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# *Modeling the Impact of Greenland Ice Sheet Melting on Global Sea Level Elevation and Climate Change Feedback Mechanisms*

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***Abstract:*** The rapid acceleration of global warming is leading to an increased rate of glacier melt at the Earth's poles, which exacerbates the threats posed by the climate crisis and contributes to rising ocean levels. The Greenland Ice Sheet, recognized as the second-largest ice sheet globally, has housed its extensive glaciers and ice caps for at least 18 million years [1]. The melting and potential collapse of this ice sheet could significantly affect Worldwide climate and sea height. This research aims to develop a coupled model to assess rising sea levels caused by the thawing of the Greenland Ice Sheet, incorporating factors such as global warming, glacier volume, hydrothermal expansion, isostatic rebound, ice dynamics, changes in the gravitational field, and the absorption and release of methane gas. Additionally, the paper investigates the hazards connected to melting glaciers exacerbating global warming. This research provides a crucial foundation for forecasting the long-term impacts of the Greenland Ice Sheet's melting on global climate change.

***Keywords:*** Greenland Ice Sheet, Thermal Expansion, Climate Change, Isostatie Rebound, Ice Dynamics, Gravity Field, Methane.

## 1. Introduction

In the autumn of 2024, osmanthus flowers did not bloom as usual, and the summer of this year broke high-temperature records again. According to a statement by Samantha Burgess, Deputy Director of ESA's Copelnix Climate Change Service, the world experienced the warmest June and August on record [2].Scorching heat waves swept across many regions, not only killing people in some areas due to severe heat sickness but also triggering a series of catastrophic effects, especially the occurrence of large-scale forest fires. The influence of extreme heat, arid vegetation, and flammable environmental conditions make wildfires more difficult to control, taking a huge toll on local ecosystems and residents' lives and property. However, even the coldest regions on Earth are not immune, and rising temperatures are quietly changing these previously frozen regions, putting them at unprecedented risk of melting. This phenomenon highlights the increasing risks posed by climate change, emphasizing the immediate need for intervention. Nowadays, "global warming" is no longer an unfamiliar term for individuals, and with global temperatures rising, the potential crisis is slowly expanding from the poles of the Earth. High temperatures accelerate the melting of ice in the Arctic and Antarctic, and this melting process further heats the planet. According to Shepherd, the Greenland

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ice sheet has played a substantial role in the increase of global sea levels. Between 1992 and 2018, Greenland lost 3,902±342 billion tons of ice, raising sea levels by an average of 10.8±0.9 mm. This illustrates the strong feedback loop between glacier melting and global warming [3].

Additionally, melting snow and ice further drive global warming, as about 90% of solar radiation hitting snow and ice is typically reflected into space. The Earth absorbs more solar energy with a less reflective surface, releasing additional heat into the atmosphere and accelerating warming [4]. This feedback cycle worsens the climate crisis, especially in the polar regions. For instance, Greenland's significant annual ice loss remains a crucial driver of rising global sea levels. Rignot et al. observed that Antarctic ice sheet loss has accelerated by 14.5±2 Gt/year² to 36.3±2 Gt/year², nearly three times faster than the loss from mountain glaciers and ice caps (12±6 Gt/year). If this trend continues, ice sheets will significantly contribute to rising sea levels in the 21st century. Eight years later, Oppenheimer noted, "The combined impact of glacier and ice sheet melt is now the primary contributor to global mean sea level rise, with very high confidence" [5][6].

