

A Föld a jövő Vénusza? – Az üvegházhatásról másképp



Vincze Miklós

ELTE Fizikai Intézet Kármán laboratóriuma, ELKH-ELTE Elméleti Fizikai Kutatócsoport

Az atomoktól a csillagokig előadássorozat

2023. január 12.

„Ikrek”



Earth, Credit: NASA's Earth Observatory



Venus, Credit: NASA/JPL-Caltech/Mariner 10

„Ikrek”



© Universal Studios

Sőt! A Vénusz mint „rossz példa”



Sőt! A Vénusz mint „rossz példa”

ÓVAKODJUNK A SZESZES ITALOKTÓL

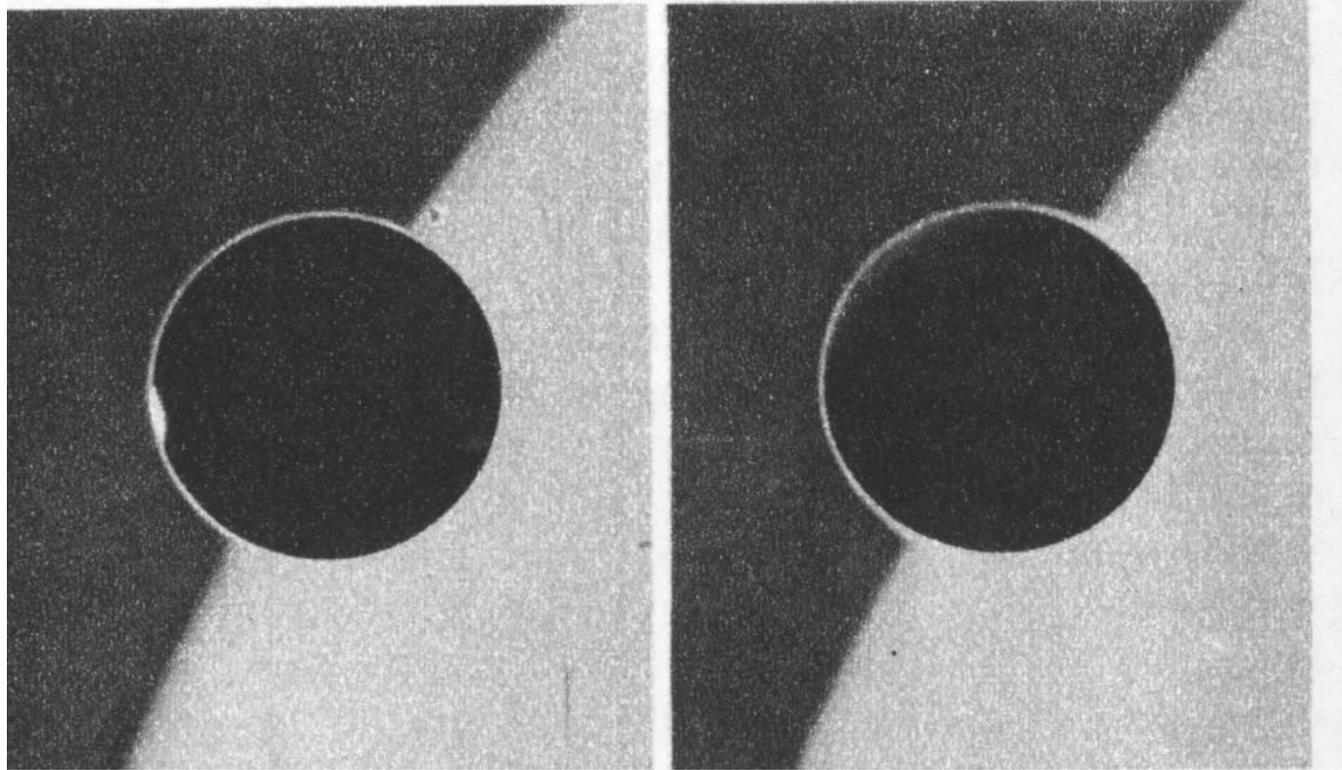
ÓVAKODJUNK A SZÉN-DIOXIDTÓL



A Vénusz légköre: mióta tudunk róla?



M. Lomonoszov
(1761)



A Vénusznak *halója*, tehát légköre van

A Vénusz légköre: mióta tudunk róla?

