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PRELIMINARY RESULTS OF LOW ALTITUDE ROCKETSONDE METEOROLOGICAL PAYLOAD DEVELOPMENT

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Abstract

Preliminary results of low altitude rocketsonde meteorological payload, development for RX-100 rocket has been tested. The payload was designed based on RX-100 specification and related atmosphere region condition of RX-100 trajectory. In its test, the payload was launched using 1000 g meteorological balloon. The payload transmitter system test showed that it was reliable until 12 km altitude. While on temperature and relative humidity sensorSHT11 test, it seemed that sensor environment conditioning and its pipeline was not good enough to create good air circulation as expected, and as a result it did not have good response to atmosphere condition change compared to radiosonde data. As for the pressure sensor MPX4115AP test, despite it has close profile to radiosonde data, it still has slower response with increasing height probably due to it has only limited space inside the payload after being casted using polyurethane even though it has attached transparent pipe as a requirement for inside room placement. In this test also, the parachute has not been tested properly as the balloon just torn apart after it exploded causing the parachute did not deploy and it descended faster than expected. Therefore, the developed payload still need further improvement and test.

Key Words: *Meteorological payload, RX-100, pressure, temperature, humidity.*

Nomenclature

V :speed
W :weight
M : mass
D : diameter

Subscripts

T :total
PY :payload
B : balloon
PC : parachute

1. Introduction

Atmosphere vertical profile study is one of the prerequisites for understanding the various processes taking place in it. Particularly, gaining knowledge on the vertical profile of the atmosphere over the topics is extremely necessary, where the high solar irradiance is responsible for atmospheric processes of different spatial scales, such as the development of deep convective systems, which transport energy and momentum from the low to the high altitudes, higher production rate of ozone molecules in stratosphere and the equatorial electro jet formation in ionosphere[1)].

Vertical profile of the atmosphere can be measured using ground-based, in-situ, and satellite instruments. Each instrument will complement each other to obtain accurate and comprehensive analysis of the phenomena being measured. The in-situ instruments used for this measurement are balloon sonde, air plane, and rocketsonde. Balloon sonde usually used for vertical profile measurement up to 30 until 40 km. While rocketsonde usually used for measurement up to altitude of low earth orbit satellite.Nowadays, there are several programmed of rocketsonde conducted by several country or institutes, such as NASA and ESA sounding rocket, which are for high altitude measurement. But, there is also utilization of rocketsonde for low altitude measurement, such as Vaisala RK91 rocketsonde which is used for atmospheric parameter measurement in boundary layer region, especially in some cases where the use of the conventional sounding techniques such as free-flight radiosonde or tethered balloon is not practical. Where availability of helium or hydrogen is a problem, or when ease and speed of deployment is desirable[2)].

The objective of this research is to develop a low altitude rocketsonde meteorological payload as an alternative for radiosonde and also for preliminary development of LAPAN rocketsonde meteorological payload. The payload was designed for RX-100 rocket produced by LAPAN which has maximum altitude until 6.83 km[3)]. The vertical profileof the atmosphere will be measured are pressure, temperature, and relative humidity.

2. Payload Design, Realization and Test

2.1. Payload Design

The payload was designed to be installed inside RX-100rocket, therefore its dimension and characteristics should match to the RX-100 specifications as mentioned in Table1[3).]Based on the specification in Table1 and related atmosphere region condition of RX-100 trajectory as well, the payload design consideration was then determined as mentioned in Table 2.

Table1. RX-100 Rocket Specifications.

Specification	**Value**	**Specification**	**Value**
Type	1110	Outer diameter	114,3 mm
Length	195 cm	Max Acceleration	10 g
Weight	34,845 kg	Thrust	289 kgf
Vertical range	6,83 km	Rocket motor mass	45,36 kg
Horizontal range	8,77 km	Propellant mass	20 kg
Inner diameter	107 mm	Burn rate	3,33 kgs^{-1}

Table2.Design Consideration

Criteria	**Value**
Max vertical range	7 km
Max payload mass	6 kg
Max payload diameter	10 cm
Max payload length	33 cm
Max acceleration	10 g
Air pressure	350 - 1015 mbar
Air temperature	-25 s/d 40 ^{o}C
Relative humidity	0 – 100 %
Descend rate	3 ms^{-1}

2.2. Payload Realization

The meteorological payload was realized based on the design consideration on Table2. All electronic components used to build the payload were the existing component in local market. As for rocket payload transmitter, YS series radio transmitter was used as it has been proven[5)]. Photograph of the developed payload was shown by Fig. 1 and its specification was described in Table3.The payload was placed into a PVC pipe in consideration of protection and to make it easier to be released from rocket body. For shock effect reduction, the payload was casted using polyurethane.

