

A Habitable Zone Drawn from Equilibrium Temperature Puts Earth Outside It

— At albedo **0.30** Earth's equilibrium temperature is **254.5781 K** (**-18.57** degrees Celsius) — The “freezing-point distance” is **0.8686 AU**, and Earth lies beyond it — Moving the albedo from **0** to **0.75** moves the boundary by exactly a factor of **2** — [Paper 361]

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— *From thinking to syncing.* —

Abstract

The habitable zone is spoken of as a property of a star. This paper asks where its boundary comes from—the answer is not from the star but from assumptions about the planet's albedo and atmosphere. No new mathematical theorem and no new law is claimed. First, at albedo **0.30** Earth's equilibrium temperature is **254.5781 K**, **18.57** degrees below freezing (Section 2). Second, this is the core of the paper. On that assumption the “freezing-point distance” is **0.8686 AU**, and Earth falls outside the boundary (Section 3). Third, set the albedo to **0** and the boundary becomes **1.0382 AU**, putting Earth inside. One assumption reverses the conclusion (Section 3). Fourth, from **0** to **0.75** the boundary moves **0.5191 AU**, a ratio of exactly **2** (Section 3). Fifth, Earth is actually at **288 K** because of **33.4219 K** of greenhouse effect (Section 4). Sixth, the separator is whether the atmosphere is in the formula, not the star and not the distance (Section 5).

Scope of this paper (scope note): No new mathematical theorem and no new law is claimed——equilibrium temperature, albedo, the greenhouse effect, and the habitable zone are all standard. We do not build climatology——radiative-convective equilibrium, the runaway greenhouse, and regulation by the carbon cycle are not entered. They are named and no more. We evaluate no planets——whether any particular exoplanet is habitable is not judged. We do not define life——conditions other than liquid water are not the subject. What is treated here is a temperature formula. Stellar evolution is not treated——main-sequence luminosity change and the continuously habitable zone are named and no more. Tides are not treated——synchronous rotation and tidal heating are not the subject. Relation to earlier papers: Paper 358 showed the “depth” of depth of field to be a convention rather than a measurement——there the convention was the circle of confusion; here it is the albedo. Paper 352 showed a transition temperature moving with the speed of measurement——there too a quantity wearing the face of a constant was conditional. Paper 300 showed whether two things share a root is decidable——by that test, equilibrium temperature and surface temperature have distinct roots. Paper 353 showed a claim turning false when its condition is dropped——here dropping it classifies Earth as uninhabitable. What is added is giving equilibrium temperature and boundary distance at five albedos, showing that the standard assumption excludes Earth itself, showing the boundary’s ratio to be exactly 2, checking the 33.4219 K greenhouse contribution against the accepted figure, and putting the separator on whether the atmosphere is in the formula.

1. Notation and the Question

Setting: The equilibrium temperature is the temperature at which a sphere of albedo A balances an irradiance S .

$$T_{\text{eq}} = \left[\frac{S(1 - A)}{4\sigma} \right]^{1/4}, \quad S = \frac{S_0}{d^2}, \quad S_0 = 1361 \text{ W/m}^2$$

Here d is distance in astronomical units and σ the Stefan--Boltzmann constant.

Observation 1.1

There is no atmosphere in this formula. Only the radiation received and the fraction reflected——no layer that absorbs and re-emits is counted.

Observation 1.2

Albedo is a property of the planet. Not of the star——so a “zone” cannot be drawn from the star alone.

Observation 1.3

And albedo is itself an outcome of that planet's climate. Ice raises it, fewer clouds lower it——what should be an input depends on an output.

Question: What fixes the boundary of a habitable zone?

2. Earth's Equilibrium Temperature Is Below Freezing

Calculation 2.1: Equilibrium temperature at 1 AU against albedo (computed in this paper).

Albedo A	T_{eq} at 1 AU [K]	Celsius
0.00	278.3214	+5.17
0.10	271.0861	−2.06
0.30	254.5781	−18.57
0.50	234.0395	−39.11
0.75	196.8029	−76.35

Observation 2.2

Earth's actual albedo is about 0.30. The equilibrium temperature there is 254.5781 K——−18.57 degrees Celsius, well below freezing.

Observation 2.3

This matches the accepted value. Earth's equilibrium temperature is usually given as about 255 K——the 254.5781 K here differs by only 0.42 K. Formula and constants are right.

Observation 2.4

Albedo acts through a fourth root. Taking A from 0 to 0.75 quarters ($1 - A$), but the temperature falls only by $\sqrt{2}$ —from 278.3214 to 196.8029, a ratio of 1.4142.

Observation 2.5

And still it moves 81.5 K. Blunted by the fourth root and this wide even so—the albedo assumption governs the temperature conclusion.

3. The Boundary Moves with the Assumption

Calculation 3.1: Solving backwards for the distance at which $T_{\text{eq}} = 273.15$ K (computed in this paper).

Albedo A	Boundary distance [AU]	Earth (1 AU) is
0.00	1.0382	inside (habitable)
0.10	0.9849	outside
0.30	0.8686	outside (uninhabitable)
0.50	0.7341	outside
0.75	0.5191	outside

Observation 3.2

This is the core of the paper. With the standard $A = 0.30$ the boundary is 0.8686 AU and Earth falls outside it—the one known instance of life is classified as uninhabitable.

Observation 3.3

Setting $A = 0$ reverses it. The boundary becomes 1.0382 AU and Earth is inside—one changed assumption about the planet flips the conclusion.

Observation 3.4

The reversal happens below $A = 0.10$. At $A = 0.10$ the boundary is 0.9849 AU, still inside Earth's orbit——so Earth qualifies only for A under about 0.1, far from the actual 0.30.

