Proceedings of the 3rd International Conference on Computing Innovation and Applied Physics
DOI: 10.54254/2753-8818/43/20240989

The energy budget of the Mercury

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Abstract. With the exhaust of the earth's energy, people need to find a new place to live. Mercury, one of the planets which is nearest to the earth, its energy budget is valuable to consider about. Energy budget can influence the surface temperature and the climate. If people want to move to any other planets, the energy budget of the planet is one of the things that must be concerned about, as it is directly proportional to the surface temperature of the planet. Plus, if the energy budget of the planet is not appropriate, then there will have no water on the surface or only ice, and moving to that planet is not available. In this studying, the energy budget of the Mercury is made, which is based on the previous research and use a way called Geebitt. This study has found that the income of solar energy of Mercury cannot be attracted by itself, leading to a enormous gap between the surface face to sun and the surface back to it. This research makes contribution to the further research about the Mercury, as it provides the idea and the process to move people to the Mercury.

Keywords: Mercury, energy budget, Geebitt.

1. Introduction

With the expansion of the population and more and more pollution of the Earth, it is necessary for people to take research of other planets.

From the United Nation, there are nearly 8 billion people at present, and this figure can reach 9.2 billion people in the 2045 [1]. On August 26, 2023, Japan decided to pour more than 200,000 tons of water which was polluted by nuclear waste to the sea for over 30 years [2], and before that, we have put more than 2 billion tons rubbish to the environment [2], which are mostly concentrated by the litter which is hard to be destroy.

Some of people concern about the size of the Mercury [2], some of them make the study of the Mercury's period of rotation [3]; some of them make the component of the atmosphere of the Mercury [4]. This time, we concern about the energy budget of the Mercury, since it is directly proportional to the surface temperature of the planet. If we want to make research of a planet, we should first concern about the surface temperature of the planet or, in other way, its energy budget, otherwise it will be quite dangerous to land on it. This is the reason we make a budget of the Mercury.

This research will concern about the influence factor of the mercury, its energy budget, and hence its climate and surface temperature.

The Mercury is one of the planets which is most close to the Earth. The radius of the Mercury is one third of the earth, and its mass is only 0.055 times that of earth [2,5]. The surface which it faces to sun has a high temperature(450°c), while another face can reach -150℃ [6]. It needs 58.65 days to finish

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rotate itself and 88 days to surround the sun [7]. It has no moon. Its core possesses 57% of its volume and 75% of its mass [8,9].

With the energy budget of the Mercury, we can find the composition of its atmosphere and we can even use it to make the Mercury available for people to live. From the equation $E=mc\Delta\theta$ [10], when the planet absorbs the solar energy, because its mass is unchanged, its temperature will rise. Hence, energy budget indicates the energy absorbed by the planet, which has a direct impact to the surface temperature of the planet. It does not have lots of people who do the research about the Mercury, so it does not have many research tool and material [11].

2. A useful way to reflect the temperature—Geebitt

When we make the discover of the planet, Dr. Andy disordered a way called Geebitt [12]. It will produce a table for calculating the surface temperature of the planet and use several factors to calculate the temperature of the planet. This is a very useful way to detect the temperature of the target planet, just need to put all the factor into the table.

The table Geebitt provided concern about some factors. In this project, we choose these factors: Black body, Reflection at surface, Carbon Soot & Tropospheric Sulfate Aerosols and Raleigh Scattering, Clouds, Tropospheric Components, Stratospheric Components, as they have the most significant effect on the surface temperature of planet. They will be shown in the following table.

2.1. The reflection of solar energy

When the solar energy comes to the surface of the planet, some of the energy will be reflected by the surface. These figures can also affect the energy budget of the Mercury.

Reflectivity is the ability of the object to reflect solar energy. (Reflectivity of the ocean, the vegetation, the desert, the snow, and ice are separately 5, 10, 20 and 70) [13]. Percentage of the planet is the ratio of the area of this kind of surface and its total surface area. (Surface of the Mercury is 100% covered by desert.) Total solar energy reflected is the percentage of the solar energy which is reflected by the surface of the planet. 20% of the solar energy will be reflected by the surface of the Mercury. [13].

