Windsond manual

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Introduction

Windsond is a novel weather sounding system for an immediate view of local conditions at different altitudes. A single person can bring the complete system to any location and do a sounding within minutes. The system makes it easy to recover and reuse all electronics, which lowers operating costs drastically.

Multiple soundings can be active simultaneously and multiple ground stations can receive the measurements and control the soundings. The included computer software visualizes measurements in real-time and gives the operator easy control over the sounding.

Warnings

Test the system before going on an important first mission!

Be careful not to apply force to the USB receiver while it is connected as the USB connector might bend or break. This risk can be mitigated by connecting to the computer via a short USB extension cable or hinge.

Do not squeeze the antenna cable of the receiver since this ruins the radio signal. Do not forcibly bend the antenna cable.

Neither sondes nor the RR1 receiver are water-proof. Keep away from water. Soundings in rain might work but are not guaranteed.

Do not use force to tighten the antenna contact (SMA) on the receiver.

Do not remove the electronics of a sonde from the enclosure, as bare electronics is susceptible to electrostatic discharge (ESD).

Observe the local radio regulations for the data link. Check that the ground station reports a solid radio link before releasing Windsond.

Observe any local regulations on the release of unmanned balloons and assure there is no risk of mid-air collisions with aircrafts. Some areas contain restricted airspace.

Do not use hydrogen balloons with Windsond, for the risk of explosion caused by sparks from electrostatic charges or from the cut-down mechanism.

While on the ground, nearby radio transmitters may impede the function of the GPS.

Dispose of the parts as electronics waste. Remove the Windsond battery for proper waste separation.

Abbreviations and concepts

- AGL = altitude Above Ground Level
- MSL = altitude over Mean Sea Level
- Launch = The operator lets go of sonde and helium ballon to start the ascent
- Cut-down = The sonde detaches from the balloon at an altitude to start falling to the ground

Kit contents

- Radiosondes in protective cardboard cylinders
- Lithium batteries for the radiosondes

- Latex balloons
- USB radio receiver "RR1"
- Magnetic roof receiver antenna
- Whip receiver antenna
- USB battery charger "CU2"
- Thread for tying sondes to balloons
- Warranty letter
- Computer software with personal license file
- This manual

Spare parts can be ordered by emailing Sparv Embedded at info@sparvembedded.com.

Not included

The user additionally needs the following for a sounding

- A canister of helium
- A laptop running Windows, preferably with internet connection
- A vehicle for retrieving the sonde again
- GPS device to navigate to the sonde landing coordinates

Sonde S1 specifications

- Sonde weight 12g
- Rechargable lithium-polymer battery 70 or 140 mAh
- Operating temperature range -50 to 50 degrees C.

Reusable versions

- Loudspeaker and power LED
- Hot wire cut-down mechanism with backup cut-down and electrical current test.
- Power-saving solutions to assist in sonde recovery during several days.

Radio specifications

- Digital two-way radio interface between sondes and ground receiver.
- Configurable power up to 100 mW.
- Frequency configurable in the range 400-479.99 MHz with 10 kHz resolution. Quarter-wave antenna for the 430 MHz band.
- Default radio settings are GFSK modulation at 2.4 Kbps, with a duty cycle of 0.2 seconds every 3 seconds.
- Customized radio protocol with forward error correction, separation of different Windsond systems, generic command/response capability and support for multiple encoding variants and future extensions.
- Radio range exceeds 15 km with line-of-sight and standard receiver antenna. With directional antenna, 50 km range.

Sonde sensor specifications

All sondes come with the following sensors. The models differ in the specifications in subsequent sections.

- GPS rated to altitude of 40 km MSL.
- Barometric pressure sensor with range 300-1100 hPa. Absolute altitude accuracy about 7 m and resolution 0.4 meters at sea level.

S1B sensors

- Thermistor temperature resolution 0.1 degrees C in range -25 - +10 degrees C, 0.2 degrees C in range -46 - +38 degrees. Absolute accuracy about +- 1 degrees C.

Temperature gradients are sensed quickly but absolute temperature value lags behind by about 10 seconds in flight due to thermal inertia. The temperature sensor can be calibrated to improve the accuracy.

S1H2 sensors

- Temperature resolution 0.01 degrees C and absolute accuracy 0.3 degrees C at 25 degrees C.
- Humidity resolution 0.05% and absolute accuracy 2.0%.

