Title: **The Mesozoic Conundrum: Global Albedo Factors Explain the Lack of Correlation Between Temperatures and CO_2 Concentrations**

Author: Ugo Bardi
Consorzio Interuniversitario di Scienza e Tecnologia dei Materiali (INSTM), Firenze, Italy
The Club of Rome, Winterthur, Switzerland
World Academy of Arts and Science, Napa, CA 94558, United States

E-mail: ugo.bardi@unifi.it

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The Mesozoic Conundrum: Global Albedo Factors Resolve the Lack of Correlation Between Temperatures and CO2 Concentrations.

Ugo Bardi

Consorzio Interuniversitario di Scienza e Tecnologia dei Materiali (INSTM), Firenze, Italy
The Club of Rome, Winterthur, Switzerland
World Academy of Arts and Science, Napa, CA 94558, United States

E-mail: ugo.bardi@unifi.it

Abstract

The "Mesozoic Conundrum" refers to the lack of correlation between CO_2 atmospheric concentration and global mean surface temperatures in Mesozoic climate reconstructions (Judd et al., 2024). Here, I show that Mesozoic forest cover, proxied by carbon burial flux (Nelsen et al., 2016), correlates strongly (R^2=0.88, p<0.01) with GMST across the Mesozoic (252–66 Ma before present). The analysis reveals a progression from low forest cover in the Early Triassic (GMST ca. 22°C) to a peak in the Mid Cretaceous (103.2 Ma; GMST ca. 27.5°C), increasing land cover from ~50% to 80%. This correlation indicates that albedo feedbacks from forest expansion amplified warming, resolving the conundrum. These findings highlight vegetation's role in Mesozoic climate, showing the influence of plate tectonics on Earth's climate over tens of millions of years.

Keywords: Mesozoic, Climate, CO_2, albedo, greenhouse effect, forest cover, biotic pump, plate tectonics

1. Introduction

The Mesozoic Era (252–66 Ma before present) was a greenhouse world. Paleoclimate reconstructions (Judd et al., 2024) reveal global mean surface temperatures (GMST) increasing from 22°C (Early Triassic, 252 Ma) to 27.5°C (Mid Cretaceous, 103.2 Ma) over ~186 million years, with a Late Cretaceous decline to 25.5°C (66 Ma). This increase does not correlate well with CO_2 levels, which typically remained in the range of 800–1000 ppm, though ranging from ca. 500–1200 ppm, with lower values (500–700 ppm) in the Early Triassic (Willis & McElwain, 2014; Judd et al., 2024; Foster et al., 2017). Judd et al. (2024) termed this discrepancy the "Mesozoic Conundrum," discussing several factors but not mentioning long-term variations in forest cover.

In this paper, I report a correlation between GMST and forest cover evolution during the Mesozoic, a novel finding to my knowledge. I propose that lower albedo from increased forestation (assumed as ~50% to 80% land cover; Nelsen et al., 2016) drove warming, despite stable CO_2 levels. Forest cover, proxied by organic carbon burial flux (Nelsen et al., 2016), correlates strongly (R^2=0.88, p<0.01) with GMST. Forests' albedo (~0.1–0.2) versus deserts/grasslands (~0.3–0.4) (Betts, 2000) suggests a ~50% to 80% land cover increase generated a ~5.1°C GMST rise (Supplementary Materials). Plant diversification (Willis & McElwain, 2014) and enhanced inland precipitation, possibly from Pangaea's breakup (Scotese et al., 2021) and a biotic pump mechanism (Makarieva & Gorshkov, 2007), drove this forestation. These factors highlight albedo's dominance over CO_2 in Mesozoic climate, informing modern vegetation-climate feedbacks (IPCC, 2021).

2. Methods

Data Sources

Forest cover was proxied using organic carbon burial flux from Nelsen et al. (2016, Figure 1), normalized to a 0–100 scale (5×10^{14} mol C Myr^{-1} = 100 at 103.2 Ma). GMST was sourced from Judd et al.'s (2024) PhanDA reconstruction, interpolated for 30 time points (252–66 Ma). Values were visually estimated from published figures due to unavailable numerical data, validated against paleobotanical proxies (Retallack, 2001; Barral et al., 2017).

