The authors thank the reviewer for the critical and competent comments on the manuscript. All replies to these comments are inserted below (in yellow) and information is provided, how the manuscript has been changed accordingly (in green). In the revised text the new parts are highlighted in grey.

Summary:

The manuscript by Kottmeier et al. describes the KITsonde dropsonde system, which can release 4 sondes simultaneously inside a dedicated launch container. This allows dropping either meteorological sondes of the same type, or sondes measuring different parameters such as cloud particles and gamma radiation. This system also allows direct transmission of data to the ground via a communication satellite.

This manuscript discusses the details of the dropsonde system and shows data from several field campaigns to demonstrate its capability.

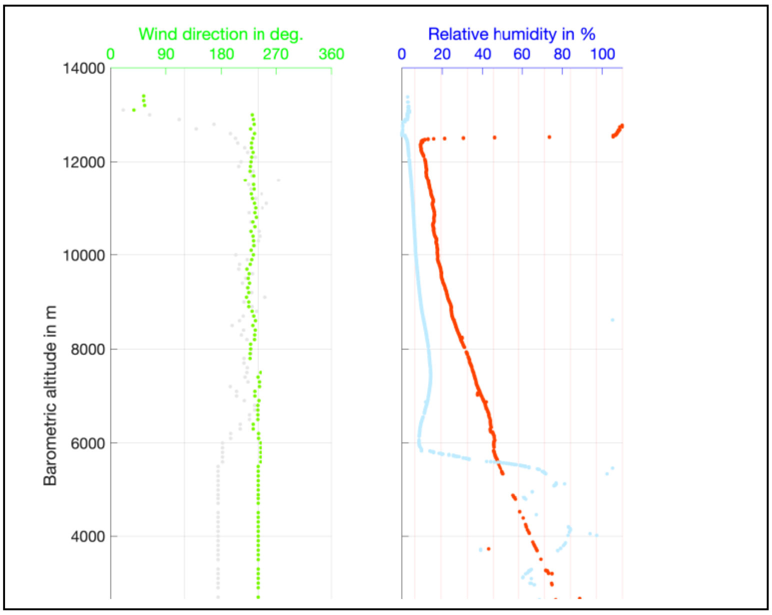
The manuscript is overall well written. Some details require more discussions and clarifications, and I can recommend publication of this manuscript after some minor modifications following comments listed below.

Detailed comments:

Section 2.2: How long does the release of the individual sondes from the release container take and how much time or altitude below the aircraft is lost before measurements can be considered reliable as a result of this delay?

The delay time consists of three parts: (i) the programmed delay between the detection of a release from the aircraft and the begin of the container opening, (ii) the time for opening the container, and (iii) the time needed by the sensors to adapt to the surroundings, and, respectively for the wind, the time needed by the GPS-receiver to provide georeferenced position data. For wind, experience shows that a cold start time to first fix of less than 30 s can be usually achieved with 10-15 satellites in view. The total delay of (i) – (iii), in accordance with analyses of SouthTRAC data is less than 30 sec, corresponding to 500 – 1000 m at 12 km height. For wind, the total delay time may be up to 60 sec.

An example is given in the figure below. Obviously the meteorological sensors seem to adapt to the ambient air immediately after leaving the aircraft, reducing the height range of „lost“ data below the aircraft to about 500 m. The equivalent height range for wind is closer to 1000 m.



In the revised version (lines 179-181) we added "In agreement between preset delays and profile analyses, the total time to get reliable temperature, humidity and pressure is less than 30 sec, respectively 500 m for HALO when dropping from 12 km height. Wind is typically already calculated correctly within less than 60 sec, respectively 1000 m".

Lines 231ff: The heating feature of the DFM-17 reduces the risk for evaporative cooling after exiting clouds. The lack of this feature in the dropsonde variant is relevant and could extend the perceived cloud thickness to lower altitudes and could potentially lead to evaporative cooling at cloud base. This potential limitation needs to be discussed. Does the sonde measure and report the temperature of the humidity sensor?

The dropsonde measures and reports the temperature of the humidity sensor. As the temperature sensor cannot be collocated on the humidity sensor, there is a small space between the two sensors, which leads to a larger uncertainty component than with the heated sensor. Nevertheless, the temperature data can be used to correct the humidity measurement for the temperature of the humidity sensor. We have rephrased the sentence to highlight this better. This setup is also able to detect situations, where the humidity sensor might experience more wet-bulbing than the ambient temperature sensor. The main difference between the two sensors for cloud-exits is the faster response time of the heated sensor. However, in the dropsonde application, response time decreases during flight progression, inverse to radiosonde operation.