Mindeközben Cook kapitányék felfedezik Ausztráliát

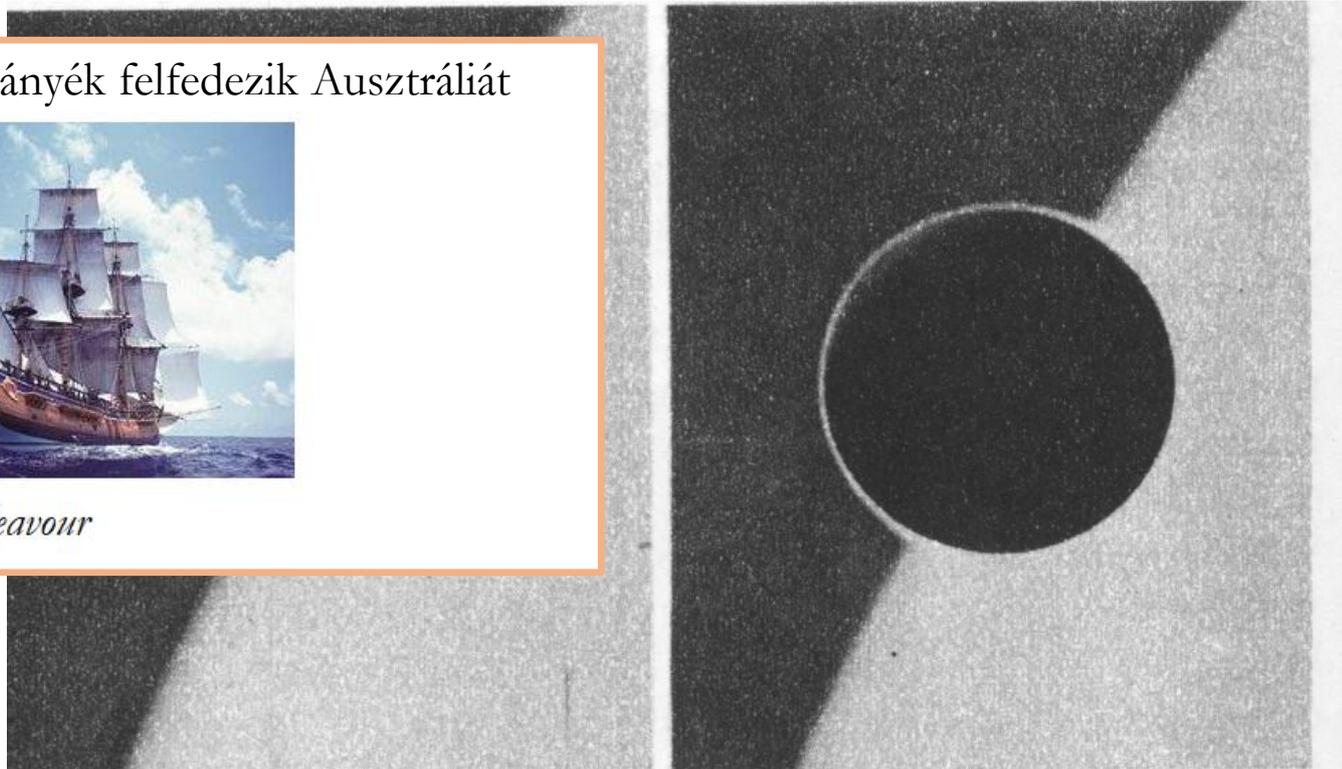


The Endeavour

M. LŐRINCZOV

(1761)

A Vénusznak *halója*, tehát légköre van



A Vénusz légköre: mióta tudunk róla?

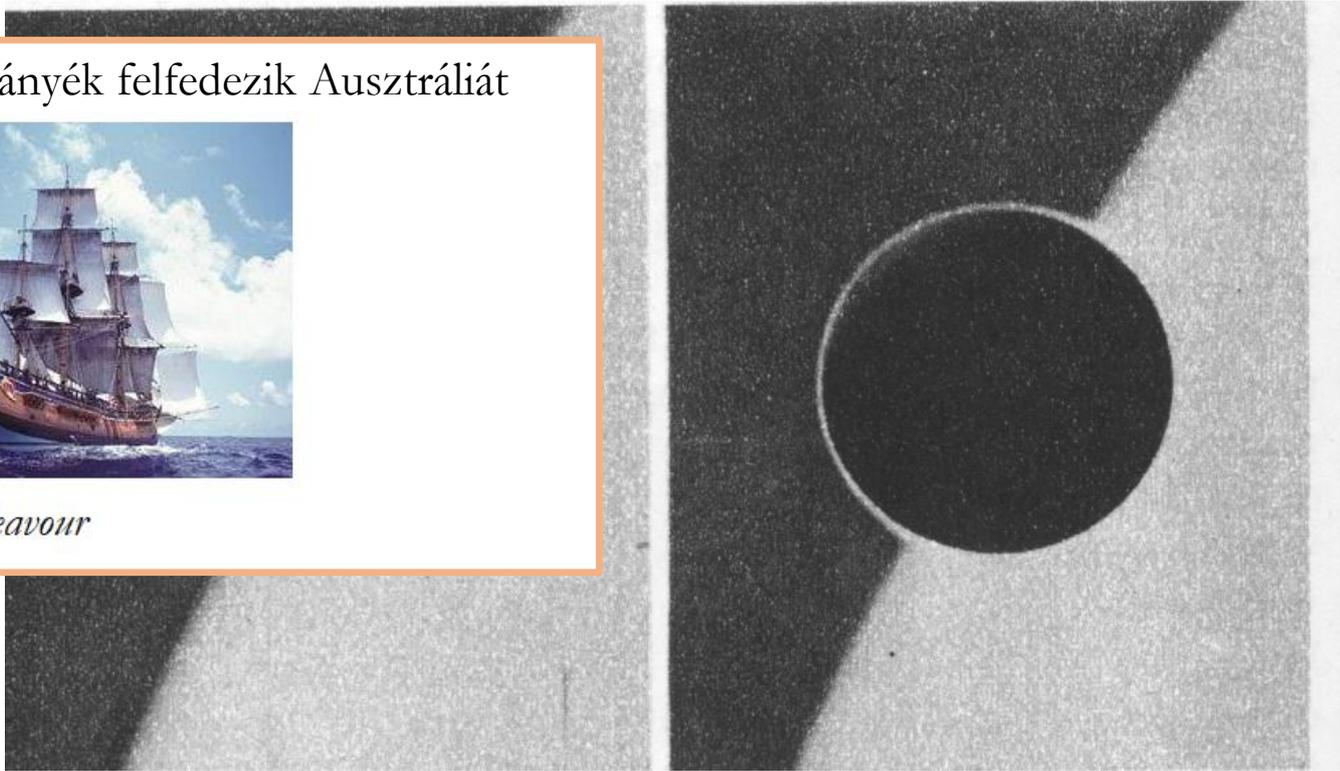
Mindeközben Cook kapitányék felfedezik Ausztráliát



The Endeavour

1770. január 17.