Table 1. The reflectivity of the surface on the mercury [14]

	Ocean	**Vegetation**	**Desert**	**Snow and ice**
Reflectivity	5	10	20	70
Percentage of the planet (%)	0	0	100	0
Total solar energy reflected (percentage of transmitted solar energy, %)	0	0	20	0

Because of the extreme condition, there is covered by rocks and sand, no water or snow is covered on it. Plus, there also have no plants.

Sea contains lots of water, which means that it will absorb most of the solar energy. The leaves of the vegetation can also absorb the solar energy. Sand and stone may have little ability to maintain the heat, so the energy can also leave out very fast. However, this also means that they can also reflect some of the solar energy. Ice and snow are white, which indicated that they can reflect most of the solar energy.

2.2. Solar energy transmitted by atmosphere (atmosphere pressure:20hpa)

Different type of gas will have different reflectivity, which means the ability of reflecting the heat. Plus, the component of the planet is also an important information of the planet. If there do not have enough oxygen in the atmosphere, species is also not possible to live at their planet.

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Percentage reflectivity is the ratio of the reflectivity of this gas and the total reflectivity of the atmosphere. (The percentage of the reflectivity of those gases are 9.52%, 12.59%, 6.24%, and total percentage reflectivity can reach 28.90%).

Boundary Layer Carbon Shoot Aerosol is the gas which is in the bottom of the atmosphere. This gas contain carbon and has the ability to reflect the solar energy. Rayleigh Scattering is a kind of the behavior of the gas to prevent the animals be damaged by the ultraviolet. Tropospheric Sulfate Aerosols is a kind of the sulfate compound which has its ability to reflect the solar energy.

Table 2. Solar energy transmitted by atmosphere (atmosphere pressure:20hpa) [14]

Gases	**Boundary Layer Carbon Shoot Aerosol**	**Rayleigh Scattering**	**Tropospheric Sulfate Aerosols**	**Total**
Percentage reflectivity%	9.52	12.59	6.24	28.90
Transmitted solar energy (percentage of solar energy, %)	95.12	87.41	90.00	71.10

2.3. Reflection of clouds (atmosphere pressure:20hpa)

Clouds has its ability to absorb the heat emitted by the surface, but the thick cloud can also reflect the heat from the sun. Clouds is also important to prevent the species from being damaged by the ultraviolet.

Number of cards is the number of days which include this weather. (The level of this is same in all kinds of the cloud, which means the low clouds, mid clouds and high clouds. They all reaches 1 in 10 days.) Optional thickness is the thickness of the cloud, compare with the thin cloud on the earth. (The lower the clouds are, the thicker the clouds are.) Percentage coverage is the ratio of the day compares with all the days in one year. (Three kinds of clouds have same level of the percentage coverage, which are all 10.00%, leading 70.00% of the days with clear day.) Reflectivity is the ability of the cloud to reflect the heat from the sun. (Lower clouds has the highest level, which is 0.4286; the mid clouds have an albedo of 0.3333, leading only 0.1111 to the high clouds. These clouds create the average reflectivity, which is 0.2910.) High clouds can reflect 3.47% of the solar energy, while other two clouds have similar level of this (4.75% and 5.36% separately). However, their average ability to reflect solar energy can reach 45.29%.

Table 3. Reflection of clouds (atmosphere pressure:20hpa) [15]

	Low clouds 2.0km	Mid clouds 5.0km	High clouds 10.0km	Average 5.0km	Clear sky	Cloud level Global mean level
Number of cards	1	1	1	3	7	3
Percentage coverage	10.00%	10.00%	10.00%	30.00%	70.00%	30.00%
Optional thickness	6	4	1	3.28358209	/	3.28358209
Reflectivity (Albedo)	0.4286	0.3333	0.1111	0.2910	/	/
Solar energy reflected (% of incoming solar)	5.36	4.75	3.47	45.29	/	33.82
Solar energy transmitted (% of incoming solar)	94.64	95.25	96.53	54.71	/	66.18

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Due to the presence of the cloud, 33.82% of the energy is reflected by the cloud, so this is also a factor that must be considered. Because of the thin atmosphere, only 30% of the time of the Mercury can see the cloud, and thick clouds, which tend to appear in the lower atmosphere, have higher ability to reflect than thin clouds.