The melting of glaciers not only exacerbates global warming but also gradually contributes to the rise in sea levels. An increase in sea level would profoundly impact coastal areas and their inhabitants. Evidence suggests that the global rise in sea levels since 1970 is largely attributable to climate change induced by human actions [7]. Globally, the Greenland Ice Sheet is recognized as the second-largest ice sheet. As the surface ice sheet melts, there is a post-glacial rebound, which is when the massive weight of the ice plate is removed, and the land is raised, resulting in isostatic subsidence[8]. Meanwhile, the Earth's gravitational field also changes with the redistribution of ice and the mass of melted water [8]. However, changes in the gravity field also mean that the Earth's axis is shifted, which in turn causes changes in the Earth's rotation, leading to a series of related effects. According to the National Ocean Service, Typically, regions of the planet with stronger gravitational forces experience higher mean sea levels, while areas where gravitational forces are weaker have lower mean sea levels [9]. When considering the ice loss from the Greenland ice sheet, the ice sheet's dynamic is also an important factor. The ice sheet flows under the action of its own weight, and its flow speed is determined by the balance between gravity, the basement resistance relative to the ice sheet, and the internal deformation of the ice sheet [10]. During a field trip to the West Greenland Ice Sheet in 2016, researchers observed that $CH_4$ concentrations in the air released by glacial runoff were significantly higher, reaching up to 15 times the atmospheric background levels at subglacial discharge points [11]. Methane, recognized as a potent greenhouse gas, has a substantial impact on global warming. However, in January 2024, researchers at the University of Copenhagen made a surprising discovery. They found that Greenland is not a significant source of methane but a net methane sink. The ice-free part of Greenland consumes more than 65,000 tons of methane per year, while the wet areas only release 9,000 tons of methane per year [12]. However, the volume of the wet areas may increase with the melting of the ice, potentially leading to a release and increase of methane gas that could exacerbate global warming. With global warming enhanced, the temperature increases, resulting in the thermal expansion of seawater, thus increasing the volume of seawater [13].

In light of these factors are linked to each other to form a feedback mechanism, they are closely related ice sheets melt and rising sea levels. The aim of this study was to quantify the contribution of glacier melting to global sea level elevation and temperature change by analyzing global warming, Ice sheet melting, hydrothermal expansion, Isostatie Rebound, Ice sheet dynamics, gravitational field changes, and methane gas release. The ice sheet model in Matlab is used to combine various models to form a coupled model to simulate temperature change, glacier melting rate, and sea level rise rate. It also discusses the possible ice sheet decline rate and its impact under future global warming scenarios [14].

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## 2. Methodology

We initially employed the mass balance method to estimate the potential rise in ocean levels resulting from Greenland's ice mass depletion. This approach assesses the impact of melting ice sheet volume on sea levels. The increase in sea level due to the ice volume can be determined by dividing the total volume of melted water by the total area of the oceans.

$$H_{ice} = \frac{V_{water}}{A_{ocean}} \tag{1}$$

where $H_{ice}$is the height of rising ocean level by melted water, Vwater is the meltwater volume, and Aocen is the surface area of the world's oceans.

For $V_{water}$ that is equal to the volume of ice in Greenland multiply the density of ice and divided by density of water. Since ice melting is related to temperature change, considering the effect of global warming on Greenland ice sheet, therefore the volume of ice melt can be denoted as V(t) which can be modeled over time as a function of rising global temperatures.

$$V(t) = V_0 - f\left(T(t)\right) \times \Delta t \tag{2}$$

$V_0$ is the initial volume of ice, T(t) is the temperature at time t, f(T(t)) is the function representing the melting rate at temperature T(t) and Δt is the time interval.

Temperature change is the primary factor driving ice melt, as well as influencing water thermal expansion. As the surface area of the ice sheet decreases, the reduction in snow and ice albedo accelerates global warming. Additionally, Greenland releases and absorbs methane, a potent greenhouse gas, each year. Therefore, the annual impact of methane on temperature change is also a crucial factor to consider.

$$T(t) = T(t-1) + \Delta T_{global}(t) + \Delta T_{ice}(t) + \Delta T_{methane}(t) \tag{3}$$

T(t-1) is the temperature at the previous point in time, $\Delta T_{global}$ (t) represents the global temperature increase due to climate changeby human activities over time, $\Delta T_{ice}$ (t) is the temperature feedback effect from the melting ice, which would further exacerbating climate warming, and $\Delta T_{methane}$ (t) accounts for the temperature change attributed to methane release from the melting ice sheet, which exacerbates global warming.