The whole text block below Table 1 has been slightly rearranged. Especially:

Modified text (now lines 240-247): "The humidity sensor uses the same type of polymer but is unheated and has its accompanying temperature sensor located a few mm apart. The heated humidity sensor of the latest DFM-17 generation was not yet available at the time when the EL-18 was designed. The close temperature sensor can be used to correct the humidity measurement for the humidity sensor temperature. Still, this slightly reduces dynamic performance and response time, especially after the sensor has experienced precipitation. However, as the sensor response time decreases during the sounding, inverse to radiosonde operation, this problem is not as severe as with radiosoundings. As for most radiosonde algorithms (Dirksen et al. 2024), an active clipping of measured relative humidity values > 100 %RH is performed. Humidity values before clipping of up to 120% could be observed, which is a typical value."

Do you have access to raw humidity data without clipping? That would provide some feeling about the issues of measuring RH near saturation. This should be discussed to

There is access to raw humidity values without clipping, and the humidity shows spikes in saturation conditions of up to 120 %, which is a typical value when small amounts of water are present on the sensor. We added a sentence to clarify this.

Added text in lines 245-247: "As for most radiosonde algorithms (Dirksen et al. 2024), an active clipping of measured relative humidity values > 100 %RH is performed. Humidity values before clipping of up to 120% could be observed, which is a typical value."

Section 2.4: This section should include the process how the meteorological sonde is released from its release container when satellite communication is used to transmit data to the ground directly. This is mentioned later in the manuscript.

The launching process in satellite configuration is in principal similar to the standard configuration with meteorological sondes. The release container detects the dropping process and activates the main parachute. After deceleration and vertical orientation of the release container the payload is set free. In this case the payload consists of (i) one meteorological sonde, connected via a cable of 5m length to (ii) the insert containing the satellite modem with communication antenna and batteries and (iii) the parachute. The size of the parachute is larger than those used for the small meteorological sondes to achieve decent rates of about 10 m/s.

The following text is added in lines 282-287: "The launching process in satellite configuration is similar to the standard configuration with meteorological sondes. The release container detects the dropping process and activates the main parachute. After deceleration and vertical orientation of the release container the payload is set free. In this case the payload consists of (i) one meteorological sonde, connected via a cable of 5m length to (ii) the insert containing the satellite modem with communication antenna and batteries and (iii) the parachute. The size of the parachute is chosen larger than those used for the small meteorological sondes to achieve decent rates in the order of, e.g., about 10 m s^{-1}."

Section 2.5: How can you be sure that the airflow through the particle detector is close to the ambient fall rate? Is the central channel straight without any obstructions? Can you account for any pendulum motion of the sonde, which would invariably affect the air flow through the instrument? Some discussion follows later but should be moved here. The meteorological sonde hanging below the OPC carries the risk of particle shedding, in particular after passing through clouds, which the particle detector may sense. This is probably not an issue for aerosol particles but should be mentioned.

Detailed descriptions of the particle detector (OPC) and its performance are provided in the references already cited (Smith et al., 2018; Girdwood et al., 2020), and answers to the Reviewer's questions can be found there. In particular, the channel is free of obstructions. As for the „pendulum motion", Smith et al. (2018) state: „*To constrict the movement of the UCASS, the payload is configured as a double pendulum...*", with the text which follows explaining that this configuration increases energy dissipation and restricts the motion of the OPC (which for both the balloon and the dropsonde case resides in the middle of the „train", as stated in the text). There are also descriptions of both computational fluid dynamics modelling and flow tests, including the impact of flow direction angle, but too extensive to repeat in the present submission. We refer the Reviewer and the future readers to these publications. As for particle shedding, if it occurs, there has been no evidence that it affects the OPC, e.g. following passage through clouds (where number concentrations are more than an order of magnitude greater than outside – see Fig. 11).

