GRUAN ICM-15 Bern

Balloon control technology aimed at advancing upper-air observations

IHI GROUP

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Introduction

Radiosondes are launched using weather balloons made of rubber for in-situ observations.

Weather balloons can access altitudes up to 35 km from the surface.

Feature of weather balloon are as follows.

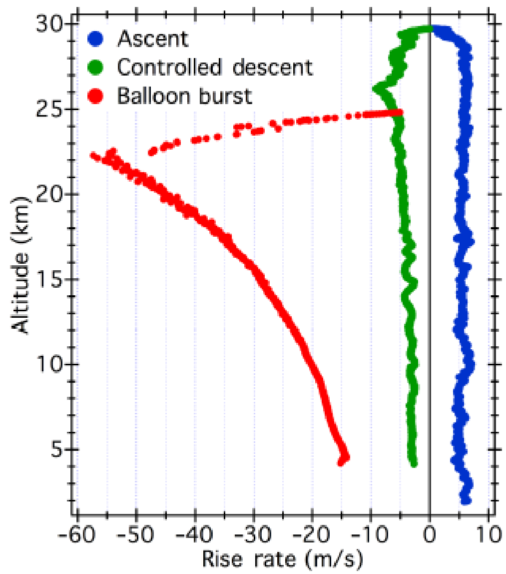
- Used to observe meteorological vertical profiles
- Drifted with horizontal wind in each altitude
- Low cost compared to other methods
- Can be used without special facilities and can be launched anywhere in the world
- One time use because it expands and bursts at high altitude.
- A method used for over 100 years

Even in the 21st century, radiosonde with weather balloon is a very important tool for weather and climate monitoring.

Introduction

Normally weather balloons burst and fall after observation, but there are several methods of controlling balloons for special purposes (Kräuchi et al. 2016, AMT).