(1761)



A Vénusznak *halója*, tehát légköre van → A Vénusz és a Föld „ikrek”, testvérbolygók

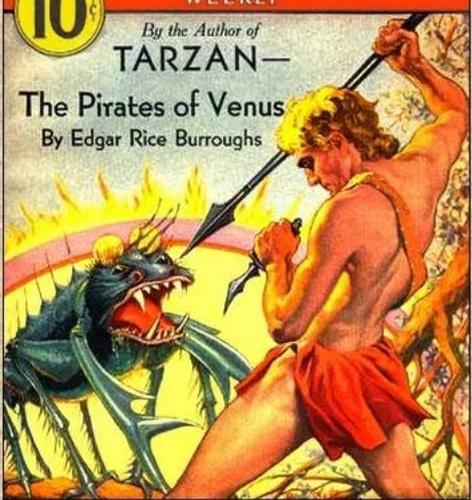
10¢

WEEKLY

By the Author of
TARZAN—

The Pirates of Venus

By Edgar Rice Burroughs



Rice Burroughs

OSY

WEEKLY

AN AVON
Fantasy
CLASSIC

TRAPPED ON A PLANET OF PERIL, HE
DARED CHALLENGE ITS MONSTER RULER

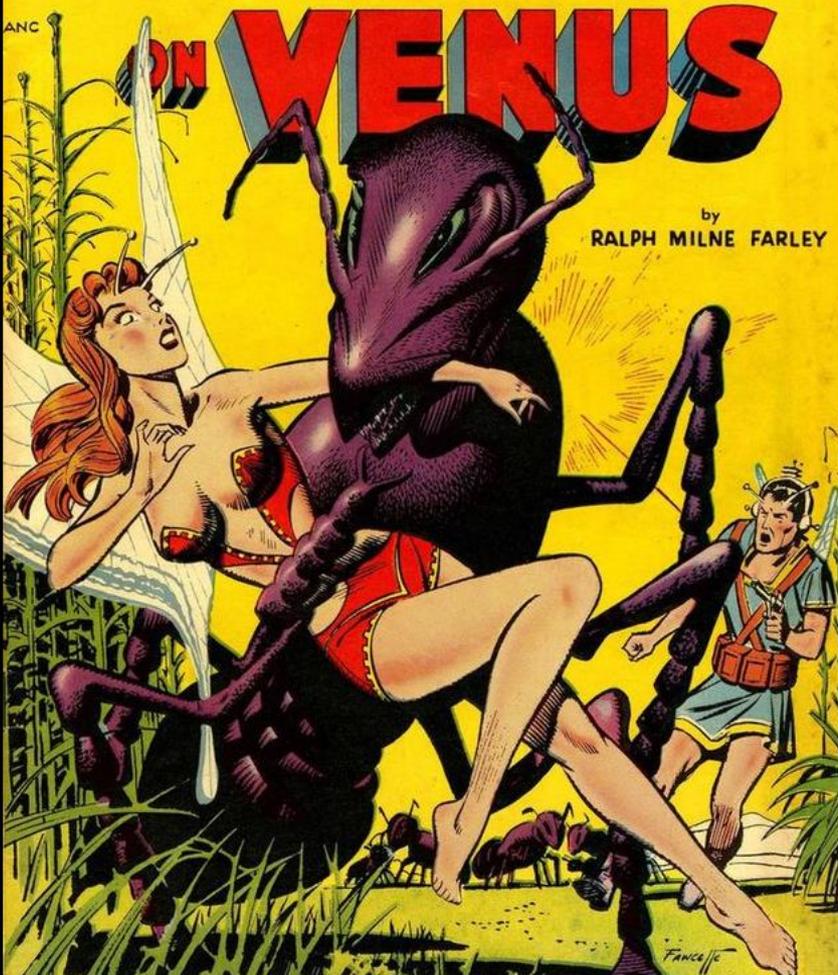
10¢

AN EARTH MAN

ANC

ON VENUS

by
RALPH MILNE FARLEY



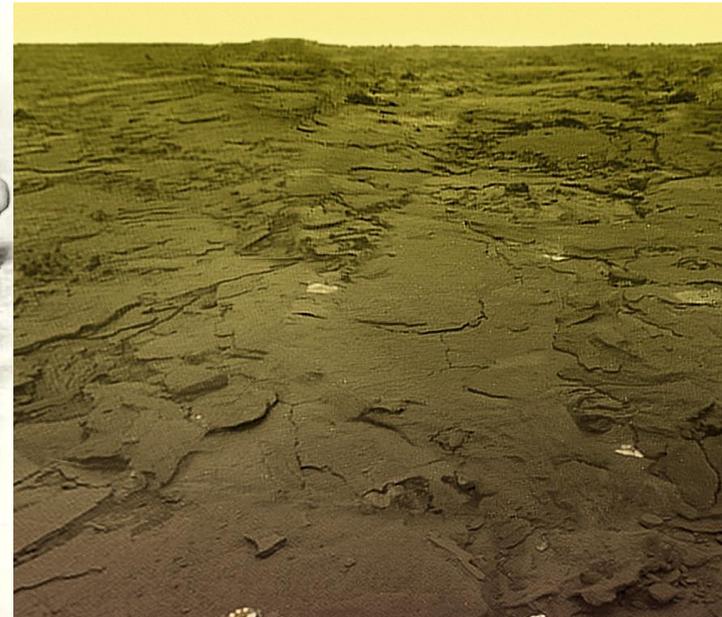
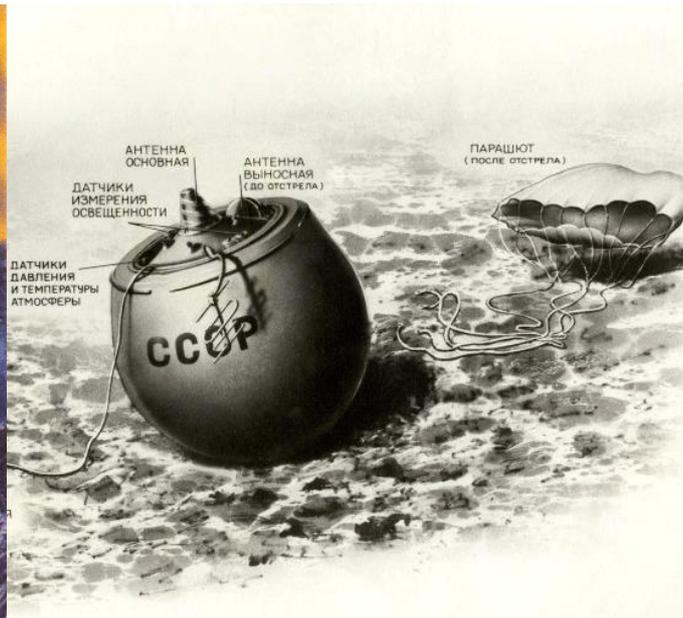
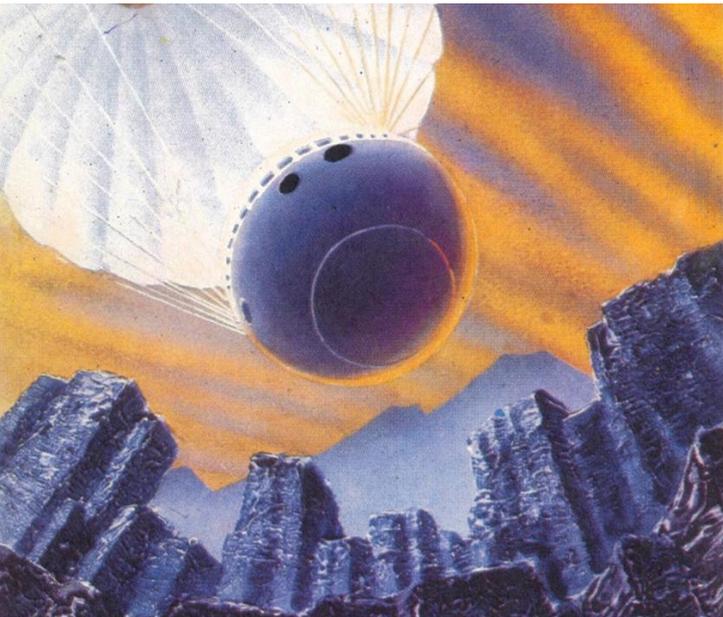
CARSON
of
VENUS



