スペースコロニー内の人工重力下における大気循環の解析

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Air Circulation Analysis under Artificial Gravity in a Space Colony

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1. Introduction

A typical space colony is cylinder in shape. It was first proposed by G. O'Neill in 1974 and named "Island Three". The diameter is 6km, the length is 30km, and ten million people are able to live in the colony. The cylinder is rotated 0.55rpm to create an artificial gravity of 1g. The inside wall of the cylinder is divided into six sections in an axial direction, which consists of three sections of habitable land and three non-habitable window sections alternately. Each window outside has a movable mirror installed to reflect sun light. It can artificially create days, nights, and seasons[1)].

The previous space colony research falls into several categories. Although there has been much research in the dynamics and structure analysis of the space colony, little research has been done concerning internal environmental analysis. There were few research projects, which took into account meteorology in a space colony[2)] and rotating dishpan experiment of the air circulation[3)]. The results predict that the temperature difference between the land sections and window sections, along with the Coriolis force cause the air circulation by window-wind from the window sections to the land sections in a space colony.

The purpose of this research is the air circulation analysis caused by the window-wind in a space colony which takes into account humans, crops, and waste process factories.

2. Modeling and Analysis

The internal space on the shell of the space colony is divided into ground and atmospheric layers. Each layer is divided into 100 x 60 cubic cells having physical quantities such as concentration of N_2, O_2, and CO_2. Each cell has almost equal sides of 300 m in length. The changes of concentrations are modeled by using Cellular Automaton (CA). The equations (1)-(3) represent the CO_2 diffusion and advection model, and the photosynthesis models in light and dark periods, respectively.

$$\frac{\partial(ppCO_2)}{\partial t} = D\left(\frac{\partial(ppCO_2)}{\partial x} + \frac{\partial(ppCO_2)}{\partial y}\right) + v_x \frac{\partial(ppCO_2)}{\partial x} + v_y \frac{\partial(ppCO_2)}{\partial y} \quad (1)$$

$$mCO2(t+1) = mCO2(t) + (-CO2\_PHO \cdot biomass + CO2\_POP \cdot population) \quad (2)$$

$$mCO2(t+1) = mCO2(t) + (CO2\_DAR \cdot biomass + CO2\_POP \cdot population) \quad (3)$$

3. Results and Discussion

The space colony could support seven million people and 30 species of crops such as rice, soybeans. These crops could be cultivated to support the population. The mirrors are opened from 5:00 to 7:00, which is dawn, and closed from 17:00 to 19:00, which is dusk. CO_2 emission from the waste process factory is released from 7:00 to 17:00 at point 1.

Fig. 1 shows the distribution of CO_2 concentration at 5:10 on day 2. The maldistribution of CO_2 concentration begins to be stirred up by window-wind in each window-land pair when mirrors begin to open. Fig. 2 shows changes in CO_2 concentration in 48 hours at points 1, 51, and 91. The abrupt decrease of CO_2 concentration at 5:10 on day 2 at three places was caused by the window-wind. The concentration decreased to the first CO_2 concentration at 0:00 of the previous day.

I have formulated and analyzed the air circulation in a space colony using a CA. I am engaged in the preparation of experiments of window-wind under artificial gravity.

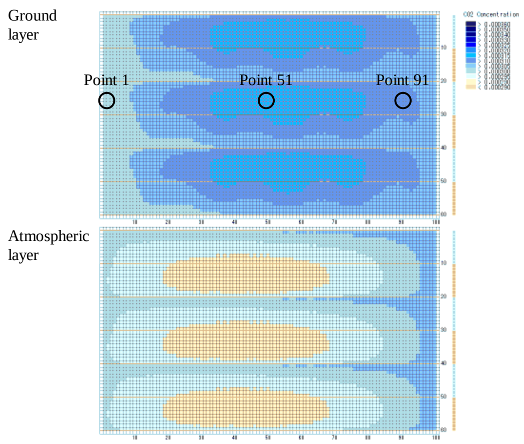

Fig. 1 Distribution of CO_2 concentration at 5:10 on day 2

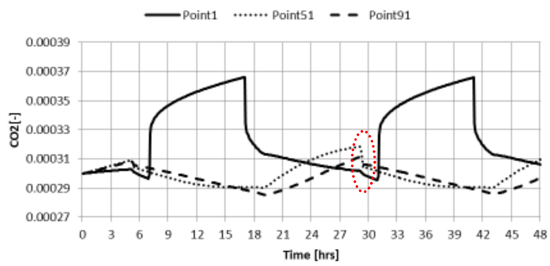

Fig. 2 Changes in CO_2 concentration in 48 hours

References

1) G. K. O'Neill, The High Frontier: Human Colonies in Space 3rd Edition, Collectors Guide Pub, 2000.

2) T. Matsuda, Meteorology in a Space Colony, Journal of the Physical Society of Japan, **52**, 6, (1983)1904-1907.

3) T. Yoshimura, On the Meteorology in a Space colony, The Astronomic Herald, **85**, 11(1992)509-514.