According to the zero dimensional climate model [16], the temperature change influenced by human factors per year can be obtained as follows:

$$\Delta T_{global}(t) = \frac{1}{C}\left[\frac{S(1-\alpha)}{4} - (A - BT_0) + a * \ln\frac{CO_2}{CO_{2PI}}\right]$$
$$A = G(T_0) + G'(T_0)(T - T_0) \tag{4}$$
$$B = -G'\ (T_0)$$

S is the solar insolation which is around 1368 W/m$^2$,α is planetary reflectivity which is around 0.3, therefore $\frac{S(1-\alpha)}{4}$ is absorbed solar radiation.G(t) denotes outgoing thermal radiation, and B represents the climate feedback parameter. Human-caused greenhouse effect is written asa $* \ln\frac{CO_2}{CO_{2PI}}$ , where a is $CO_2$ forcing coefficient and $CO_{2PI}$is preindustrial $CO_2$ concentration.

In a similar manner, $T_{ice}(t)$ can be expressed as:

$$\Delta T_{ice}(t) = \frac{1}{C} \cdot \frac{1}{S - \sigma \cdot T_{ice}(t-1)^4 + \frac{L_f \cdot \rho_{ice} \cdot \left(u(t) \cdot A_{base}(t) \cdot h(t)\right)}{\Delta t}} \tag{5}$$

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$$C \cdot \frac{dT}{dt} = S - \sigma \cdot T^4 + Q_{ice}(t)$$
$$Q_{ice}(t) = \frac{L_f \cdot \rho_{ice} \cdot V_{ice}(t)}{\Delta t}$$
$$V_{ice}(t) = u(t) \cdot A_{base}(t) \cdot h(t)$$

C is heat capacty of the Earth system, S is solar radiation input, $\sigma \cdot T^4$ represents The energy radiated by the Earth into space (Stefan-Boltzmann law), $Q_{ice}(t)$ represents additional heat input due to melting ice sheet, $L_f$ is the latent heat of melting of ice about 334,000 J/kg, u(t) is ice velocity at time t, the speedat which ice moves outward and is usually affected by temperature and ice thickness, $A_{base}(t)$ is the area of the bottom of the ice sheet refers to the area of the base of the ice sheet in contact with the surface and the area can change as ice melts or accumulates, and the thickness of the ice sheet in time is written as h(t).

The direct relationship between methane emissions and temperature change can be express it as:

$$\Delta T_{methane}(t) = \alpha_{CH4} \cdot \ln\left(\frac{C_{CH4}(t-1)+\Delta C_{CH4}(t)}{C_{CH4}(t_0)}\right) \quad (6)$$

$\alpha_{CH4}$ is radiative forcing sensitivity constant for methane, used to convert changes in methane concentration into changes in temperature ,$C_{CH4}(t)$ is methane concentration at time t, usually expressed in parts per million (ppm).

According to Jesper and Christian hourly flux rate calculation formula [11]:

$$F_{\frac{CO2}{CH4}} = \frac{C \cdot \bar{u} \cdot A \cdot 273.15}{M_v \cdot (273.15+T_a)} \cdot M \cdot 3600 \cdot 10^{-6} \quad (7)$$

$FCO_2/CH_4$ represents the flux rate in g $CH_4/CO_2$ m-2h-1, C is the dry mole fraction concentration (μmol mol-1), $\bar{u}$ is the wind speed(m s-1), A is the cross-section area(m2), Mv is the molar volume (m3 mol-1),Ta is the air temperature(℃) and M is the molar mass of CH4 or CO2(g mol-1)