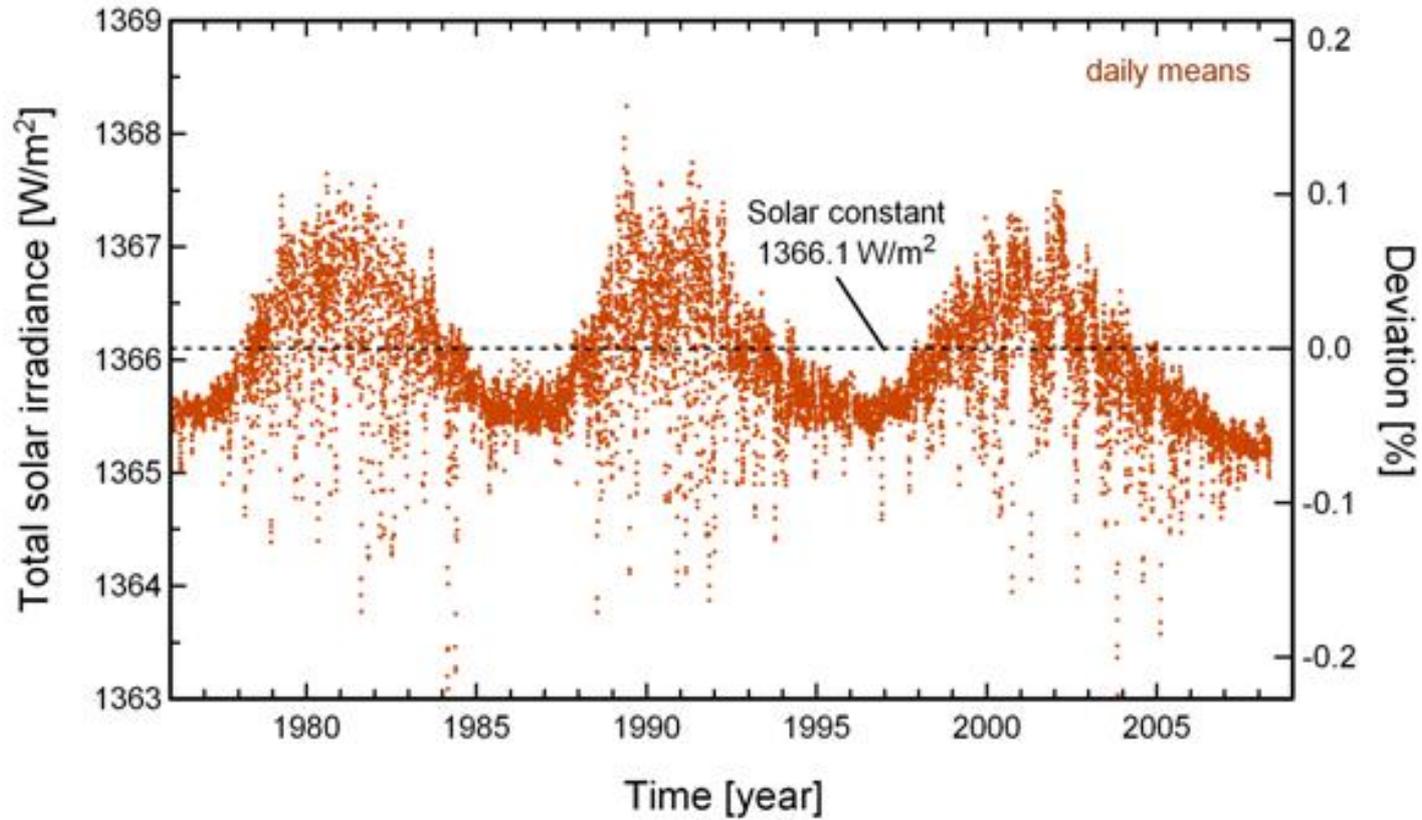
EDGAR RICE BURROUGHS

A hidegzuhany: a 70-es évek szovjet leszállóegységei.