Fig.1



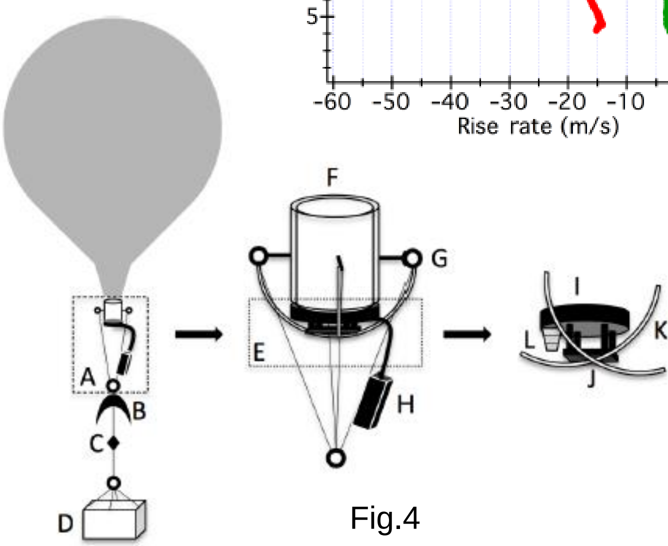


Fig.4

Fig.8

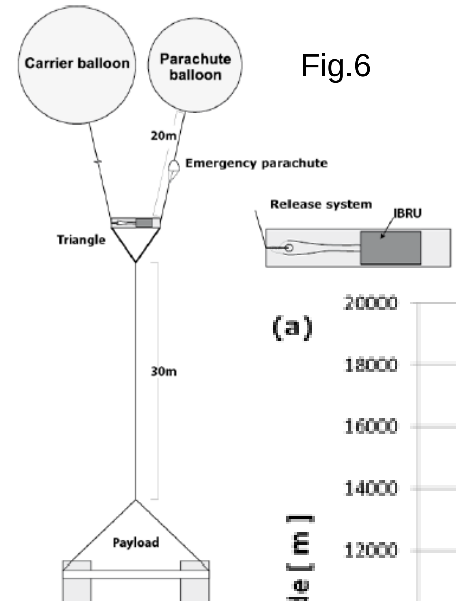


Fig.6

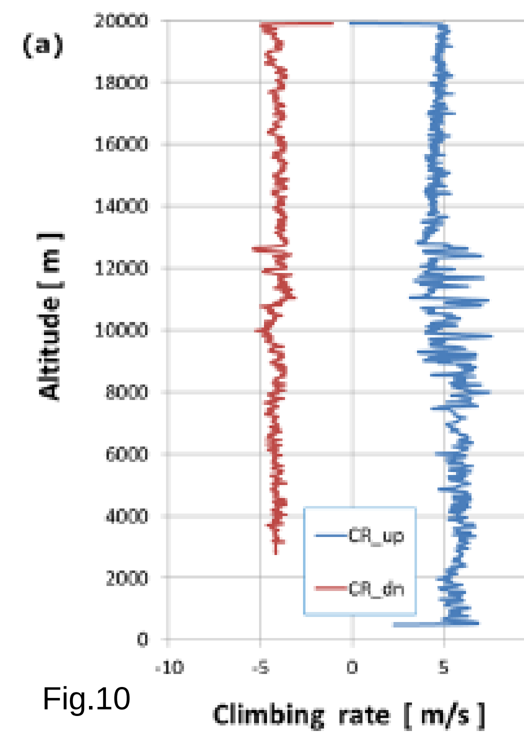


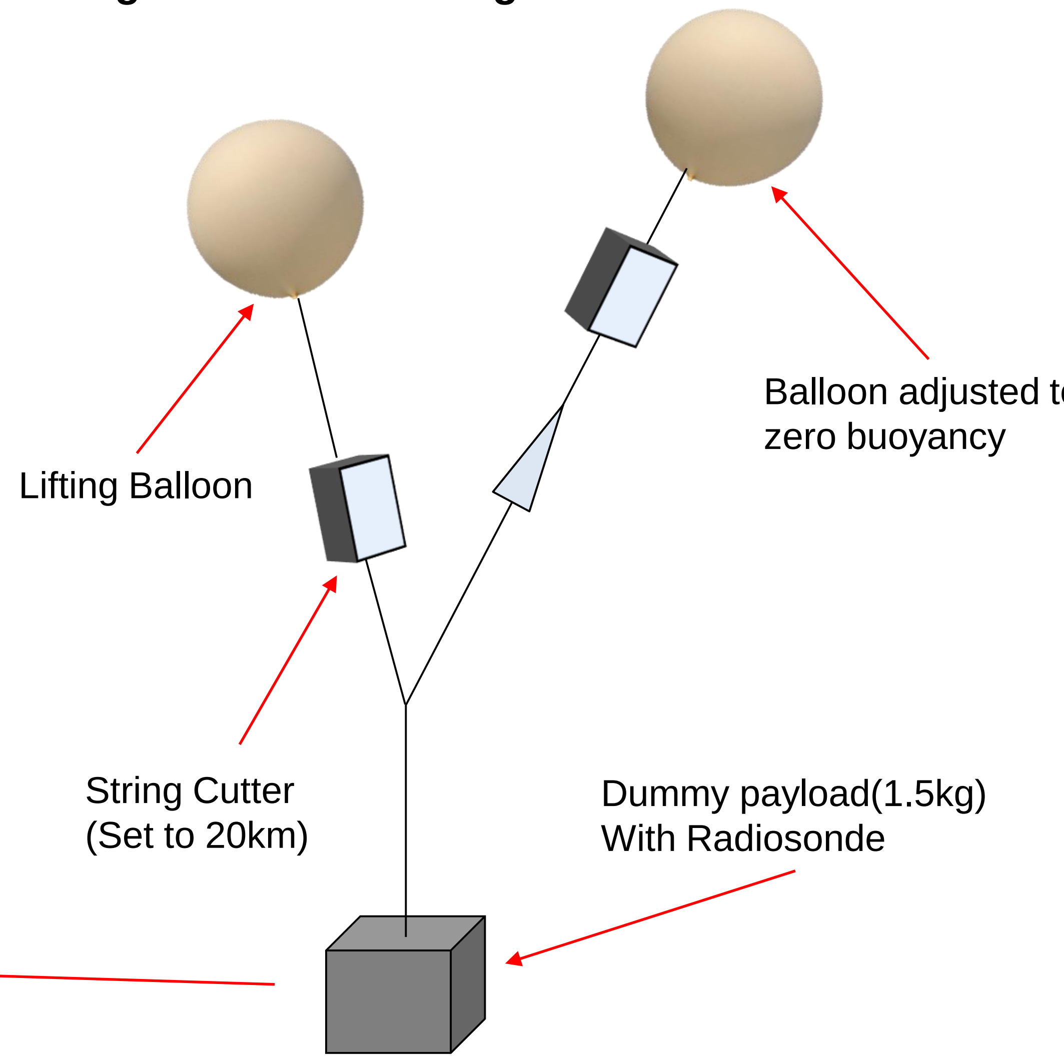
Fig.10

These technologies are effective in stabilizing the attitude of equipment and conducting descend observations with less temperature/humidity contaminations.