S1H3 sensors

- Temperature resolution 0.01 degrees C and absolute accuracy 0.2 degrees C at 25 degrees C.
- Humidity resolution 0.05% and absolute accuracy 1.8%.

Other specifications

- Balloon 9 gram, 18" clear latex. Launch volume 30 liters. Burst volume ca 80 liters.
- Alternative balloon: 20 gram sounding balloon
- Polyester thread as tether between sonde and balloon. Breaking tension about 9 Newton.
- Charger powered by USB. No data interface to the charger. Max charge current 100 mA.

Battery

The sonde battery is a 70 mAh or 140 mAh Lithium Polymer rechargable battery. Thanks to automated power management, this is enough for a sounding and several days of subsequent recovery assistance by sending radio beacon signals.

To recharge the battery, first remove it from the sonde: Remove the lid of the styrofoam cup, then remove the battery without dislodging the circuit board from the enclosure. Use the included charger powered from a USB port. Orange light means the battery is charging. Simultaneous orange and green lights means the battery is fully charged. Charging takes at most 30 minutes.

Fully charged the software reports 4.1-4.2 V battery voltage. The fully discharged voltage is 3.3 V. Therefore the sonde will shut down at this voltage level. The battery voltage is supervised as a sub-system status light in the computer software.

Fully charged the sonde can remain inactive for years and still have enough charge for a sounding. Make sure the switch is in the 'off' position (towards the sensor arm) or remove the battery altogether.

Receiver RR1

The RR1 receiver is a USB unit with SMA antenna contact, to be connected to a Windows laptop. It is powered from the laptop USB port.

- SMA antenna connector
- Receiver with FTDI virtual COM port over USB 2.0
- Utilizes a 100 mW radio transceiver
- Average USB current consumption: 25 mA
- Peak USB current consumption: < 100 mA

Sparv Embedded also offers the more advanced RR2 receiver.

Computer software

Software license

A sounding requires the Windsond application to be installed and running on a Windows computer with connected USB receiver RR1. The software requires a license file to be present to enable the USB receiver. The license filename starts with `windsondlic_` and is received by email. To let the license intially be found and copied by the software, place the file in the root of `C:\`. Without the software, only pre-recorded soundings can be loaded for review.

The license file can also be stored on a USB memory stick. Insert the memory stick before starting the Windsond software to automatically find and copy the license.

Software overview

When the software gains contact with a new sonde a window dedicated to the sonde pops up. The sonde window features a number of tabs to display various aspects of the sonde and the sounding. Above the tabs there is a status text in bold font, showing the current state of the sonde. Closing the Receiver window will close the application and should not be done until the sounding is complete.

The File menu of the Receiver window contains options to load the data of a previous sounding, to view the ongoing flight path in Google Earth and change various settings such as units of metrics.

Among other things, the Settings dialog offers a list of output formats to generate for soundings, in addition to the proprietary .sounding file format. Users can also define their own export formats. The file `fileformat_template.csv.txt` contains instructions how to define custom file formats. The template is found in the directory Windsond was installed in.

Multiple sondes are supported. Each started sonde will open a window specific to that sonde. The window is named by the first time of contact. When opening a previous sounding, a control panel is also shown, supporting start/pause and jumping in the series of received data.

It is recommended to install Google Earth to be able to predict the landing location on a map. Test Google Earth before the first sounding, using a sample sounding file to make sure it works as expected. A sample sounding is included in the Windsond installation directory.

Windsond can also use the OziExplorer mapping software for visualization.

For older Windows versions, the USB receiver might need a driver to be installed before the application can use the receiver. If the hardware is not recognized when connecting the receiver, please download a FTDI Virtual Com Port (VCP) driver from http://www.ftdichip.com/Drivers/VCP.htm

Receiver

When connected, the receiver is assigned a COM port number by the computer, for example `COM2`. This number will be used every time the receiver is connected. If the receiver is used with another computer, a different COM number might be assigned. If several receivers are used with the same computer, they will each get a unique COM number. Remove the receiver from the laptop when not in use as the receiver will otherwise tax the laptop battery slightly, even when not doing a sounding.

Google Earth

Google Earth is available as a free download from http://www.google.com/earth/download-earth.html

Windsond creates a file `windsond_live.kml` with three-dimensional tracks of all ongoing soundings and loaded files. For ongoing soundings with reuseable sondes, some predicted landing sites are marked on the map to help plan for a suitable landing.