- A felszínen 460-470°C (dacára annak, hogy a Vénusz fényvisszaverőképessége hatalmas: $a = 0,7$)
- 92 atmoszférás nyomás
- Elviselhetetlen viszonyok, villámok, esetenként savasesők (még fluor-kénsav is kialakulhat).
- A legrobosztusabb leszállóegységek sem bírták ott néhány óránál tovább.
- (Bár a légkör 60-70 kilométer magasságban nem is tűnik olyan nagyon rossz helynek...)



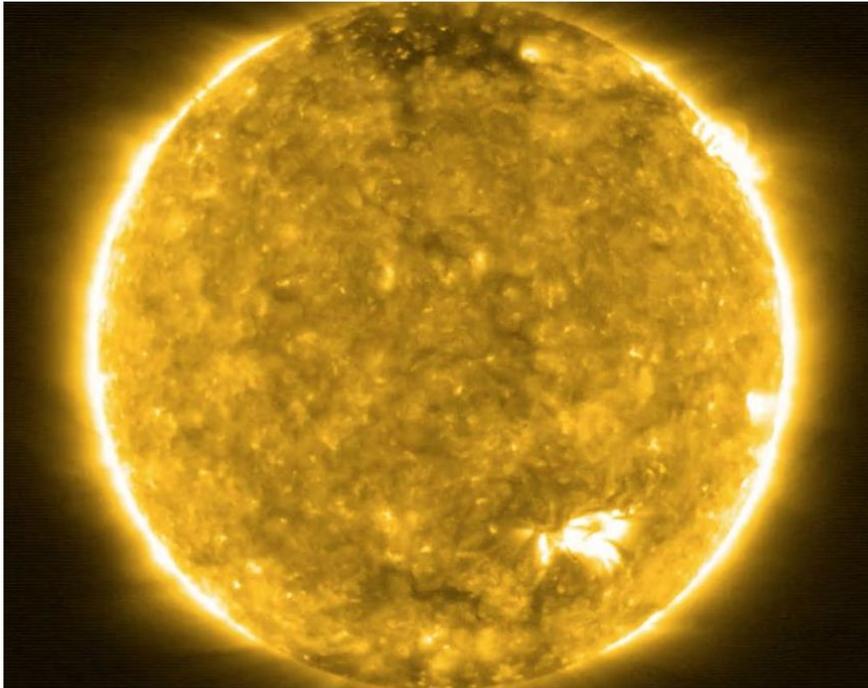
Mi határozza meg egy bolygó hőmérsékletét?



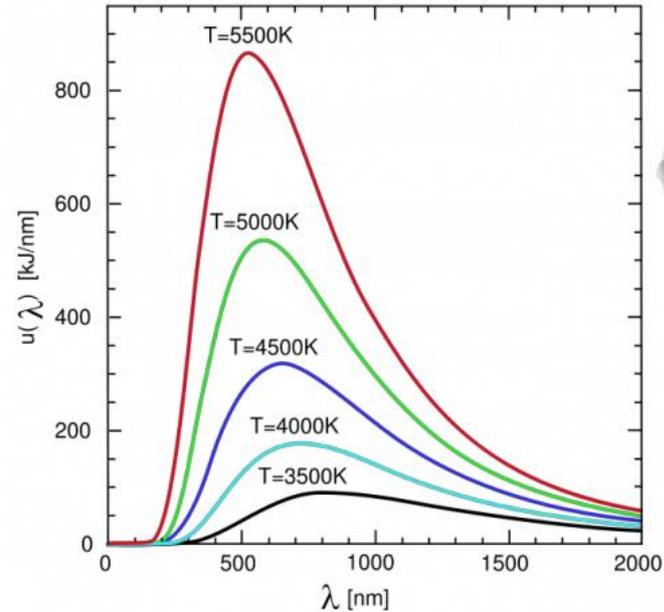
[forrás: NOAA]

Mi határozza meg egy bolygó hőmérsékletét?

Napfelszín: 5-6000 K



[forrás: ESA]