Advanced double balloon technology (concept test)

If weather balloon that can easily and inexpensively access to stratosphere can actively control more, future observation needs would be satisfied.

⇨ Conducted the level flight test at a targeted altitude using a weather balloon



Advanced double balloon technology (concept test)

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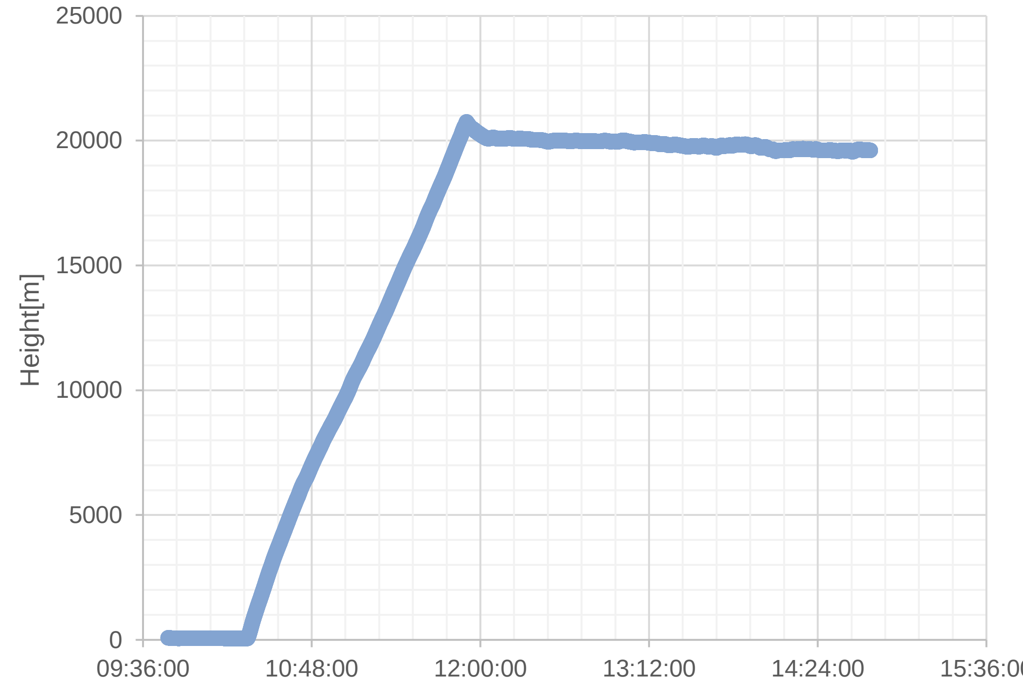
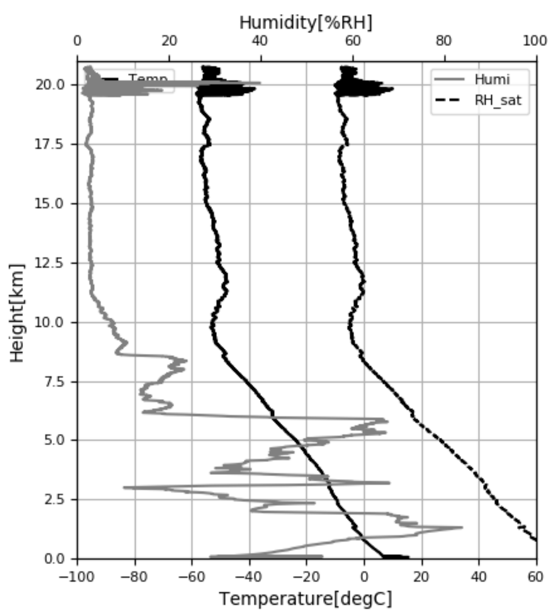
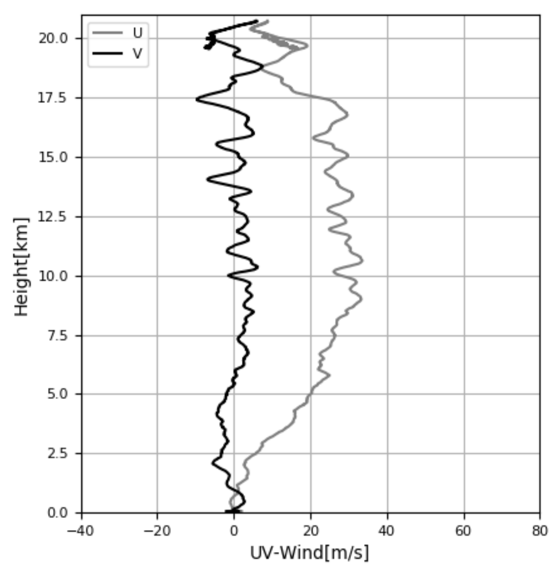
The double balloon system, which was separated from the lifting balloon at 20km, succeeded into level flight.