The KML file is loaded into Google Earth by a receiver window menu option. This requires Google Earth to be installed and associated with the KML file suffix (as it is per default).

The file `windsond_live.kml` makes Google Earth regularly load another file which lists the active sondes. Each sonde is in turn a separate file, reloaded every five seconds. When starting Google Earth, it might be necessary to double-click `windsond_live.kml` in the Places panel to focus on the flight.

There are three options for accessing map materials, to help plan the landing location:

- With a mobile internet connection, Google Earth downloads the needed maps automatically
- Recently viewed areas are remembered ("cached") so scrolling through the area in advance can preserve those maps once the internet connection is out of reach.
- Google Earth can load and project other maps to become independent of internet data, but such maps have to be acquired somehow.

OziExplorer

Windsond supports the mapping software OziExplorer for visualization. Enable this in the Settings dialog, then start OziExplorer manually. OziExplorer has better support for offline maps than Google Earth.

OziExplorer is available to buy from http://www.oziexplorer.com.

At launch time

The preparations before launching a balloon have three parts: receiver, balloon and sonde. If the launch site can be chosen, a general idea of prevailing winds helps to estimate the area of flight and landing. The online tools http://predict.habhub.org/ or http://astra-planner.soton.ac.uk/ can be used to predict a flight path.

1. Receiver

Start the receiver laptop, connect the receiver dongle and start the Windsond application. The receiver antenna of the "magnetic car roof whip" type needs to be connected. For best reception, place the antenna in the middle of a car roof as the metal surface helps to direct the radio signal. Be careful to avoid squeezing the coaxial cable in the car door; this can ruin the cable and the reception of radio signals. When screwing the antenna to the receiver, don't use force to tighten the nut. Especially the RR2 receiver might be damaged by overtightening the antenna connector.

2. Balloon

Inflate a helium balloon and tie it to the thread of the sonde. Use the full length of the included string (5 meters). If the balloons is hard to tie, a method is suggested at http://windsond.com/instructions_to_seal_balloon.pdf The volume of gas is not important for the measurements but will affect how far the balloon travels before it reaches the peak altitude. For reference, a 9 gram balloon with inflated **diameter of 40 cm** or **circumference of 123 cm** gives a volume of 30 liters and an ascent rate of 2 m/s.

Note that "party balloon helium" commonly sold to consumers has a low purity which means the lifting force is lower than for these numbers helium.

The balloon will expand as it ascends, since the air pressure decreases with altitude. At altitude 5500 m (18000 ft), the pressure is halved and the balloon has double the volume. Over-inflating the balloon might make it burst before the peak altitude. The 9 gram balloon can hold about 80 liters before bursting.

3. Sonde

Toggle the switch to the left to activate the sonde. The sonde immediately blinks once. Reusable sondes also emit two deep tones. (If this does not happen, the battery charge is too low even for a low-altitude sounding.) Make sure the sonde antenna is pointing straight down and that the thread is not tangled or jammed by the lid.

Reusable sondes will now beep with a deep tone every few seconds to indicate it is not ready for launch yet. Before the sonde can be launched, it needs to acquire a GPS lock and get contact with the ground station software. Hold the sonde with a clear view of the sky and be careful not to let go prematurely. After a half to two minutes, reusable sonde emits a series of tones of rising pitch and then beeps with two short, high-pitch tones every few seconds. This means the sonde is now ready to launch at any time. To launch single-launch sondes, the computer has to monitored to know when the sonde is ready.

In sunshine, the sensors need a constant air flow to get accurate readings. If the sunshine heats the sonde before launch, it will take about 30 meters of climb until the air flow makes the sonde adjust to the ambient temperature and humidity. It's therefore best to keep the sonde in the shade before launch.

Due to the continuous battery drain, the sonde should be launched within some ten minutes of activation.

4. Software

For extra safety, check the colored sub-system status panels on the "Sond status" tab of the computer software. The radio subsystem assumes the sonde starts within 5 meters from the receiver antenna. A starting position further away works just as well but the subsystem will complain about low reception. This is normal.

For reusable sondes, also set the approximate peak altitude "cut-down altitude". This is the altitude above ground where the sonde will automatically detach from the balloon and fall to the ground. The cut-down altitude will be remembered to the next flight of the same sonde. The factory setting is 1500 m AGL. Single-flight sondes don't feature the cut-down mechanism.