Josef Stefan
1835 - 1893



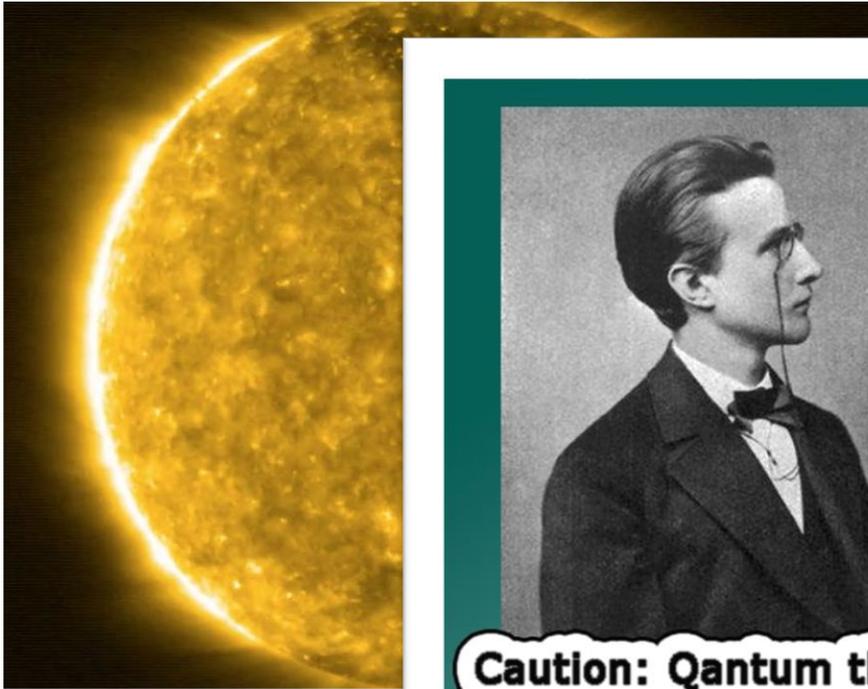
Ludwig Boltzmann
1844 - 1906

$$\frac{P}{A} = \sigma T^4$$

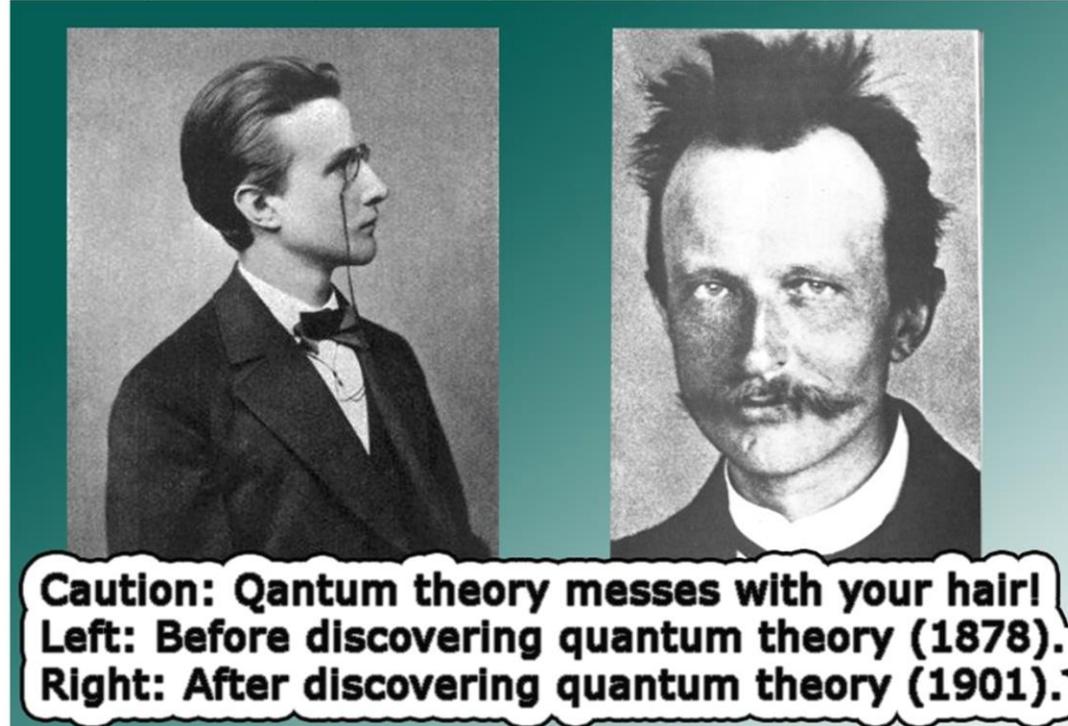
$$\sigma = 5.6703 \cdot 10^{-8} \cdot \text{W} / \text{m}^2 \text{K}^4$$

Mi határozza meg egy bolygó hőmérsékletét?

Napfelszín: 5-6000 K



[forrás: ESA]



Josef Stefan
1835 - 1893



Ludwig Boltzmann
1844 - 1906

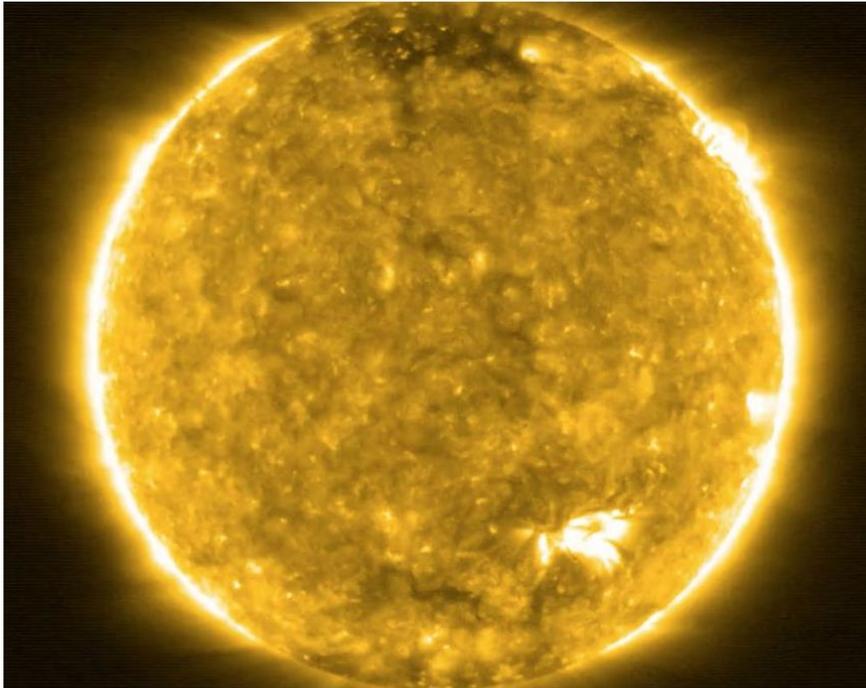
000

$$\frac{P}{A} = \sigma T^4$$

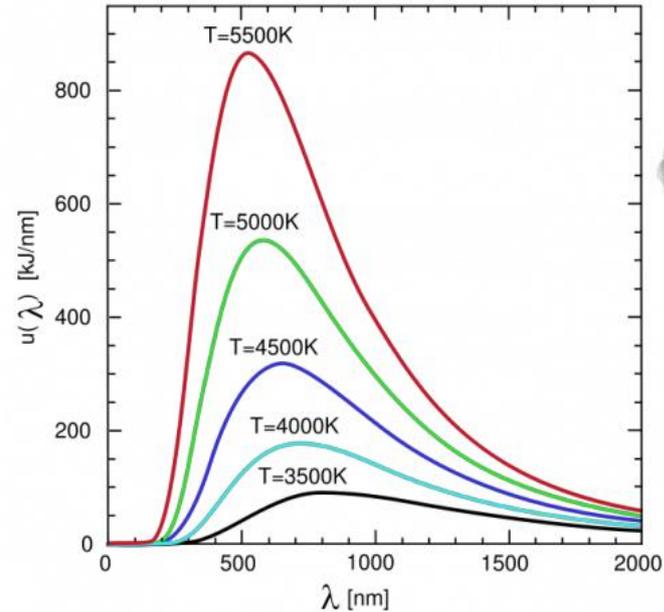
$$\sigma = 5.6703 \cdot 10^{-8} \cdot W / m^2 K^4$$

Mi határozza meg egy bolygó hőmérsékletét?