The balloon, properly adjusted to zero buoyancy, maintained an altitude of ±500 m for 3 hours.

However, a double balloon technique can only change the ascent speed one time.







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Advanced control balloon technology

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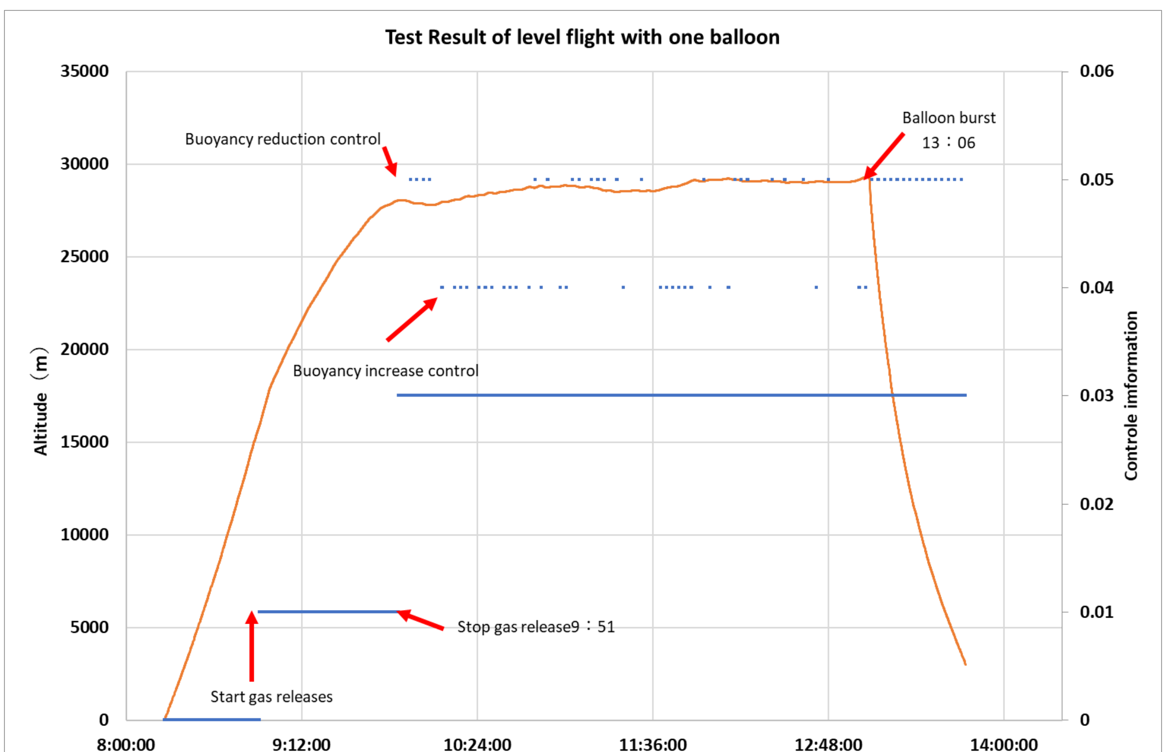
So, development of “weather balloon system” that can control buoyancy has been started in 2021.

The controller of “weather balloon system” has parameters such as the characteristics of weather balloons and helium/hydrogen gas at various condition of pressures and temperatures, also is equipped with a filter that ignores the effects of atmospheric gravity waves to avoid unnecessary level control.