Following the reviewer, we moved the section „After release, the meteorological sonde and the OPC separated, but remained tied together by a 1 m long polyester line, with the meteorological sonde located lowest, followed by the OPC, and the parachute attached at the top of the "train" (Fig. 6d). This configuration creates a double pendulum which tends to dissipate kinetic energy and helps to reduce swinging motions of the OPC, thus aligning it with the air velocity vector for correct particle sampling (Smith et al., 2019)." to this place (line 335 in revised paper).

Incidentally, the submitted text requires a correction in three places, Smith et al. is cited variously as 2018 and 2019, but only the 2019 year is correct.

Line 253: The statement about size and cost is relative and should be deleted here.

Accepted, i.e. the statement dropped in the manuscript

Section 2.6: Can you show the profile of the test drop near Magdeburg? There is possibly a detectable increase in radioactivity due to cosmic ray activity as a function of altitude, which would be worthwhile showing. This would give a feeling of the baseline that the detector would see.

We agree that such an increase in the detected signal would be a good indicator of the baseline the counter sees. Geiger-Müller-Counters, however, are known to be not ideal for cosmic ray measurements, since they lack energy discrimination and have low efficiency for detecting high-energy muons. As we do not see a clear increase in this single profile, we prefer not to show it and to gather more information with the system, before a discussion of quantitative data becomes possible.

For temperature, humidity, pressure, and wind it would be good to know what the true uncertainties in flight are after all systematic and random errors are considered. The uncertainties listed in Table 1 are extremely optimistic and unrealistic for real world observations. This becomes relevant when the reader tries to interpret the differences of soundings discussed in section 3. Large scale structures shown in Figure 9 are certainly real, but when the differences reach those of the stated uncertainties, caution is warranted.

The uncertainties stated in Table 1 are derived from the manufacturer's specifications, based on industrial sensor production processes and testing. Real world uncertainties depend on several changing influences, such as solar heating, and riming on sensors. There have been previous validation flights against radiosondes, but from these, no general quantitative uncertainties can be derived. We have added a paragraph in section 2.3 where we set the expected uncertainties in context to the uncertainties observed in the UAII 2022 campaign. This extense radiosonde intercomparison, although not fully applicable, gives important information on the DFM-17, the EL-18 being derived from it's electronic circuity and sensors (with some changes, discussed in the proposed added text below). The authors are not aware of sufficient experimental approach for dropsondes, neither by other manufacturers or at all, to assess similarly the real world uncertainties.

Additional text in lines 230-244:

“The uncertainties stated in Table 1 are derived from the manufacturer’s specifications. To estimate whether these can be used as uncertainty estimates for the EL-18 dropsonde electronics, a closer look at the WMO intercomparison campaign UAII 2022 (Dirksen et al., 2024) is undertaken. In particular, the sensors and analogue to digital converter circuity as well as the manufacturing and calibration processes are the same for both sondes. The EL-18 uses a slightly modified sensor boom shape to accommodate the dropsonde application (Fig. 5b). Due to the different nature of the applications, not all corrections used in the DFM-17 data product can be used for the EL-18. The measurement method for all GNSS-derived variables, such as wind and geopotential height, all measurements are identical between the two sondes. For pressure, there might be a small decrease in uncertainty near the ground due to the dedicated barometric pressure sensor, compared to the DFM-17 used in the UAII 2022 campaign. The temperature sensor is also identical between the two models, however, the dropsonde uses a slightly altered solar correction model to account for the different orientation of the sensor boom and the adjacent parts of the housing. The humidity sensor uses the same type of polymer but is unheated and has its accompanying temperature sensor located a few mm apart. The heated humidity sensor of the latest DFM-17 generation was not yet available at the time when the EL-18 was designed. The close temperature sensor can be used to correct the humidity measurement for the humidity sensor temperature. Still, this slightly reduces dynamic performance and response time, especially after the sensor has experienced precipitation.”

A particular challenge for dropsonde measurements is their validation. Are there any baseline measurements on the aircraft prior to launch? Are there any additional measurements on the ground prior to a mission? Have there been any attempts to compare the dropsonde observations with nearby balloon or remote sensing (e.g. lidar) measurements? Have there been any attempts to have four sondes from a release container to measure as close by as possible, i.e. using identical parachute size? If so, it would be good to show the scatter of all four sondes around their mean. Any additional information that could be used to quantify the accuracy of the measurements in flight would be helpful to get a better impression about the true capabilities of the meteorological sondes.