Therefore the aunnally flux rate model would be:

$$F^{annual}_{\frac{CO2}{CH4}} = \frac{C \cdot \bar{u} \cdot A \cdot 273.15}{M_v \cdot (273.15+T_a)} \cdot M \cdot 8760 \cdot 10^{-6} \quad (8)$$

$$\Delta C_{CH4}(t) = F^{annual}_{\frac{CO2}{CH4}} \times \Delta t(\Delta t \text{ here is per year}) \quad (9)$$

Moreover, researchers at the University of Copenhagen claims that the ice-free part of Greenland consumes more than 65,000 tons of methane per year, while the wet areas only release 9,000 tons of methane per year [12]. Therefore we assume Fwet is methane released from wetland areas and α wetFwet is methane released converted to temperature increments and α wet is a coefficient that represents the positive effect of methane released from a wetland area on temperature. Similarly we can also write methane consume as αconsumeFconsume. Since the amount of methane been released and consumed might change, thus we can write Fwet and Fconsume into:

$$F_{wet}(t) = \alpha_{wet} \cdot F^{annual}_{CO2/CH4}$$
$$F_{consume}(t) = \alpha_{consume} \cdot \cdot F^{annual}_{CO2/CH4}$$
$$\Delta T_{methane}(t) = \alpha_{CH4} \cdot \ln\left(\frac{C_{CH4}(t-1)+\alpha_{wet} \cdot F^{annual}_{\frac{CO2}{CH4}} - \alpha_{consume} \cdot F^{annual}_{\frac{CO2}{CH4}}}{C_{CH4}(t_0)}\right) \quad (10)$$

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Fwet, baseis the amount of methane released from wet areas under baseline conditions (in tons). Fconsume, base is the amount of methane consumed by the ice sheet under baseline conditions (in tons). $\alpha_{wet}$ and $\alpha_{consume}$ here is a coefficient reflecting the effect of wetland release and ice sheet depletion on the total flux

Thus, the full temperature model can be expressed as:

$$T(t) = T(t-1) + \frac{1}{C}\left[\frac{S(1-\alpha)}{4} - (A - BT_0) + a * \ln\frac{CO_2}{CO_{2PI}}\right] + \frac{1}{C}\cdot\frac{1}{S-\sigma\cdot T_{ice}(t-1)^4 + \frac{L_f\rho_{ice}\cdot\left(u(t)\cdot A_{base}(t)\cdot h(t)\right)}{\Delta t}} + \alpha_{CH4}\cdot\ln\left(\frac{C_{CH4}(t-1) + \alpha_{wet}\cdot F_{\frac{CO2}{CH4}}^{annual} - \alpha_{consume}\cdot F_{\frac{CO2}{CH4}}^{annual}}{C_{CH4}(t_0)}\right) \quad (11)$$

Since water thermal expansion includes initial sea water and greenland ice sheet meltwater, it is crucial to account for the combined volume change when estimating sea level elevation.

$$\Delta V_{expansion}(t) = V_{total}(t-1) + V_{icemelt}(t)\cdot\beta\cdot\Delta T(t) \quad (12)$$

Vinitial is the initial volume of seawater which is the volume before ice melts, Vtotal(t-1) represents the total volume of seawater at the previous time step t-1, Vicemelt(t) is the volume of meltwater from the Greenland ice sheet at the current time t, $\beta$ is the coefficient of thermal expansion of water and $\Delta T(t)$ represents the temperature increase at time t, which influences the expansion and is equal to T(t) subtract Tbaseline.

