第 4 次作业

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摘　要：第三章作业. 截止日期：2022-04-03.

关键词：关键词 1，关键词 2

Homework 4

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Abstract: Selected exercises for chapter 4. Due date: Apr. 3rd, 2022.

Keywords: keyword 1, keyword 2

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1 Question 1

If the top 100 m of ocean warms by 5°C during a 3-month summer period, what is the average rate of net energy flow into the ocean during this period in units of W m^{-2}? If the atmosphere warms by 20°C during the same period, what is the average rate of net energy flow into the atmosphere? (Hartmann, 2016, p. 129)

1.1 Solution

If the top 100 m of ocean warms by 5°C during a 3-month summer period, the average rate of net energy flow into the ocean during this period is

$$G_o = \frac{\partial E_o}{\partial t} = \frac{c_w \rho_w d_w \Delta T_w}{\tau} = \frac{4218 \times 10^3 \times 100 \times 5}{90 \times 24 \times 3600} \mathrm{W\ m^{-2}} = 271\ \mathrm{W\ m^{-2}}. \tag{1.1}$$

If the atmosphere warms by 20°C during the same period, the average rate of net energy flow into the atmosphere is

$$G_a = \frac{\partial E_a}{\partial t} = \frac{\overline{C}_a \Delta T_a}{\tau} = c_p \frac{p_s}{g} \frac{\Delta T_a}{\tau} = 1004 \times \frac{10^5}{9.81} \times \frac{20\ \mathrm{W\ m^{-2}}}{90 \times 24 \times 3600} = 26.3\ \mathrm{W\ m^{-2}}. \tag{1.2}$$

2 Question 2

The blackbody emission from the surface can be linearized about some reference temperature T_0. $\sigma T_s^4 \approx \sigma T_0^4 + 4\sigma T_0^3 (T_s - T_0) + \cdots$. And the sensible cooling of the surface can be written as $\mathrm{SH} \approx c_p \rho C_D U (T_s - T_{a0}) + \cdots$. Calculate and compare the rates at which longwave emission and sensible heat flux vary with surface temperature, T_s. In other words, if the surface temperature rises by 1°C, by how much will the longwave and sensible cooling increase? Assume that $T_0 = 288$ K, T_a is fixed, $\rho = 1.2$ kg m^{-3}, $c_p = 1004$ J kg^{-1} K^{-1}, $C_D = 2 \times 10^{-3}$, and $U = 5$ m s^{-1}. (Hartmann, 2016, p. 129)

2.1 Solution

We have

$$\mathrm{d}\left(\sigma T_s^4\right)\big|_{T_s = T_0} = 4\sigma T_0^3\ \mathrm{d}T_s \tag{2.1}$$

and

$$\mathrm{d}(\mathrm{SH})|_{T_s = T_0} = c_p \rho C_D U\ \mathrm{d}T_s. \tag{2.2}$$

So, if the surface temperature rises by 1°C, the longwave and sensible cooling will increase by

$$\Delta\left(\sigma T_s^4\right) \approx \mathrm{d}\left(\sigma T_s^4\right)\big|_{T_s = T_0} = 4\sigma T_0^3\ \mathrm{d}T_s = 4 \times 5.67 \times 10^{-8} \times 288^3 \times 1\ \mathrm{W\ m^{-2}} = 5.4\ \mathrm{W\ m^{-2}} \tag{2.3}$$

and

$$\Delta(\mathrm{SH}) \approx \mathrm{d}(\mathrm{SH})|_{T_s = T_0} = c_p \rho C_D U\ \mathrm{d}T_s = 1004 \times 1.2 \times \left(2 \times 10^{-3}\right) \times 5 \times 1\ \mathrm{W\ m^{-2}} = 12\ \mathrm{W\ m^{-2}}, \tag{2.4}$$

respectively.

References

Hartmann, D. L. (2016). Chapter 4 - The Energy Balance of the Surface. In D. L. Hartmann (Ed.), *Global Physical Climatology (Second Edition)* (pp. 95-130). Elsevier. https://doi.org/10.1016/B978-0-12-328531-7.00004-9