The general part of the question is similar to the one above, and is answered there. In addition:

- no ground measurements are done before flights, other to radiosondes; ground data before a flight would also differ much to those of dropsondes landed later and elsewhere
- aircraft data from flight level are available for rough comparison with dropsondes once adapted to the surroundings (i.e. a few hundred meters after dropping)
- comparisons between several sondes with identical parachutes have not yet been done; several hundred of sondes launched during the upcoming ASCCII and NAWDIC campaigns will provide opportunities. But we optimistically expect, that sondes following industrial production standards will under same conditions behave according to the given uncertainties.

Line 379f: You correctly state that the atmosphere above 2 km is stably stratified. What then does the statement refer to that says "Two more stable shallow layers are present at about 6 and 8 km AMSL", when the entire region is stable? Please clarify.

We rewrote the sentences for clarification (new lines 444-447)

"The four temperature profiles in the area east of the Sierras de Córdoba show a similar vertical stratification (Fig. 10a). A well-mixed boundary layer reaches up to approximately 2 km AMSL and stable stratification of approximately 4 K km^{-1} is found above. Additionally, in the data of sonde 1a and 1b shallow layers with stronger stability can be found at the top of the cloud layer, i.e. between about 5.5 and 6.0 km AMSL (Fig. 10b)."

Line 381f: There seems to be a problem with the color coding of the profiles or with referencing the profiles in the text. The cloud top in profile 1d seems to be closer to 4.5 km (not 5.5 km). Profile 1c (not 1b) does not appear to fall through a cloud. Please check the description of the text of this section.

The suggested modifications were applied (new lines 447-451)

"The largest differences between the profiles of the sondes are obtained for relative humidity (Fig. 10b). While sonde 1d measures the cloud top at about 4.5 km AMSL already, sonde 1c did not even fall into a cloud at all. The cloud bases also vary considerably, i.e. between about 1.5 km (sonde 1b) and about 3 km AMSL (sondes 1a and 1d). Thus, the high thermodynamic variability in areas with deep convection is captured well by this kind of quadruple information – which cannot be provided by individual dropsondes or single radiosondes."

Is there a reason that all four sondes of drop 1 seem to be missing data in the region between 10 km and 11 km? The wind speed in that layer seems to be at or above 50 m/s (not 40 m/s as stated).

The missing data between 10 and 11 km are due to transmission problems for unknown reasons, i.e. no data could be received from the sondes. 40 m/s has been replaced by 50 m/s (also indicated in red in the text)

"The horizontal wind speed varies between 5 m s^{-1} at 2 km AMSL and 50 m s^{-1} at 10 km AMSL (Fig. 10c) in all profiles."

The new textblock in the revised version (lines 444-454-388 with changes in red) is:

"The four temperature profiles in the area east of the Sierras de Córdoba show a similar vertical stratification (Fig. 10a). A well-mixed boundary layer reaches up to approximately 2 km AMSL and stable stratification of approximately 4 K km^{-1} is found above. Additionally, in the data of sonde 1a and 1b shallow layers with stronger stability can be found at the top of the cloud layer, i.e. between about 5.5 and 6.0 km AMSL (Fig. 10b). The largest differences between the profiles of the sondes are obtained for relative humidity (Fig. 10b). While sonde 1d measures the cloud top at about 4.5 km AMSL already, sonde 1c did not even fall into a cloud at all. The cloud bases also vary considerably, i.e. between about 1.5 km (sonde 1b) and about 3 km AMSL (sondes 1a and 1d). Thus, the high thermodynamic variability in areas with deep convection is captured well by this kind of quadruple information – which cannot be provided by individual dropsondes or single radiosondes. The horizontal wind speed varies between 5 m s^{-1} at 2 km AMSL and 50 m s^{-1} at 10 km

AMSL (Fig. 10c) in all profiles. The wind direction in the boundary layer shows some veering from northerly to westerly winds. It is predominantly northwesterly between 2 and 6 km AMSL and westerly above (Fig. 10d). This vertical profile of the horizontal wind is visible in all four soundings. "

Lines 414ff: This explanation about the OPC sounding should be moved up to the instrument description in section 2.5.

Yes, we agree, that fits better.