Observation 3.5

The boundary's motion has a closed form. $d \propto \sqrt{1 - A}$, so the ratio between $A = 0$ and $A = 0.75$ is $\sqrt{1/0.25} = 2$ ——measured, exactly 2.0000, opening a span of 0.5191 AU.

Observation 3.6

The inversion closes. Putting the resulting 0.8686 AU back into the formula returns 273.15000000 K——this is not an arithmetic error.

4. The Missing 33.4219 K

Observation 4.1

Earth's actual mean surface temperature is 288 K. The gap from the equilibrium value 254.5781 K is **33.4219 K**——that is the greenhouse contribution.

Observation 4.2

It falls in the accepted 30 to 35 K. **33.4219 K**——agreement with an independently known value, and a check on the computation here.

Observation 4.3

So what the formula omits is the atmosphere. The equilibrium formula has no absorbing layer——**33.4219 K** is the size of what was left out.

Observation 4.4

Venus is the extreme case. Its albedo is high and its equilibrium temperature lower than Earth's, yet its surface exceeds 700 K—the ordering by equilibrium temperature does not match the ordering by surface temperature. This paper has not computed those numbers and states the fact only.

Observation 4.5

Distinct roots by the criterion of Paper 300. Equilibrium temperature is fixed by a radiation balance; surface temperature by that balance and the atmosphere's optical depth—both are “temperature”, and different things fix them.

5. The Separator: Is the Atmosphere in the Formula?

Observation 5.1

The separator—whether the atmosphere is in the formula; not the star and not the distance.

	What enters	Answer for Earth	Classifies Earth
Equilibrium temperature	S and A only	254.5781 K	wrongly
Surface temperature	plus optical depth	288 K	correctly

Observation 5.2

The rightmost column is the whole verdict. Tried on the one known instance, the top row fails—the same discipline as the corpus's scanning rule: test on a case that ought to hit.

Observation 5.3

The separator can be moved. Add a fixed greenhouse increment and the boundary moves outward—but how much to add differs by planet, and that is itself a new assumption.

Observation 5.4

The assumption does not vanish; it changes place. Assume an albedo, or assume a greenhouse effect—the same shape as the circle-of-confusion convention merely changing place in Paper 358.

Observation 5.5

To be stated honestly—actual habitable-zone research does not draw boundaries from equilibrium temperature alone. Models including radiative-convective equilibrium and the runaway greenhouse are used—what this paper shows is that the most naive way of drawing it fails on the one known instance.

Observation 5.6

One last thing—a classifier should be tried on a case whose answer is known. Tried on Earth, classification by equilibrium temperature fails—apply it to exoplanets without trying it, and the failure goes unnoticed.

6. The Census and the Close

1. $T_{\text{eq}} = 254.5781 \text{ K}$ at $A = 0.30$ (Calculation 2.1): **−18.57 degrees Celsius.**
2. **Only 0.42 K from the accepted 255 K** (Observation 2.3): **the formula is right.**
3. **278.3214 K at $A = 0$** (Calculation 2.1): **a span of 81.5 K.**
4. **Boundary 0.8686 AU at $A = 0.30$** (Calculation 3.1): **Earth outside.**
5. **Boundary 1.0382 AU at $A = 0$** (Calculation 3.1): **Earth inside; the conclusion reverses.**
6. **Ratio exactly 2.0000** (Observation 3.5): **$d \propto \sqrt{1 - A}$.**
7. **Back-substitution gives 273.15000000 K** (Observation 3.6): **the formula closes.**
8. **Greenhouse contribution 33.4219 K** (Observation 4.1): **inside the accepted 30–35 K.**
9. **Albedo is itself a climate outcome** (Observation 1.3): **an input depending on an output.**
10. **Test on a known case** (Observation 5.2): **tried on Earth, it fails.**

Closing: The habitable zone is spoken of as a property of a star—but its boundary cannot be drawn from the star alone. The equilibrium-temperature formula has no atmosphere in it—only the radiation received and the fraction reflected, and albedo is a property of the planet—indeed an outcome of that planet’s climate. What should be an input depends on an output. And the standard assumption puts Earth itself outside—at $A = 0.30$ Earth’s

equilibrium temperature is **254.5781 K**, -18.57 degrees Celsius (only **0.42 K** from the accepted **255 K**). On that assumption the “freezing-point distance” is **0.8686 AU** and Earth falls outside the boundary. The one known instance of life is classified as uninhabitable. One changed assumption reverses the conclusion—set $A = 0$ and the boundary becomes **1.0382 AU**, putting Earth inside. At $A = 0.10$ it is still **0.9849 AU**, so Earth qualifies only for A under about **0.1** — far from the actual **0.30**. Since $d \propto \sqrt{1 - A}$, the ratio between $A = 0$ and $A = 0.75$ is exactly **2.0000**, a span of **0.5191 AU**. What is missing is **33.4219 K**—the gap between Earth’s actual **288 K** and its equilibrium value, inside the accepted **30 to 35 K**. It is the greenhouse contribution, and equally the size of what the formula left out. By the criterion of Paper 300, equilibrium temperature and surface temperature have distinct roots: both are “temperature” and different things fix them. One thing separates them—whether the atmosphere is in the formula; not the star and not the distance. And the assumption does not vanish, it changes place—assume an albedo, or assume a greenhouse effect: the same shape as the circle-of-confusion convention merely changing place in Paper 358. To be said honestly—actual habitable-zone research does not draw boundaries from equilibrium temperature alone; models including radiative-convective equilibrium and the runaway greenhouse are used. What this paper shows is that the most naive way of drawing it fails on the one known instance. One last thing—a classifier should be tried on a case whose answer is known. Tried on Earth, classification by equilibrium temperature fails. Apply it to exoplanets without trying it, and the failure goes unnoticed.

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