Napfelszín: 5-6000 K



[forrás: ESA]



Josef Stefan
1835 - 1893



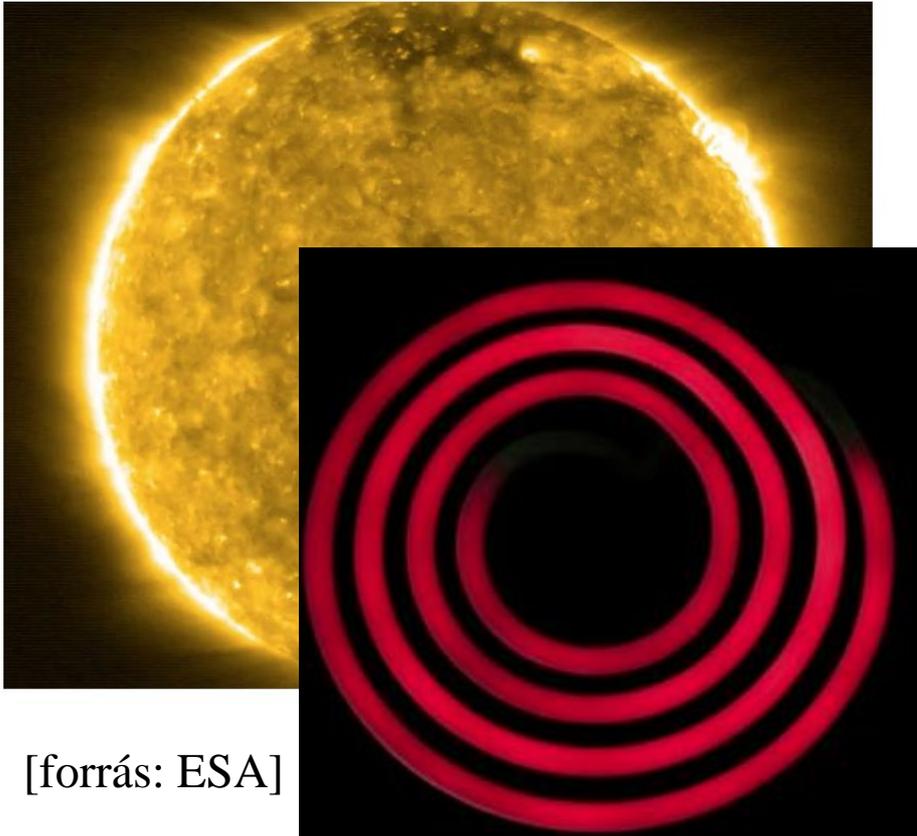
Ludwig Boltzmann
1844 - 1906

$$\frac{P}{A} = \sigma T^4$$

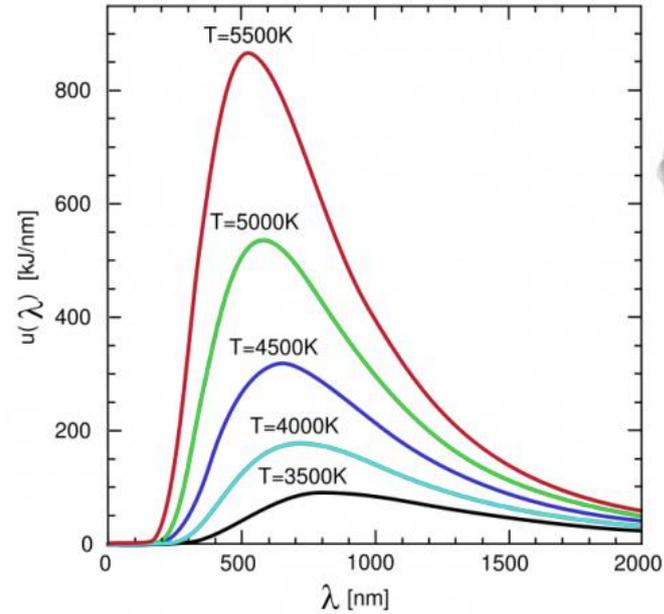
$$\sigma = 5.6703 \cdot 10^{-8} \cdot W / m^2 K^4$$

Mi határozza meg egy bolygó hőmérsékletét?

Napfelszín: 5-6000 K



[forrás: ESA]