By default, the first air pressure reading after activation is assumed to be the pressure at ground. The altitude reading of the first GPS fix is assumed to be the elevation of the ground above sea level ("ground altitude"). These two figures are then used to calculate all sonde altitudes above sea level (MSL) and above ground (AGL). These figures can be overridden by the user by adjusting two fields "Ground altitude" and "Ground pressure" on the "Sond status" tab, pressing enter after each change. This is possible both before and after a sounding.

GPS altitude readings can be wrong, even by hundreds of meters. For this reason all altitudes after the initial one are calculated from the known elevation and air pressure at the ground.

To avoid losing any data, Windsond frequently writes files on the computer disk. Under Windows 7, this can make the "Windows Search Indexing" take up a lot of CPU power. Windows Search Indexing can be

disabled for the Windsond folder, or if not needed, disabled altogether (http://www.howtogeek.com/howto/10246/how-to-disable-search-in-windows-7/).

During a sounding

Radio communication

The radio communication between USB receiver and sonde uses the 434 MHz radio band, with 100 mW effect. The exact frequency is configurable at run-time in the range 400-479.9 MHz. The transmission power can also be lowered to follow local radio regulations. For safety, before launch check that the software reports a solid radio link by a green radio sub-system panel on the status tab.

When the sonde starts, it looks for the receiver at the last known frequency for 5 seconds. If the receiver is not found, the sonde starts alternating between a pre-defined frequency (434.00 MHz) and the last known frequency. At first start of a new sonde or to make the sonde recognize a new frequency, press the software button "Pair with sonde" until a window appears for the new sonde.

Transmission speed and encoding settings are also communicated to the sonde. The encoding settings allows multiple systems can co-exist in the same area. Note that the binding procedure above means any sonde can be transferred to a new receiver if the previous receiver is not connected when the sonde is started.

The radio link exceeds 10 km in open terrain and has sometimes worked at 50-100 km distance, using the included omnidirectional car root antenna. Note that obstacles in the direct line-of-sight between sonde and receiver (such as trees and buildings) can break the link. For best transmission, the sonde antenna should be kept straight and vertical. The receiver antenna should also be vertical. Reception straight underneath the flying sonde will suffer because of the antenna orientations.

The reception quality reported by the software runs 0 - 100%. Unless the software reports a loss of connection, the data connection is fully functional, without data corruption, regardless of the reported reception. When the sonde is within a few meters of the receiver at the starting point, normal reception is 85-95%. During flight, the number will quickly drop to 30-50% as the distance increases. Reception lower than 20% indicates that the connection might soon be lost; assure a good receiver antenna location and review the automatic cut-down altitude.

The option "Pling when data arrives" in the sonde "Control" panel offers audio feedback of each received radio packet. High tone pitch means a strong signal was received, low tone pitch means a weaker signal.

When the sonde falls to the ground, the connection is typically broken due to obstacles on the ground. When retrieving the sonde again, the reception returns at typically 100-400m distance, depending on landing and terrain.

For later retrieval of the sonde, a data connection close to the top of the ascent is very helpful to get a good idea of the landing location.

Measurements

The sonde sends weather data in real-time to the receiver, in a data packet every third second. Each data packet contains three measurements, for a sampling frequency of 1 hz. The standard sonde versions do not record the data. If some radio packets are lost, the data at that altitude is lost as well. The software will instead interpolate the values from known data.

The weather panel shows wind direction, wind speed and temperature/humidity. The measured values are displayed as dots and averaged values are displayed with bold lines. Gray, thick grid lines mark every 1000 m or 3000 ft of altitude above MSL. In the direction plot, each 90 degrees is also marked by a gray line. Missing data shows up as bigger gaps between the dots.

Holding the mouse pointer over the plots displays a tooltip with all averaged values at the altitude of the mouse pointer tip. Clicking on a plot will maximize that plot to cover the whole window. Clicking again restores the view.

The report panel presents the generated data in a number of formats. Through the Settings dialog, available from the menu of the receiver window, the user can choose from an array of supported data formats. The formats will show up in the dropdown of the report panel, along with an "Overview" option that shows statistics on the sonde status and path. The report panel and the corresponding data files are updated in real-time as new data comes in from the sonde.