The sentences

"After release, the meteorological sonde and the OPC separate, but remain tied together by a 1 m long polyester line, with the meteorological sonde located lowest, followed by the OPC, and the parachute attached at the top of the "train" (Fig. 6d). This configuration creates a double pendulum which tends to dissipate kinetic energy and helps to reduce swinging motions of the OPC, thus aligning it with the air velocity vector for correct particle sampling (Smith et al., 2019)."

are moved to section 2.5.

Line 424: Figures 13 and 14 are referred to before Figures 11 and 12. Please add a reference to Figure 11 and 12 before that.

Checked and modified

Line 472f: Paragliders require active control or the parafoil. Are there any plans to implement this? Otherwise, maybe delete this statement.

We think of parafoils. As a future option this seems worth mentioning, since there are several inexpensive models available. The container concept of the KITsonde allows for simple ways of testing.

Paragliders replaced by parafoils.

Lines 494ff: Although I don't doubt this capability, you only showed evidence for one Sahara dust layer, but not for any aerosol layer embedded in clouds. If such results exist, it would be good to include them, otherwise this statement should be revised.

The sentence in 494ff reads: "Tests presented here demonstrate that the soundings do not only yield the profiles of coarse aerosol, but also allow for the identification and characterisation of embedded cloud layers." We do not claim to be able to identify aerosol layers within clouds.
While cloud layers embedded in dust are easy to identify in UCASS data, the reverse is not necessarily the case. This is because number concentrations of larger particles are many times greater in clouds than in dust layers. Consequently, in clouds the presence of coarse dust is „masked" by the presence of droplets – see Fig. 11. Having said that, the presence of dust within a cloud could be apparent if the OPC was calibrated to count particles within a lower, submicron size range, below the size range for cloud droplets. However, while technically possible, this remain hypothetical.

We believe the text is correct as stated

Line 507f: What is meant by “aviation consulting processes”? Please clarify.

Line 508f: Similarly, what is meant by “a concept for validation based on measurement data”?

We clarified the sentences in Line 577 and 581 and modified the description (new lines 569-573).

“One aim of MEASURE is the implementation of dropsondes into a drone-based measurement system for use in a radiological emergency. Quickly available dropsonde profiles can offer substantial added value in evaluating potential pollutant distributions in the airspace, thus supporting the aviation consulting process of DWD. In addition, real-time data from dropsondes provide a valuable contribution to the validation of radiological dispersion calculations of DWD, which serve as a reliable information basis for decision-makers.”

Line 62: The reference by Hartmann et al., 1996 does not mention any dropsonde releases. The Berichte zur Polarforschung Nr. 218 was published in 1997. If dropsondes were released during that project, a different reference would be helpful.

That is right, we added a reviewed paper (Chechin et al., 2013) instead, that makes extended use of these dropsondes.

Chechin, D. G., Lüpkes, C., Repina, I. A., & Gryanik, V. M.: Idealized dry quasi 2-Dmesoscale simulations of cold-air outbreaks over the marginal sea ice zone with fine and coarse resolution. J. Geophys. Res. Atmos., 118(16), 8787-8813, https://doi.org/10.1002/jgrd.50679, 2013.

Table 1:

Table 1 lists uncertainties and reproducibilities. What is their significance level, i.e. one standard deviation (k=1) or two standard deviations (k=2) or something else?

The significance level is given as k=2. We have added a footnote to the table to clarify.

Footnote Table 1: Uncertainties are expressed with 2-sigma confidence level (k=2).

The datasheet for the Bosch Sensortec pressure sensor lists its operating range as 300... 1250 hPa. Where does the measurement range to 1 hPa and the uncertainties at the lower pressures come from?

The measurement data from the BMP388 is used at lower altitudes, while a GNSS derived pressure is used at higher altitudes. This approach combines the advantages of both barometric pressure sensors and GNSS-derived pressures. We have added a footnote to the table to clarify.

Footnote Table 1: GNSS derived pressure is used to augment the barometric pressure measurement at lower pressures.

The measurement range for the wind speed is probably larger than 200 m/s and the sonde can probably sense the aircraft speed prior to launch.

Thank you for pointing that out, the maximum value is indeed 500 m/s. Yes, GPS reception is only interrupted in the dispenser tube and 100 – 200 m below the aircraft.

We have corrected the value in the table accordingly.

Figures:

Figure 5: Where is the humidity sensor located and what is the airflow around it?

We replaced Fig. 5b by a figure showing the location of the humidity and the temperature sensor better.