Data Analysis

Thirty time points were selected at ~6.2 Myr intervals, spanning the Triassic (252–201 Ma), Jurassic (201–145 Ma), and Cretaceous (145–66 Ma). Carbon burial flux was normalized to relative forest cover based on the Mid Cretaceous maximum. GMST values were interpolated to match these points. A scatter plot (forest cover on x-axis, GMST on y-axis) was generated using Python/Matplotlib, with linear regression (SciPy) to compute R^2 and p-value. Analysis was supported by Grok, an AI developed by xAI.

Limitations

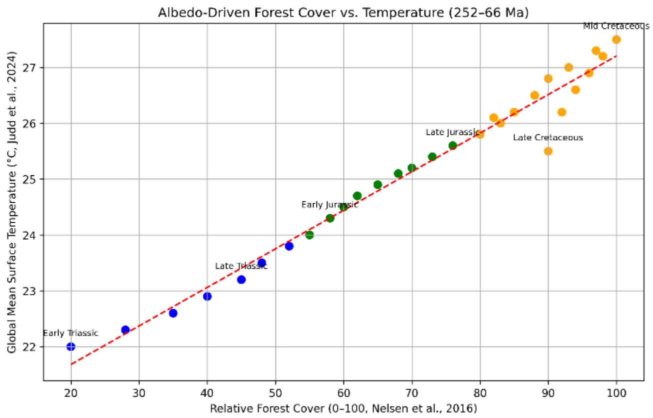
Carbon burial flux indirectly proxies forest cover, influenced by preservation and plant types. No direct data exist for quantitative global forest cover; assumptions (~50%–80% land cover) are used for albedo modeling. Paleobotanical evidence (e.g., polar forests; Willis & McElwain, 2014) and pollen/leaf fossils (Cleal & Thomas, 2010; Barral et al., 2017) validate forest expansion trends. GMST interpolation introduces uncertainty (~0.5°C), and visual flux estimation adds ~5% error. Access to numerical data from Nelsen et al. (2016) and Judd et al. (2024) would enhance precision. These limitations are mitigated by cross-referencing literature to confirm forest cover and GMST trends, ensuring consistency with Mesozoic vegetation and climate reconstructions (Willis & McElwain, 2014; Barral et al., 2017; Upchurch et al., 1999).

3. Results

We observed a strong positive correlation (R^2=0.88, $p<0.01$) between relative forest cover and GMST across the Mesozoic (Figure 1). Key trends include:

- Early Triassic (252 Ma): Sparse forest cover and GMST (22°C), reflecting post-Permian extinction.
- Mid Cretaceous (103.2 Ma): Peak forest cover and GMST (27.5°C), coincident with polar forests.
- Late Cretaceous (66 Ma): Reduced forest cover and GMST (25.5°C).

The correlation supports albedo feedbacks: forest expansion (assumed as ~50% to 80% land cover; Nelsen et al., 2016) likely reduced albedo (~0.25 to ~0.15), increasing radiative forcing by ~10.2 W/m² (Betts, 2000). A supplementary calculation estimates a 5.1°C GMST rise, closely matching the observed 5.5°C increase (Supplementary Materials).



Caption: Scatter plot of relative forest cover (Nelsen et al., 2016) versus GMST (Judd et al., 2024) for 30 Mesozoic time points (252–66 Ma). Colors: blue (Triassic), green (Jurassic), orange (Cretaceous). Linear regression (red dashed line, R^2=0.88) highlights the correlation.

4. Discussion

This study resolves the "Mesozoic Conundrum" by showing that albedo-driven forest cover amplified Mesozoic warming, reconciling Judd's GMST with CO_2 data. CO_2 levels (typically ~800–1000 ppm, within ~500–1200 ppm; Judd et al., 2024; Foster et al., 2017) and humidity from Pangaea's breakup drove forest expansion, reducing albedo and sustaining greenhouse conditions (Willis & McElwain, 2014; Scotese et al., 2021). The Pangaea split enhanced precipitation by creating coastlines and inland seas, while forests amplified this via the biotic pump, drawing moist air inland through evapotranspiration (Makarieva & Gorshkov, 2007). This sustained forest expansion (assumed as ~50% to 80% land cover), lowering albedo (0.25 → 0.15) and driving ~5.1°C GMST rise (Supplementary Materials), particularly in polar regions (Francis et al., 2008). The albedo model quantifies a 5.1°C warming, reinforcing the correlation (R^2=0.88).