(b) (c) (d)

Fig. 1.Realization of the meteorological payload.(a) Payload bottom view. The temperature and relative humidity sensor pipeline was shown by red cross. The pressure sensor (black) was connected to transparent pipe. (b)Payload top view after it was placed into PVC pipe. (c) Payload side view after it has just casted using polyurethane. (d) Ready to launch payload.

Table3.Specification of the meteorological payload

Item	**Spesification**
Payload Dimension Diameter Length Weight (parachute included)	 76 mm 150 mm 610 g
Payload Material Body Framework Casting material	 PVC pipe Acrylic Polyurethane
Power	9 Volt battery
Transmitter Modulation Frequency Power Baud rate Antenna	 FSK 433 MHz 1 watt 9600 bps Wipe 1/4λ
Sensor Temperature sensor type Measuring range Respon time Accuracy Humidity sensor type Measuring range Respon time Accuracy Pressure sensor type Measuring range Respon time Accuracy GPS receiver Maximum altitude	 SHT11 -40 to 123.8 ^oC min 5 s ±0.5 ^oC SHT11 0 to 100 %RH 8 s ±3 %RH MPX4115AP 150 to 1150 mbar 1 ms ±1.5 $\%V_{FSS}$ 12 km
Parachute diameter	1.5 m

As for parachute design, the descent speed (*V*) can be calculated as follow. [4)]

$$V = \sqrt{(2W/\rho CS)} \quad (1)$$

Where *W* is weight of the parachute plus load in Newton, *C* is parachute drag coefficient which is approx 0.75 for a parachutewithout holes, and *S* is total surface area in meters.ρ is air density in kgm^{-3}, near sea level its value is given by 1.225 kgm^{-3}, near 1219 m above sea level its value isapproximately 1.07 Kgm^{-3}.The relation between *S* and diameter of parachute (*D*) in meter can be calculatedas follow[4)].

$$D = 2\sqrt{(S/3.1416)} \quad (2)$$

2.3. Payload Test

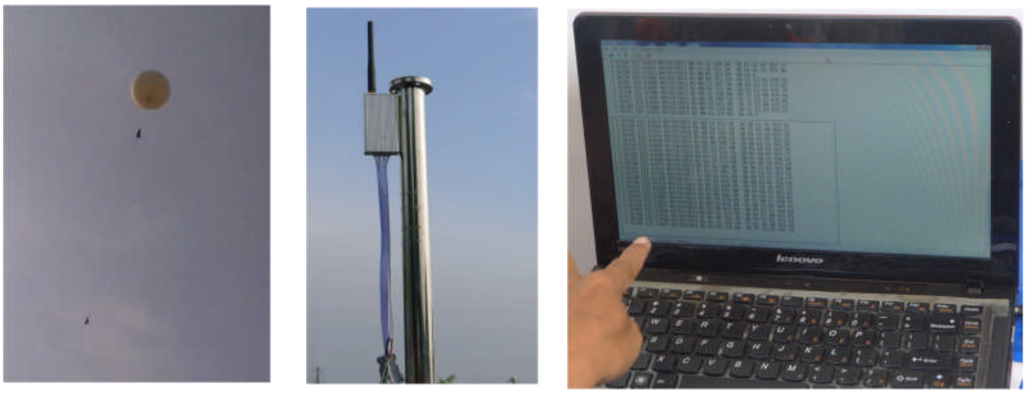
The payload test was aimed to analyze the transmitter performance during its launch until 7 km, the sensor response to various atmosphere condition until 7 km, and parachute deployment performance as well. In this initial test, payload was launched using 1000 gram meteorological balloon before it will be tested using low altitude rocketsonde. The test was conducted in Watukosek Aerospace Observatory of LAPAN, about 40 km southward from Surabaya.

Balloon ascent rate for this test was planned to be 4 ms^{-1}.To obtain this ascent rate, the balloon was filled with hydrogen gaswhich it mass can be calculated using this following formula.

$$M_T = M_{PY} + M_{PC} + M_B \quad (3)$$

Where M_T is total mass in kg, $M_{PY}$is payload mass in kg, M_{PC} is parachute mass in kg, and M_B is balloon mass in kg. Mass of hydrogen should be filled into balloon for ascent rate 5 ms^{-1} is 30% of total mass.Fig. 2show the payload launching during the test.

The payload was launched as high as possible the balloon can do. This was intended to test maximum altitude data that GPS receiver can produce and maximum range of the transmitter that the receiver still receive its signal. Data transmitted by the payload and then received by the receiver was saved in a text file.



(a) (b) (c)

Fig.2. The payload test, using 1000 gram meteorological balloon. (a) Balloon launched the payload. Below the balloon were parachute and then payload which connected to the parachute using 6 m rope. (b) Payload data receiver using wipe antenna to test its reliability for minimum antenna gain of receiver. (c) Notebook for data recording.