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Advanced control balloon technology

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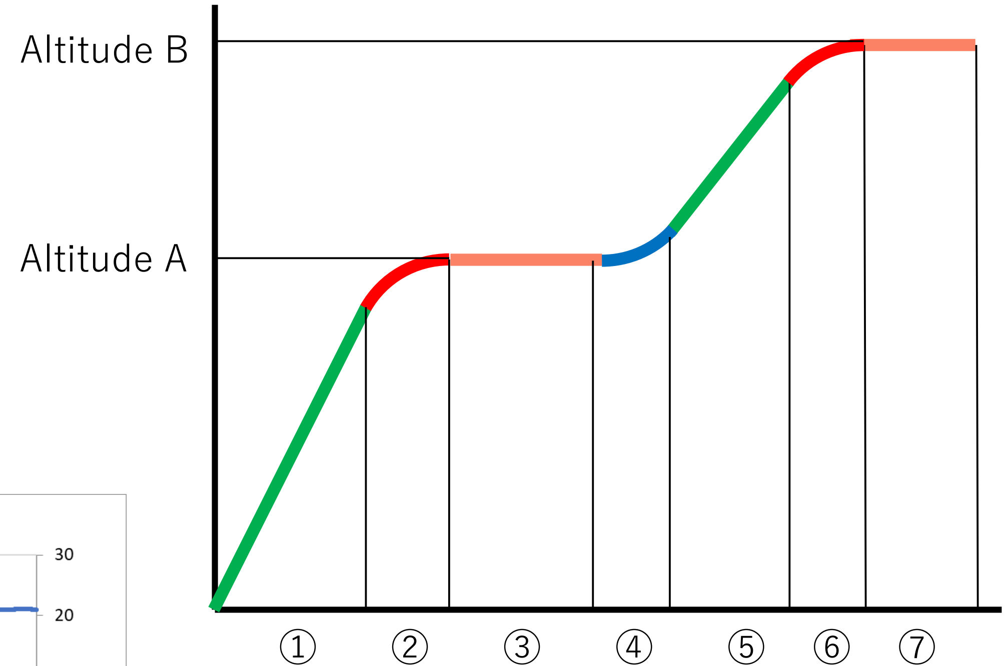
Weather balloon system's controller flies toward a preset target altitude (Pre-programed before launch)

- **Stop at desired altitude**
- **Level flight (hold)**
- **Re-ascend**
- **Re-descend**