Deviations (e.g., Early Cretaceous, 125 Ma) align with cooling events or preservation biases (Judd et al., 2024; Hay, 2017). While CO_2 is likely to have been an important factor (Foster et al., 2017; McElwain et al., 2005), albedo feedbacks explain the correlation's strength, extending prior models (Berner, 2003; Otto-Bliesner et al., 2002). Implications include improved paleoclimate modeling and modern reforestation strategies, balancing albedo and carbon sequestration (IPCC, 2021; Winguth et al., 2010). Limitations involve the carbon burial proxy's indirectness, addressable with pollen or biome data (Barral et al., 2017; Upchurch et al., 1999). The biotic pump's role, though debated (Sheil &

Murdiyarso, 2009), merits further exploration in paleoclimatic contexts.

The stability of CO_2 levels (~800–1000 ppm) despite rising temperatures may relate to Pangaea's breakup, which created longer coastlines and enhanced nutrient runoff to oceans (Scotese et al., 2021). Nutrient runoff likely fertilized marine ecosystems, increasing carbon burial and counterbalancing CO_2 release from warmer oceans (Kidder & Worsley, 2010). Future work should quantify albedo, biotic pump, and nutrient dynamics in Mesozoic climate models.

4. Conclusion

Earth's climate is a complex system, with parameters driven by interacting factors. Hence, it is not surprising that, during Earth's history, CO_2 concentration (typically ~800–1000 ppm, within ~500–1200 ppm during the Mesozoic; Judd et al., 2024; Foster et al., 2017) was not always the primary driver of global surface temperatures, unlike in the Cenozoic (Rae et al., 2023; Judd et al., 2024) or modern times. The approximate stability of CO_2 despite increasing temperatures during the Mesozoic resulted from two factors. First, the high CO_2 concentration weakened the logarithmic greenhouse forcing, reducing its control compared to albedo (Betts, 2000). Second, over tens of millions of years, plate tectonic movements enabled forestation of inland areas after Pangaea's breakup (Scotese et al., 2021), increasing land cover from ~50% to 80% and driving a ~5.1°C GMST rise (Supplementary Materials). In contrast, Pleistocene CO_2 variations (180–280 ppm) dominated temperature shifts. These findings provide insights into the ecosystem's temperature control mechanisms.

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Supplementary Materials

Data Extraction Details: Carbon burial flux was visually estimated from Nelsen et al. (2016, Figure 1) at 30 points. GMST was interpolated from Judd et al.'s (2024) PhanDA curve. Exact data access would enhance precision.

Proxy Validation: Pollen/leaf fossil evidence (Cleal & Thomas, 2010; Barral et al., 2017; Francis et al., 2008) confirms extensive Cretaceous forests, supporting carbon burial trends.

Albedo-Driven Radiative Forcing Calculation:

To confirm albedo-driven warming from forest cover increase (50% to 80% land cover, Early Triassic to Mid Cretaceous; Nelsen et al., 2016), we calculate radiative forcing (ΔF) and GMST change (ΔT).

Albedo Change: Land albedo dropped from 0.25 (50% forest, deserts) to 0.15 (80% forest), $\Delta\alpha\_land = 0.1$ (Betts, 2000). Global albedo change (30% land): $\Delta\alpha\_global = 0.1 \times 0.3 = 0.03$.

Radiative Forcing: $\Delta F = -340\ W/m^2 \times (-0.03) = 10.2\ W/m^2$ (solar flux $S = 340\ W/m^2$).

Temperature Change: With climate sensitivity $\lambda = 0.5°C/(W/m^2)$ (Hansen et al., 2008), $\Delta T = 0.5 \times 10.2 = 5.1°C$ (range 3.06–8.16°C for $\lambda = 0.3–0.8$).

Comparison: Observed $\Delta T = 5.5°C$ (22°C to 27.5°C, Judd et al., 2024). The albedo change explains most of the reported warming.