3. Results and Discussions

During it ascending flight, with ascent rate 4 to 5 ms^{-1}, the balloon was reaching 12 km altitude when the GPS receiver could not produce valid data anymore where it produced the same altitude data for the higher altitude. Therefore, the payload altitude after 12 km was undetectable. At that range, the receiver was still able to receive data from the transmitter correctly.
During its descending flight, GPS receiver was able to produce valid data again after it reached 12 km. The receiver has received correct payload descending data from 12 km until 3.756 km altitude. Hence, it can be concluded that the transmitter and receiver system were reliable and have been running well. Descent rate of the payload was about 24 ms^{-1}. This rate exceeded the designed rate probably because the balloon did not exploded in pieces and just torn apart instead. Therefore, the parachute was not able to deploy itself because balloon pieces were attached on it. In the next test, to avoid the same case, the balloon will be separated from payload and parachute at 12 km height.
Performance of the sensor system was compared to balloon radiosonde data launched in Surabaya Juanda international airport in the same date and hour to obtain similar atmosphere condition. The data comparison is shown by Fig. 3.The radiosonde data was taken from University of Wyoming web site. Temperature and relative humidity sensor results showed that sensor environment conditioning and its pipeline was not good enough to create good air circulation as expected, and as a result it did not have good response to atmosphere condition change compared to radiosonde data. For further improvement, temperature and humidity sensor should hasmore direct contact to air in atmosphere. As for the pressure sensor, despite it has close profile to radiosonde data, it still has slower response with increasing height probably due to it has only limited space inside the payload after being casted using polyurethane even though a transparent pipe has attached on it as a requirement for inside room placement. For further improvement, placement of pressure sensor should be in more free area and its sensor calibration should be improved.

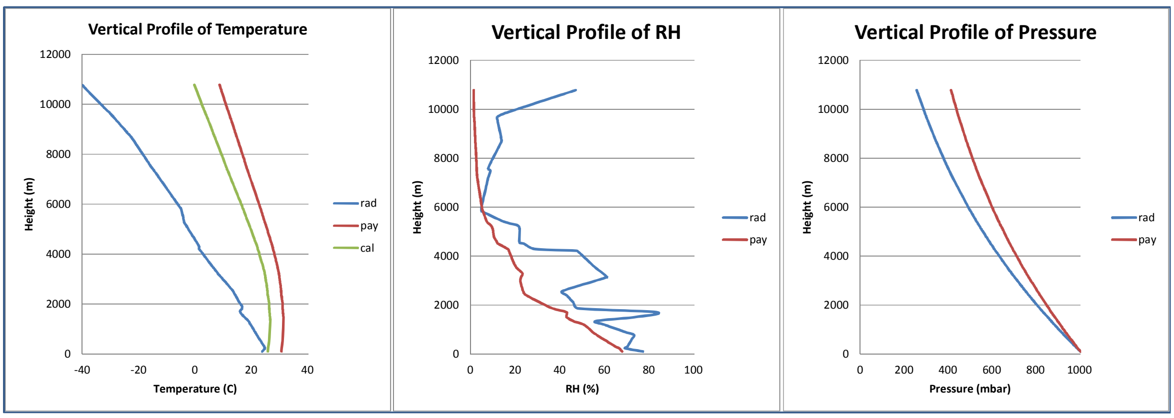
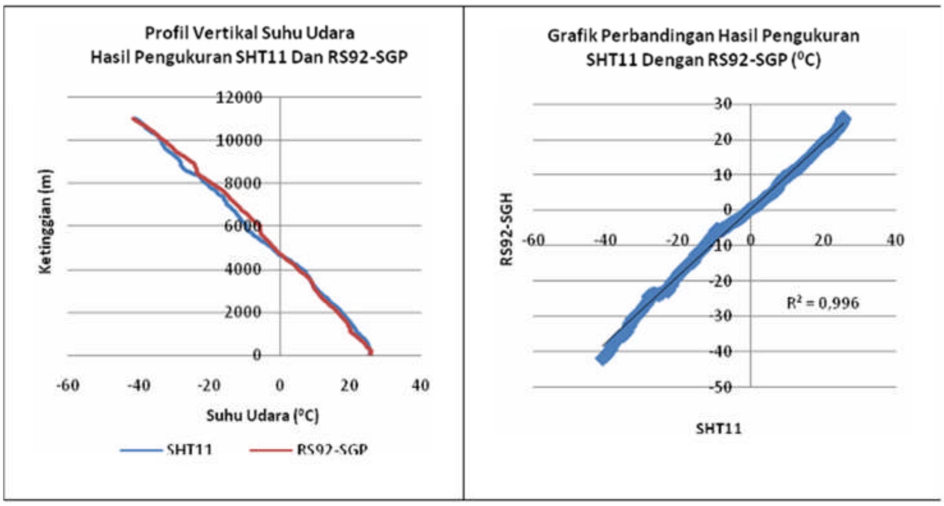