①: Ascend to altitude A

②: Gas release until the ascend speed 0 m/s

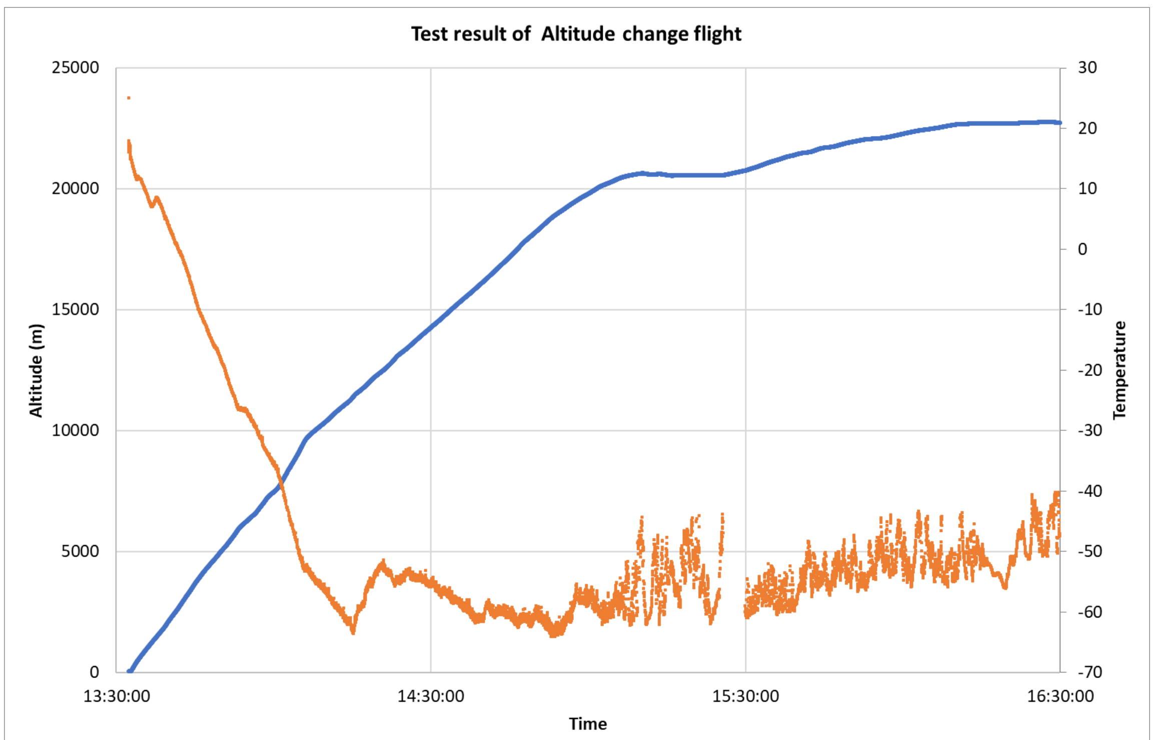
③: Stop gas release and wait stabilize

④: Release ballast up to ascend speed 1 m/s

⑤: Ascend to altitude B

⑥: Gas release until the ascend speed 0 m/s

⑦: Gas release stopped



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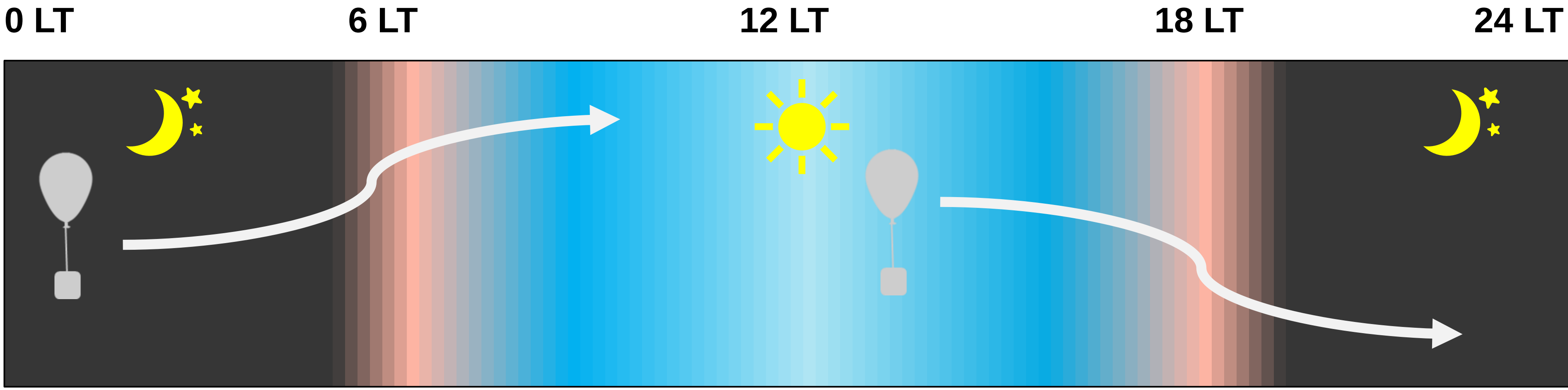
Challenges of weather balloon systems

In order to aim for longer level flights, the thermal changes on weather balloon due to radiation (day/night) should be considered.



Challenges

- **Early in the morning, the balloon heats up by short wave radiation from the rising sun, increasing its buoyancy and ascending.**
- **In the evening, as the sun sets, the balloon no longer receives sunlight, cools down due to long wave radiation, loses its buoyancy, and descends.**
- **Other issue, hydrogen and helium leak from the balloon's surface through a rubber membrane, so balloon lost its buoyancy.**