Additionally, all received data is logged in a file named with the starting date and time and file suffix "sounding". The default directory is My Documents/Windsond files. This directory can be changed in menu File -> Pick log directory.

Sounding files can be loaded at later time by File -> Open. This presents a control panel to load all data or replay the flight with control over position and speed.

Data correction

The software optionally calculates the following corrections. These can be turned off in the Settings. Custom output formats can choose whether to include uncorrected or corrected values.

- direction, a correction based on magnetic direction is available
- humidity, a correction based on the air temperature, light intensity and sun position
- temperature, a correction based on the sun effect using light intensity and sun position
- plots, an averaging algorithm is used to present smother plots on weather tab

Terminating a sounding

Data files can be copied and used at any point during an ascent or descent. While the very latest data might not yet be recorded to file, the output files are continuously refreshed as new data is received. The data collection is complete when the sonde has reached its highest point. Additional data will be collected during the fall and on the ground, until the sonde is recovered and turned off, but this data is not generally not necessary.

Closing the sounding window will stop the data collection to that sounding. Clicking "close" in the list of soundings in the receiver window will have the same effect. Any additional data from the sonde after this will open a new window to collect data from a new sounding.

Reusing sondes

This section is only relevant for reusable sondes.

Picking the landing location

During the flight, the computer program predicts the landing location from ascent rate, wind conditions and from the assumed future fall speed. Predictions are given after the sonde ascends above 60 m AGL. The landing location of an immediate cut-down is predicted with an accuracy generally better than 50 m. This accuracy mostly depends on predicting the right fall speed (configured in menu File -> Settings). Predictions of landing locations are also given on Google Earth for some higher cut-down altitudes and for the currently set cut-down altitude. These assume the current wind direction and speed will prevail at higher altitudes. Since the wind probably changes to some degree at higher altitudes, keep an eye on how the predictions change with time.

There are two different conditions that each will cause the sonde to detach from the balloon thread and fall to the ground:

- The sonde exceeds the programmed cut-down altitude AGL for a couple of seconds
- The user sends a manual cut-down command

The cut-down altitude is visible on the "Status" tab. Change the value and press Enter to send the new setting to the sonde. The status text next to the input field tells if an acknowledgement from the sonde was

received. Immediate cut-down is done by the button "Cut-down now!". On the Status tab is also an input field where the user can set the name of the launch site, for future reference. Options for launch sites can be entered in the windsond.cfg file, under the section "sites". Each site needs a unique key.

To pick the best cut-down altitude, choose the menu option File -> Google Earth live view in the Receiver window. The flight path of the sonde and some predicted landing sites are marked on the map and continuously updated.

All altitudes in Google Earth are specified AGL (altitude above ground level). The ground level is determined from the first altitude reported by the GPS when first starting, or by a user-supplied value as detailed earlier.

The most accurate choice of landing site is achieved by releasing the sonde manually when the Google Earth map landing pin reaches a convenient location. For the eventuality that the sonde has weak radio reception at the moment of desired detaching, set the cut-down altitude in advance to still give a landing site reasonable close.

If the sonde payload is changed in any way, the assumed fall speed has to be adjusted to give accurate landing predictions. The report panel calculates the actual fall speed of each sounding.

Cut-down and fall

This section is only relevant for reusable sondes.

When reaching the peak altitude, the sonde detaches from the balloon (cut-down) to fall to the ground and enable recovery. The cut-down is performed by heating the polyester thread to its melting point, virtually instantaneously. In case the cut-down fails, the sonde will continue to try to do cut-down with the primary and secondary cut-down wires.

The fall speed is about 7.5-8.0 m/s. Thanks to the low weight, a parachute is not necessary. Low weight, moderate fall speed and non-rigid antenna means a falling sonde does not pose any risk to objects or people on the ground.

The metal loops are fragile and break at about 0.9 kg of force. This is enough to withstand the forces during flight, but avoid yanking on the thread.

Retrieving the sonde

When the sonde lands, it goes through three modes to save power and prolong the duration during which it actively helps in the recovery. The modes are as follows:

- `FIND ME` ("On ground, beeping"): Play a few tones (first rising, then falling tones) and blink every 5 seconds. Send GPS reports every 4 seconds. After 45 minutes, change to `SLOW FIND ME`.
- `SLOW FIND ME` ("On ground, sometimes beeping"): Play tones and blink every 15 seconds. Send GPS reports every 4 seconds. After 3 hours, change to `POWERSAVE`.
- `POWERSAVE` ("On ground, silent"): Do not blink or beep. Send a brief radio message every 15 seconds and listen for the receiver to reply. Send the full GPS position once every two minutes.