2.4. The component of atmosphere

The component of atmosphere is also very important to the surface temperature of people. Besides, with unsuitable atmosphere, the weather on the planet is also not suitable. Atmosphere is one of the major factors of the climate and the surface temperature of a planet.

There have lots of factors which can change the component of the air. These factors are the most important factors: They can reflect the solar energy, while Tropospheric Carbon Soot Aerosol will have different behavior.

Contribution to the optical depth is the ratio of the depth of the gas and the depth of the atmosphere. Concentration value is the ability of the energy absorbed and reflected by this kind of gas. Tropospheric Carbon Soot Aerosol is a component of the atmosphere, which can absorb the heat from the sun. Mineral Dust Aerosol is dust in the atmosphere. It can help to create clouds, which can also maintain the heat. Tropospheric Ozone is the oxygen in the tropical area, which is very important for people or any other species. Tropospheric Carbon Dioxide has some ability to attract the heat from sun. Tropospheric Oxygen is also very useful for plants, which can protect them from getting damaged by the ultraviolet. Tropospheric Water Vapor is the component of the water in the atmosphere. Volcanic Aerosol can put lots of ash in the atmosphere, leading a dramatic reduce in the surface temperature of the planet.

Table 4. Tropospheric Components [14,16,17]

	Tropospheric Carbon Soot Aerosol	**Tropospheric Mineral Dust Aerosol**	**Tropospheric Ozone**	**Tropospheric Carbon Dioxide**	**Tropospheric Oxygen**	**Tropospheric Water Vapor**	**Volcanic Aerosol**	**Combined Value** With All Factors
Concentration Value/Factor	/	/	1	1	1	/	/	/
Optical Thickness Value/Factor	1	1	0.00139	**0.00681**	**0.02935**	0	1	/
% Contribution to Optical Depth	4.04%	20.20%	0.56%	**2.75%**	**11.86%**	0.00%	60.59%	/
Percent Total Reflectivity	-1.33%	0.87%	0.28%	1.35%	5.70%	0.00%	2.91%	33.23%
Solar Energy Reflected	-118.17	77.88	24.78	120.56	508.14	0.00	259.59	2961.86
(% of Incoming Solar)	-1.33%	0.87%	0.28%	1.35%	5.70%	0.00%	2.91%	33.23%
Solar Energy Transmitted	9030.92	8834.87	8887.97	8792.19	8404.61	8912.75	8653.16	5950.89
(% of Incoming Solar)	101.33%	99.13%	99.72%	98.65%	94.30%	100.00%	97.09%	66.77%

The concentration value/factor of Tropospheric Ozone, Carbon Dioxide and Oxygen are at the same level, are both 1. The optical thickness value/factor of Tropospheric Carbon Soot Aerosol, Mineral Dust Aerosol and Volcanic Aerosol are at the same level (1), while the three value before have much lower value, which are separately 0.00139, 0.00681 and 0.02395. Besides, because there has no water on the Mercury, the optional thickness of this value is 0. The contribution to optical depth of the Volcanic Aerosol is the highest, which is 60.59%. Then is the Tropospheric Mineral Dust Aerosol, which also reaches a level of 20.20%. The Tropospheric Oxygen also reached the level of 11.86%. The lowest rate of the area is Tropospheric Ozone, which has only 0.56%. The reflectivity of the Tropospheric Oxygen is highest, is 5.70%. Then is the Volcanic Aerosol, which is 2.91%. The lowest level of the reflectivity is Tropospheric Ozone, whose figure is 0.28%. There has no water on the Mercury, so the reflectivity

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of the Tropospheric Water Vapor is 0. Not like other factors, Tropospheric Carbon Soot Aerosol is more likely to absorb the heat emitted from the surface, so its reflectivity is -1.33%. The final results of these figure are: the atmosphere reflected 33.23% of the solar energy, only 66.77% of them reached to the surface of the planet.