⇨ **Developing a buoyancy control algorithm that overcomes these above issues**

Comparison between light balloon and large balloon

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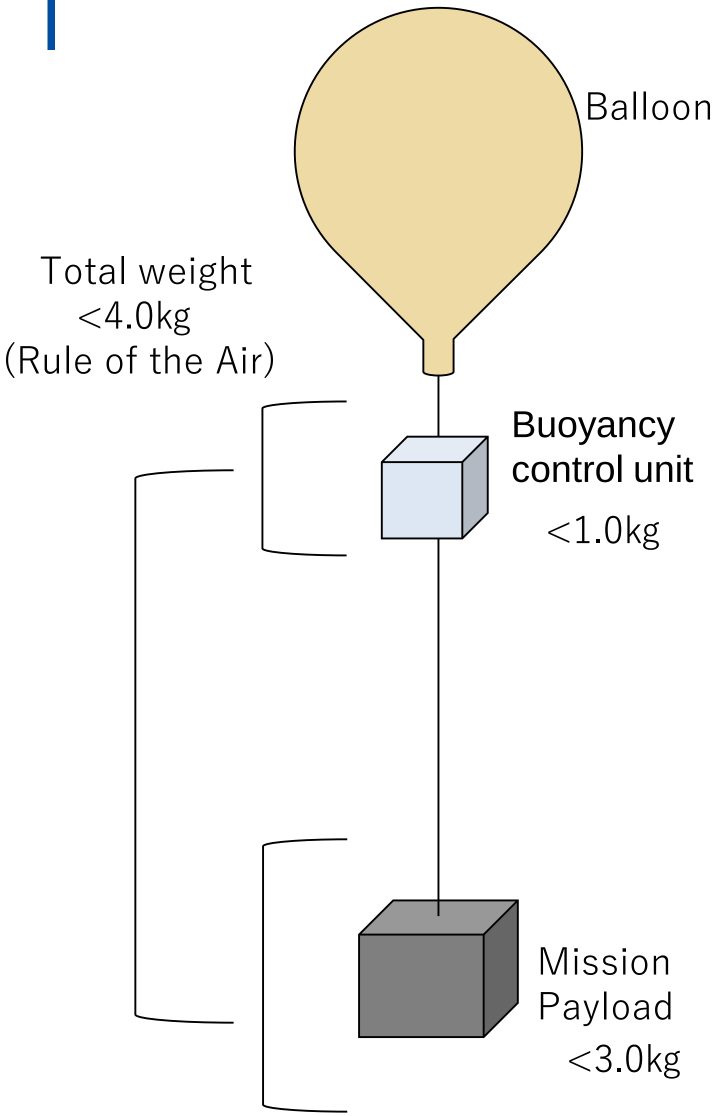


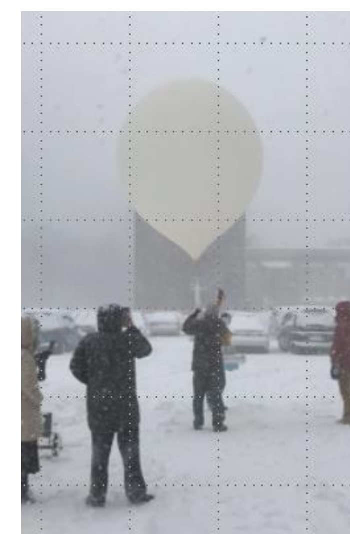
Developing to operate in “light balloon” category.

Advantage of light balloon compared with large balloon

- **Easy to handle (Place, timing and facility)**
- **Very low cost**
- **All weather operation**
- **There are fewer requirements for planning and flight compared with large balloon.**

Disadvantage of light balloon compared with large balloon

- **Total 4 kg payload (up to 3kg/package)**
- **Payload density should be less than 13 g/㎠**



<u>Ref: Rule of te Air Appendix 4</u>

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Future usage of weather balloon system

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Future usage

- Advanced control ascend/descend observation
- Lagrange observation
- Diurnal variation in stratosphere
- Dropsonde observation over sea like “Driftsonde”
- Research on stratosphere-tropospheric connection
- Measurement of atmospheric gravity waves
- Evaluation of radiosonde sensors that cannot be performed in a ground-based climate chamber

Target specification

Operation time:	24 hour or more
Cruising altitude:	18000m or more
Control height accuracy	±300m
Maximum payload:	3kg (exclude flight controller)
Flight plan:	Pre-programming before launch
Termination mechanism:	Balloon cutter / Descending by gas release / Ascending for balloon burst by ballast release
Price:	?

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Summary

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Weather balloons made of rubber are the cheapest way to transport observation instruments to the stratosphere.

So far, the reduce buoyancy control have been conducted for weather balloons like "controlled descend", but no operations have been performed to recover buoyancy and hold/change altitude.

Meisei are developing a “weather balloon system” that can control the buoyancy of weather balloons made of rubber and change its altitude.

”Weather balloon system” can be adapted to the light balloon category and will carry instruments up to 3 kg weight.

In order to control altitude with a longer duration, controller that overcomes the effects of short/long wave radiation on the balloon is necessary.

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