Vicemelt(t) is strongly influenced by temperature change, at the same time, the surface area of ocean would also change as increasingin sea level.

$$V_{icemelt}(t) = \frac{A_{ice}(t)\cdot d_{ice}(t)\cdot\frac{\Delta T_{ice}(t)}{T_{melt}}}{\rho_{ice}} \quad (13)$$

Aice(t) is the surface area of the Greenland ice sheet at time t, dice(t) is the thinkness o the ice sheet at time t, $\Delta$ Tice(t) is the temperature change affecting the ice sheet at time t, and Tmelt is the temperature threshold above which ice starts melting.

$$A_{ocean}(t) = A_{ocean}(0) + 2\pi R_{Earth}\cdot H_{total}(t) \quad (14)$$

Aocean(t) is the increase in surface area due to sea level rise at time t, Aocean(o) is the initial surface area of the ocean which is approximately to 3.61 $\times$108, REarth is the radius of Earth which is approximately 6,371 kmand Htotal represents the total ocean level rise at time t, which is the result of both thermal expansion and ice melt.

Thus the height of thermal expansion-driven rise in ocean levels at time t would looks like:

$$H_{thermal\ expansion}(t) = \frac{V_{total}(t-1) + \frac{A_{ice}(t)\cdot d_{ice}(t)\cdot\frac{\Delta T_{ice}(t)}{T_{melt}}}{\rho_{ice}}\cdot\beta\cdot\Delta T(t)}{A_{ocean}(0) + 2\pi R_{Earth}\cdot H_{total}(t)} \quad (15)$$

Apart from the volume of ice in the Greenland ice sheet itself, as well as thermal expansion, affects sea level, as does Isostatic Rebound.

$$H_{rebound}(t) = \frac{\alpha_2}{\rho g}\cdot\Delta m(t)\cdot e^{\frac{-t}{\tau}} \quad (16)$$

Hrebound(t) represents the height rebound of the land surface at time t due to teh melting of ice sheet, $\alpha$ 2is a proportionality constant that can account for local geological variations, effectively converting teh mass change into a height change, $\Delta$ m(t) is the change in mass of ice sheet over time

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which is equal to the substration of Vmelt(t) and density of ice. ρ is the average density of the crust(kg/m3). This varies depending on geological conditions but normally around 2700 kg/m3 for continental crust, g is the acceleration depends on gravity, approximately 9.81 m/s2, and $e^{\frac{-t}{\tau}}$ is the exponential decay term accounts for the time-dependent nature of the rebound. τ is a time constant that reflects how fast the rebound occurs after the removal of the ice load.

Ice sheet dynamics is another essential factor, and it is closely related to Isostatic rebound. According to Glen’ s Flow Law:

$$\dot{u} = A(t) \cdot \tau^n \tag{17}$$

$$A(t) = A_0 \cdot e^{\frac{-Q}{R \cdot (T+273.15)}} \tag{18}$$

$\dot{u}$ is the velocity of ice flow, A is the flow rate factor that depends on temperature and other conditions,τ is the effective stress acting on the ice and n is typically around 3 for ice. A0 is the initial area at t equal to 0, Q represent the heat energy involved in the preocess and ice usually is 60 kJ/mol, R is the universal gas constant, typically R euqal to 8.314J/(mol·K)and T is temperature. Since Δm(t) is equivalent to Vmelt(t) times ρ ice. Furthermore, Vmelt(t) can be written as $\dot{u}(t) \cdot A_{base}(t) \cdot h(t)$. Thus Hrebound after consider ice sheet dynamics can be written as:

$$H_{rebound}(t) = \frac{\alpha_2}{\rho g} \cdot \left( A_0 \cdot e^{\frac{-Q}{R \cdot (T+273.15)}} \cdot \tau^n \cdot A_{base}(t) \cdot h(t) \cdot \rho_{ice} \right) \cdot e^{\frac{-t}{\tau}} \tag{19}$$

As Greenland ice sheet melt, the gravitational field would also change. The change of sea level height due to gravity field change can be written as :

$$\Delta H_{gravity}(t) = \frac{G \cdot \Delta M_{ice}(t)}{R^2} \left( 1 - \frac{3}{2} \cos^2(\theta) \right) \tag{20}$$

G represents gravitational constant($6.674 \times 10^{-11}$ $m^3 kg^{-1} s^{-2}$), $\Delta M_{ice}(t)$ is Change in the mass of the Greenland ice sheet at timeR is mean radius of the Earth which is approximately 6.371×106m, and θ is latitude of the observation point.

