source of APN information. Search for ‘APN <your provider name> <your country name>’. If you are not getting any relevant search results, you could consider contacting your mobile network provider to ask for their APN information. Alternatively, you could try the fairly generic APN ‘internet’ without specifying the username and password, which is accepted by many providers.

11.2. FLOW DIAGRAM