Figure 8, legend: change “white circles” to “white dots”

Right, done.

Figure 11, legend: Please make sure that the unit µm is displayed properly (also in lines 438 and 440). Capitalize “Individual”.

That has been corrected.

Technical comments:

Lines 33-35: Rephrase to improve the clarity of that statement.

Corrected text (changes in red)

Moreover, a configuration consisting of a meteorological sonde coupled with an optical counter for particle sizing was tested during a Saharan dust episode over Germany using a Dornier Do 128-6 aircraft. Secondly, a meteorological sonde together with a radioactivity sensor was successfully dropped from a Learjet 35A.

Line 48: A better reference to the NCAR dropsonde is:

The reference is replaced as proposed.

Hock, T. F., and J. L. Franklin, 1999: The NCAR GPS Dropwindsonde. Bull. Amer. Meteor. Soc., 80, 407–420, https://doi.org/10.1175/1520-0477(1999)080<0407:TNGD>2.0.CO;2.

“Airborne” replaces “Advanced”

“on” changed to “for”

Line 145: insert a hyphen into “system-control”

Done

Line 189: replace “independently” with ““independent”

Done

Line 319: Add “/” to “Upper Troposphere/Lower Stratosphere”

Done

Line 338: The distance given sounds a little short.

Due to strong headwinds the airspeed above ground was less.

We replaced by

At true air speed of 200 m/s and strong head winds of 50 m/s, 1 to 2 min corresponds 9 to 18 km.

Line 339: What are typical dropsonde parachute cross sections?

A new section on the parachutes for the EL-18 and their dimensions is added in Section 2. We analysed the fall speeds depending on effective size in dependence on height. (see below)

The parachutes for the container, for the coupled radioactivity/meteorological measurements, and the particle/meteorological measurements are different and of the shape of the figure below. It consists of 5 quadratic sections, each 15 x 15 cm. The total area is 1125 cm^2.

New section added:

2.3.2 Parachutes

The parachutes are chosen to determine the descent rates, which affects how closely the sounding trajectory approximates a vertical profile as well as how closely the sounding approximates to an “instantaneous” profile. The parachutes of 64 cm in diameter for the EL-18 being used are manufactured by BBL Elektronik & Aeromet GmbH (https://www.meteorologyshop.eu/en/balloons/radiosonde-balloons/368/meteorological-parachute-pc-055). To allow for different fall speeds, the effective areas of the parachutes were reduced by cutting away outer trapezoidal sectors of fabric between the holding lines. Tab. 2 shows the effective diameters, corresponding to the effective area of the parachute. Fall speeds versus parachute size were analysed for the SouthTRAC Campaign (see Sect. 3), where 60 meteorological sondes EL-18 without any additional sensor or communication electronics were used.

Table 2: Mean fall speed and standard deviations in m s^{-1} of meteorological sondes dropped with parachutes of different effective diameters. The fall speeds are given for different height ranges during the SouthTRAC campaign.

Height range (km)	Parachute effective diameter (cm) in line 2 and area (cm^2) in line 3 for the meteorological sonde EL-18 of 73 g weight			
	64	40	32	24
	3217	1257	804	452
8 - 12	4,5±1,2	7,0±2,1	8,1±2,1	11,2±1,6
4 - 8	3,3±1,0	4,9±1,5	5,9±1,4	8,7±1,0
0 - 4	2,6±0,6	3,8±1,2	4,8±1,1	7,3±0,5

The parachutes for the container, for the coupled radioactivity/meteorological measurements and for the particle/meteorological measurements are more robust and of a x-pentamine shape. They are manufactured by Spekon Co. (https://spekon.de/seilschirme.html) and consists of 5 quadratic sections, each 15 x 15 cm. The total area is 1125 cm^2.

Line 466: Replace “aöö” with “all”

Done

Lines 355 and 470: Please specify the altitude for this fall rate. Or alternatively, specify the fall rate near the surface.

A new section on the parachutes is added in Section 2

Line 484: Replace “exposition” with “exposure”

done

Table 1 lists a Tellit J-N3 GNSS module as well as a UBLOX MAX-MBC. I assume the text is correct and that the UBLOX MAX-M8C is used. Please correct Table 1.

The module correctly is „u-blox MAX-M8C“

Corrected in Table 1