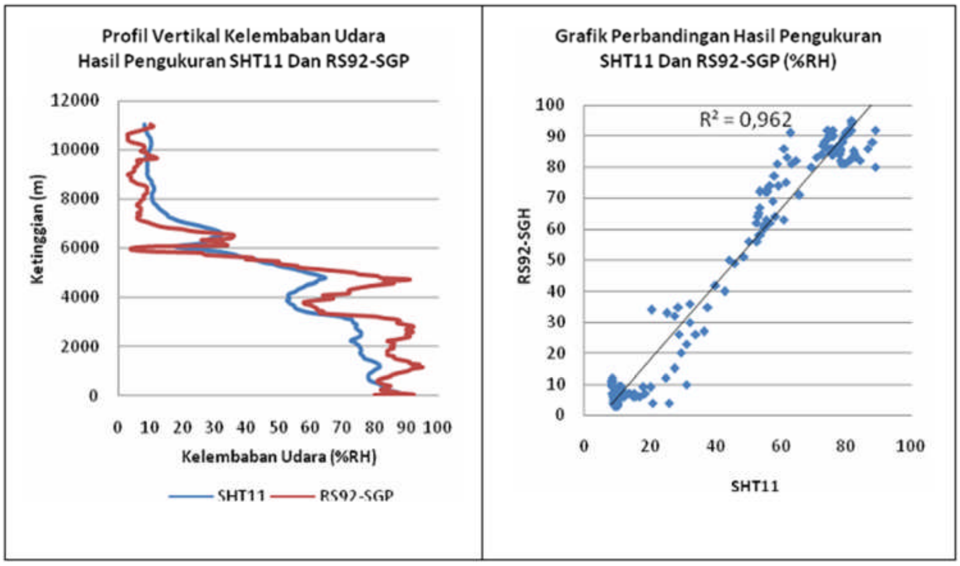
Fig. 3.Vertical profile graphics of temperature, relative humidity, and pressure.Blue line (rad) is balloon radiosonde data, red line (pay) is payload data, and green line (cal) is calibrated payload data.

SHT11 temperature and relative humidity sensor, and MPX4115AP pressure sensor, has been utilized before for atmosphere measurement using balloon in the last campaign. SHT11 temperature measurement has slower response compared to balloon radiosonde temperature sensor, therefore it should be calibrated and corrected, and the results is shown by Fig. 4(a).While

SHT11 relative humidity measurement has more good response to atmosphere change therefore it do not need any response time calibration and correction, and its result is shown by Fig. 4 (b)[6]. MPX4115AP also has good response to atmosphere change and it do not need any response time calibration and correction.



(a)



(b)

Fig. 4.SHT11temperature and relative humidity measurement results in the last campaign where it was placed in outside area to have direct contact to atmosphere. (a) Calibrated SHT11 temperature measurement (blue line) compared to radiosonde data (red line). (b) Non calibrated SHT11 relative humidity measurement (blue line) compared to radiosonde data (red line).

To obtain better result, payload's SHT11 was calibrated using the same equation as SHT11 in Fig. 4 used. The result was shown by the green line in temperature profile in Fig. 3. The result was still has very huge deviation compared to its compared radiosonde data. This evidence ensure that SHT11 sensor environment conditioning and its pipeline was not good enough to create good air circulation as expected.

The test results, compared to payload design, have shown that the transmitter system has run well until 12 km even more and exceeded its 7 km design limitation. Radiosonde data also shown that 7 km profile data of temperature, relative humidity, and pressure are still in the measurement range of designed sensor. Therefore, the payload design and its sensor and radio transmitter are compatible for this application. Nevertheless, its sensor mounting and placement should be improved. In this test also, the parachute has not been tested properly, hence it needed another appropriate test.

5. Conclusions

Preliminary results of low altitude rocketsonde meteorological payload, development for RX-100 rocket has been tested. The payload transmitter system test showed that it was reliable until 12 km altitude. While on temperature and relative humidity sensor SHT11 test, it seemed that sensor environment conditioning and its pipeline was not good enough to create good air circulation as expected, and as a result it did not have good response to atmosphere condition change compared to radiosonde data. As for the pressure sensor MPX4115AP test, despite it has close profile to radiosonde data, it still has slower response with increasing height probably due to it has only limited space inside the payload after being casted using polyurethane even though it has attached transparent pipe as a requirement for inside room placement. In this test also, the parachute has not been tested properly as the balloon just torn apart after it exploded causing the parachute did not deploy and it descended faster than expected. Therefore, the developed payload still need further improvement and test.

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