Therefore the total sea level height change would be:

$$H_{total} = H_{thermal\ expansion} + H_{gravity} - H_{rebound} \tag{21}$$

## 2.1. Contribution of Greenland Ice Sheet Melt to Sea Level Rise

The study found that with global warming, the melting rate of the Greenland ice sheet has accelerated significantly, becoming one of the main drivers of global ocean level rise. The rate of ice sheet melting is directly related to the rise in global temperature, and the simulation results show that the melting of the Greenland ice sheet will lead to global rise in ocean levels of several centimeters to tens of centimeters in the coming decades, depending on the magnitude of the temperature rise. Under the high-temperature scenario, the rate of ice sheet loss will accelerate significantly, and the contribution to the rise of the global ocean level will be more significant.

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### 2.2. The Relationship Between Thermal Expansion of Seawater and Sea Level Rise

In addition to melting ice sheets, the thermal expansion of ocean water is a crucial contributor to sea level elevation. As global temperatures rise, the oceans absorb more heat, causing the volume of seawater to expand, further exacerbating sea level rise. The study shows that the thermal expansion effect contributes to a considerable proportion of elevated sea levels globally, especially in tropical and subtropical seas, so the thermal expansion effect is more pronounced. The simulation results show that even without additional ice sheet melting, the thermal expansion effect of seawater alone would cause significant rise in sea levels.

### 2.3. The Impact of Isostatic Rebound and Changes in the Gravitational Field

With the melting of the Greenland ice sheet, the isostatic rebound effect has gradually emerged. After the ice sheet lost its massive mass, the Earth's crust gradually rose, leading to a slower rate of sea level rise in and around Greenland than the global average. At the same time, melting ice sheets also trigger changes in the Earth's gravity field, further affecting the global distribution of sea levels. The study found that some areas farther away from Greenland could experience faster ocean level rise due to the redistribution of the gravitational field. In contrast, the rise of sea level near Greenland would be relatively slower. In addition, the impact of melting ice sheets on Earth's rotation could also have potential follow-on effects, further altering global climate and ocean dynamics.

### 2.4. The Impact of Integrated Feedback Mechanisms

In conclusion, the study explores the multiple impacts of the loss of ice sheets from Greenland on the rise of the global sea level by establishing a coupled model. Studies have shown that with the intensification of global warming, the melting rate of ice sheets has increased significantly, becoming one of the critical factors driving ocean level elevation. In addition, the thermal expansion effect of seawater also plays a significant role in rising sea levels, especially in higher-temperature waters. At the same time, the melting of the ice sheet also triggered the isostatic rebound of the crust and the change of the gravity field, resulting in the sea level rise in different regions showing obvious imbalance. These results reveal the complex feedback mechanism between ice sheet melting and global climate change. They provide an essential scientific basis for predicting future sea level changes and their impacts on coastal regions worldwide. Through the analysis of this study, we can better understand the interaction between climate change, ice sheet melting, and ocean level rise, which can help promote more effective climate response measures and disaster prevention planning of coastal cities worldwide.

## 3. Conclusion

This paper systematically analyses the role of the melting of the Greenland ice sheet in rising global sea levels through coupled models. Global warming has been found to lead to the accelerated melting of the Greenland Ice Sheet, which has become one of the main drivers of sea level rise. Model simulations show that sea levels will rise significantly in the coming decades as temperatures rise. The study also analyzed the impacts of hydrothermal expansion, equilibrium rebound, and changes in gravity field on sea level and found that the combined effects of these factors lead to an uneven rise in sea level, which provides a scientific reference for disaster prevention planning in coastal areas.