3. Results

3.1. Income of the solar energy

The solar energy income can be reflected or observed by the surface or the atmosphere. Meanwhile, the surface of the planet and its atmosphere will also emit heat to some places.

From the table below, because of the thin atmosphere, the impact of the atmosphere is not so strong to remain the energy emitted by the surface.

Table 5. The energy income of the Mercury

	Energy reflected (W m^{-2})	Energy absorbed (W m^{-2})	Energy transmitted (W m^{-2})
Solar energy income	2788.19	0	6124.56
Energy transmitted to the surface of the planet	673.7016	5450.8584	0
Energy emitted by the surface	0	109.02 (absorbed by atmosphere)	5341.84
Energy emitted by the atmosphere	0	43.61 (absorbed by the surface	65.41

Energy transmitted is the energy reached to the surface directly. (There are 8912.75W m^{-2} solar energy reached Mercury, but only 6124.56W m^{-2} energy reached the surface of the planet.) Energy reflected is the energy reflected by the surface or the atmosphere. (2788.19W m^{-2} solar energy will be reflected by the atmosphere, and 673.7016W m^{-2} will be reflected by the surface of Mercury.) Energy absorbed is the energy which is absorbed by the surface or the atmosphere. (Surface of the Mercury will absorb 5450.8584W m^{-2} solar energy, while itself will emit the radiation with same intensity. However, only 109.02W m^{-2} will be absorbed by the atmosphere, as it will also emit same level of radiation and the surface of planet only absorb 43.61W m^{-2}, others all emitted to the outer space.)

3.2. Energy output

The energy it comes for any daytime is $1.59x10^{8}Jxm^{-2}$; 75% of them was used to heat the Mercury itself, and another 25% was released by earthquakes.

3.3. Surface temperature of the Mercury

The surface temperature of the planet can directly interact the climate on the planet, and also determine the possibility this planet is habitable for people.

Table 6. The surface temperature of the Mercury

(Incoming Solar Radiation must be in watts/$meter^2$)	Resulting Surface Temperature		
	Kelvin	Centigrade	Fahrenheit
Black body	445.2	172.1	341.8
With Reflectivity of Surface Features: But Without Atmospheric Effects	421.1	147.9	298.3
With Reflectivity of Surface Features: Including Carbon Soot, Tropospheric Sulfate Aerosols, and Rayleigh	408.9	135.7	276.3
Average Cloudy Sky Conditions:	382.9	109.8	229.6
Global Mean Cloud Effects:	401.6	128.4	263.2
With All Tropospheric Components	402.5	129.3	264.8
With All Stratospheric Components [18,19]	405.4	132.2	270.0

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Stratospheric component is another component of the atmosphere, include the greenhouse gases and the gases which can cool down the surface of the Mercury.

If we just consider the Black body, then the surface temperature of the Mercury is 445.2K; the reflection of the surface of the Mercury, Carbon Soot, Tropospheric, Sulfate Aerosols, Rayleigh and the cloudy sky conditions can lead the surface temperature become lower; the Global Mean Cloud Effects, Tropospheric Components, and Stratospheric Components is available to make the surface of the planet hotter.

Difference of the temperature between the place which is face to the sun and the place which is back to the sun can reach 600K [18].

4. Conclusion

4.1. Further research about the Mercury

A research detector called The Baby Columbo, which was made by Japanese researcher and Europeans researcher will reach the Mercury in December 5th, 2025, and then it will start its work for one or two years. It was launched in October 20th, 2018, and then it reached to the Venus and the Mercury for six times (each are all three times) [18,20].

Although there has no water on the surface, and the temperature difference of surface of the Mercury can reach 600K, there has lots of ice and water in the underground of the Mercury, just like the Mars. [18].

4.2. The climate of the Mercury

Because of the thin atmosphere, it cannot create lots kind of weather, just like only the big sun in the middle of the sight, and sometimes have some small winds. It is hot on the surface face to sun, and cold in another side of it.

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