The user can choose before or during the flight which mode to enter at landing:

1. `Beacon at once` - If the sonde will be retrieved within a few hours. The beeping will make the sonde easy to discover for anyone.
2. `Power-save` - If the sonde will be retrieved within a couple of days. By bringing the ground station when retrieving the sonde, the receiver will "wake up" the sonde to `FINDME` mode once radio contact is re-established (within 300-1000 m of the sonde).

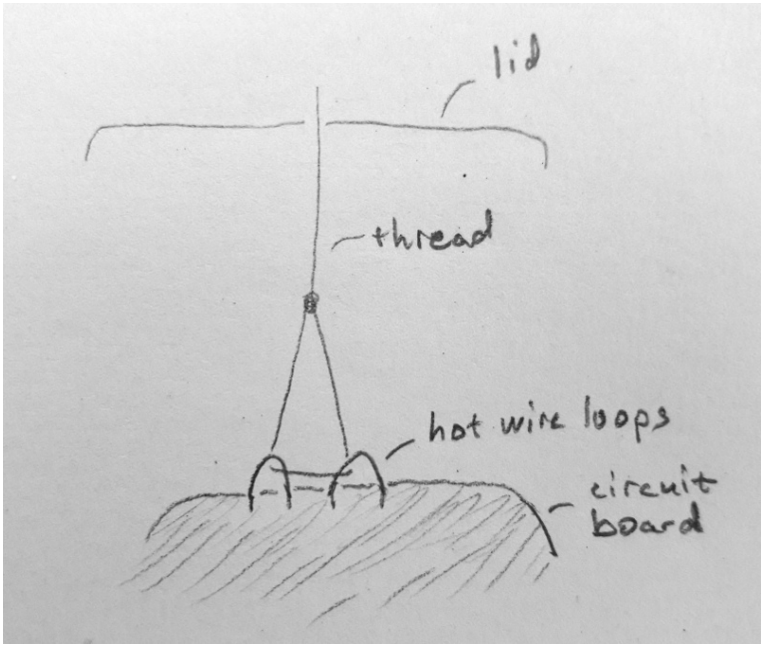
If the sonde lands some distance away from the road, it is very helpful to have a GPS device that can visualize the position relative to the GPS device or even point a compass arrow towards the position. Smartphones also offer this possibility with a suitable app. For Android, the free app "GeoHunter" supports entering custom coordinates in DD MM.MM format. The Windsond application can switch between different coordinate formats from the menu File -> Options.

Preparation for the next flight

This section is only relevant for reusable sondes.

Toggle the switch to the right (towards the sensor arm) to deactivate.

Charge the sonde battery using the USB-powered charger. Remove the lid of the styrofoam cup, then remove the battery from the circuit board and charge it with the included charger. The battery is fully charged when the orange charger LED turns off, within 30 minutes. When connecting and disconnecting the charger contact, be careful not to displace the circuit board or damage the enclosure. To avoid pulling the circuit board out of position, it might be necessary to brace against it when pulling out the battery cable.



Tie a new piece of string, five meters long, to the circuit board by carefully leading it through the thin metal loops labelled "LIFT 1" and "LIFT 2", using a pair of tweezers. The metal loops are so thin they are hard to spot but the round fastening points are easy to distinguish. If possible, avoid removing the circuit board from the enclosure when doing this. Avoid excessive force or bending of the fragile metal loops. Check that the thread does not tangle in the battery so the sonde cut-down will work. The sonde will perform a self-test of the cut-down wires on start-up, and the software status panel will warn if there's a problem.

The computer program cannot handle a second flight of the same sonde without closing the sonde window in-between.

Environmental considerations

Windsond does not contain materials harmful to the natural environment. Neither battery nor electronics components contain heavy metals. The latex balloons used are biodegradable. If a sonde is not recovered, it will unfortunately contribute to the litter in our environment. While regrettable, this can be compared to around a thousand weather balloons 10-30 times the Windsond weight that are released in the world every day without an ambition to recover the parts.

Disclaimers

Sparv Embedded and its employees are not liable for any losses or damages arising from the use of Windsond, with causes including but not limited to measurement errors, equipment failure or misuse.

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