## References

[1] *Wikipedia Contributors. "Greenland Ice Sheet." Wikipedia, Wikimedia Foundation, 24 Aug. 2019, en.wikipedia.org/wiki/Greenland_ice sheet.*

DOI: 10.54254/2753-8818/86/2025.20193

[2] Smith, Hayley. "Summer 2024 Was Earth's Hottest on Record." Los Angeles Times, 6 Sept. 2024, www.latimes.com/environment/story/2024-09-06/summer-2024-was-earths-hottest-on-record.
[3] Shepherd, A., et al. (2020). "Mass balance of the Greenland Ice Sheet from 1992 to 2018." Nature, 579(7798), 233-239.
[4] UCAR. "Climate and Ice | UCAR Center for Science Education." Scied.ucar.edu, 2019, scied.ucar.edu/learning-zone/climate-change-impacts/climate-and-ice.Rignot, E., et al. (2011). "Acceleration of the contribution of the Greenland and Antarctic ice sheets to sea level rise." Geophysical Research Letters, 38(5).
[5] Oppenheimer, M., et al. (2019). "Sea Level Rise and Implications for Low-Lying Islands, Coasts and Communities." IPCC Special Report on the Ocean and Cryosphere in a Changing Climate.
[6] DeConto, R. M., & Pollard, D. (2016). "Contribution of Antarctica to past and future sea-level rise." Nature, 531(7596), 591-597.
[7] Slangen, A. B. A., et al. (2017). "Anthropogenic forcing dominates global mean sea-level rise since 1970." Nature Climate Change, 6(7), 701-705.
[8] Morris, E. M., et al. (2021). "The thinning and retreat of Nioghalvfjerdsfjorden Glacier in northeast Greenland: Observations from 1999–2020." Journal of Glaciology, 67(263), 273-287.
[9] Wikipedia Contributors. "Post-Glacial Rebound." Wikipedia, Wikimedia Foundation, 6 Oct. 2019, en.wikipedia.org/wiki/Post-glacial_rebound.
[10] Vermeersen, B. "Effects of Ice-Melt Induced Gravity Changes and Solid Earth Deformation in the Netherlands." Netherlands Journal of Geosciences - Geologie En Mijnbouw, vol. 87, no. 3, Sept. 2008, pp. 215–215, www.cambridge.org/core/services/aop-cambridge-core/content/view/F104FAA95BEA8D6138FBBC8BCEF0BD64/S0016774600023295a.pdf/effects-of-ice-melt-induced-gravity-changes-and-solid-earth-deformation-in-the-netherlands.pdf, https://doi.org/10.1017/s0016774600023295. Accessed 3 June 2024.
[11] "Ice Sheet Dynamics – Geophysical Fluid Dynamics Laboratory." Noaa.gov, 2018, www.gfdl.noaa.gov/ice-sheet-dynamics/.
[12] Christiansen, Jesper Riis, and Christian Juncher Jørgensen. "First Observation of Direct Methane Emission to the Atmosphere from the Subglacial Domain of the Greenland Ice Sheet." Scientific Reports, vol. 8, no. 1, 9 Nov. 2018, https://doi.org/10.1038/s41598-018-35054-7.
[13] "Greenland Is a Methane Sink rather than a Source." ScienceDaily, 2024, www.sciencedaily.com/releases/2024/01/240131144459.htm. Accessed 19 Oct. 2024.
[14] "Educator Guide: Thermal Expansion Model." NASA/JPL Edu, www.jpl.nasa.gov/edu/teach/activity/thermal-expansion-model/.
[15] Wikipedia Contributors. "Ice-Sheet Model." Wikipedia, Wikimedia Foundation, 24 Mar. 2024, en.wikipedia.org/wiki/Ice-sheet_model. Accessed 4 Oct. 2024.
[16] "Lecture 2, a "Zero-Dimensional" Energy Balance Model of Earth's Climate — Climate of the Earth." Florianboergel.github.io, florianboergel.github.io/climateoftheocean/2020-11-11-energy-model.html.