Josef Stefan
1835 - 1893



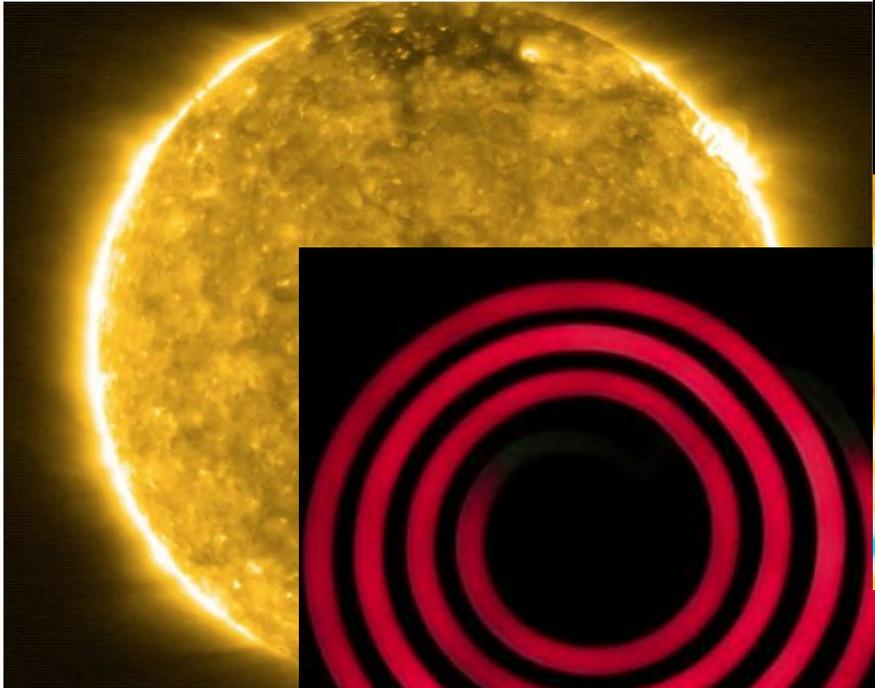
Ludwig Boltzmann
1844 - 1906

$$\frac{P}{A} = \sigma T^4$$

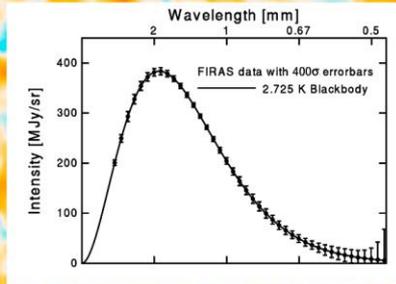
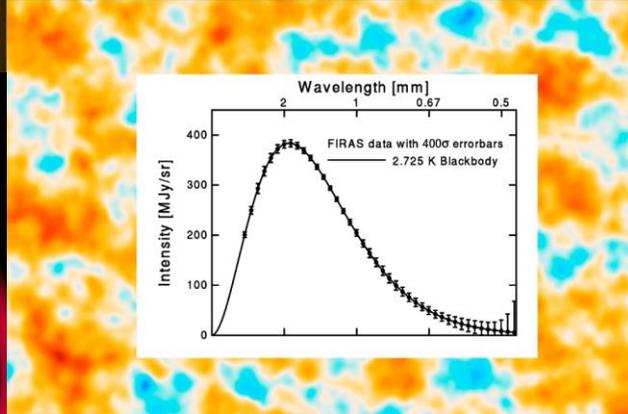
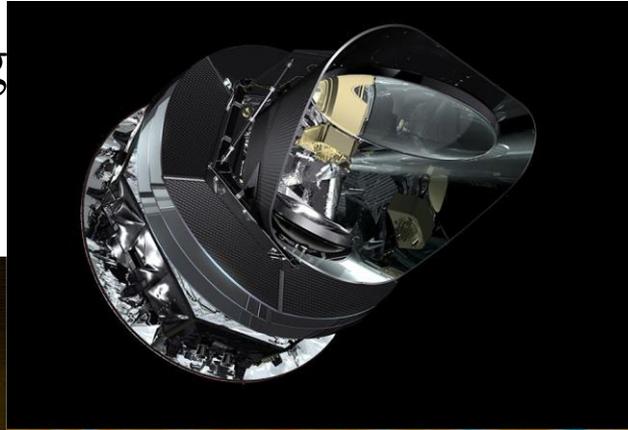
$$\sigma = 5.6703 \cdot 10^{-8} \cdot \text{W/m}^2\text{K}^4$$

Mi határozza meg a ... etét?

Napfelszín: 5-6000 K



[forrás: ESA]



Josef Stefan
1835 - 1893



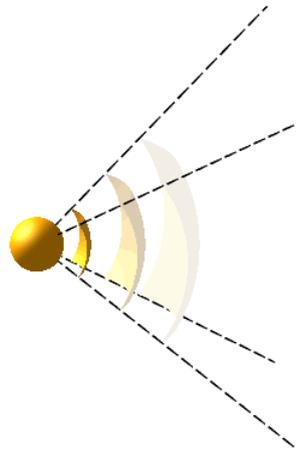
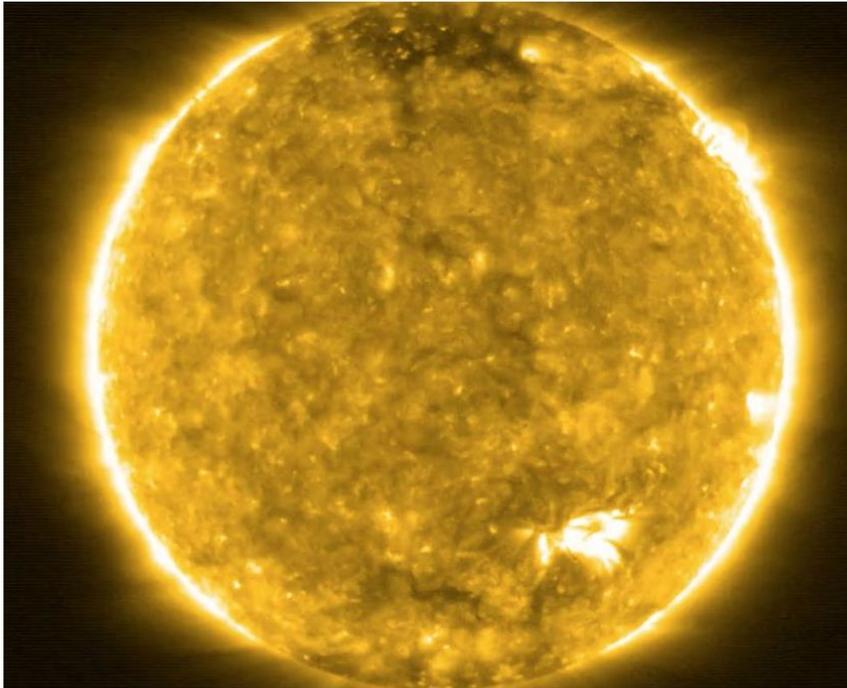
Ludwig Boltzmann
1844 - 1906

$$\frac{P}{A} = \sigma T^4$$

$$\sigma = 5.6703 \cdot 10^{-8} \cdot W / m^2 K^4$$

Mi határozza meg egy bolygó hőmérsékletét?

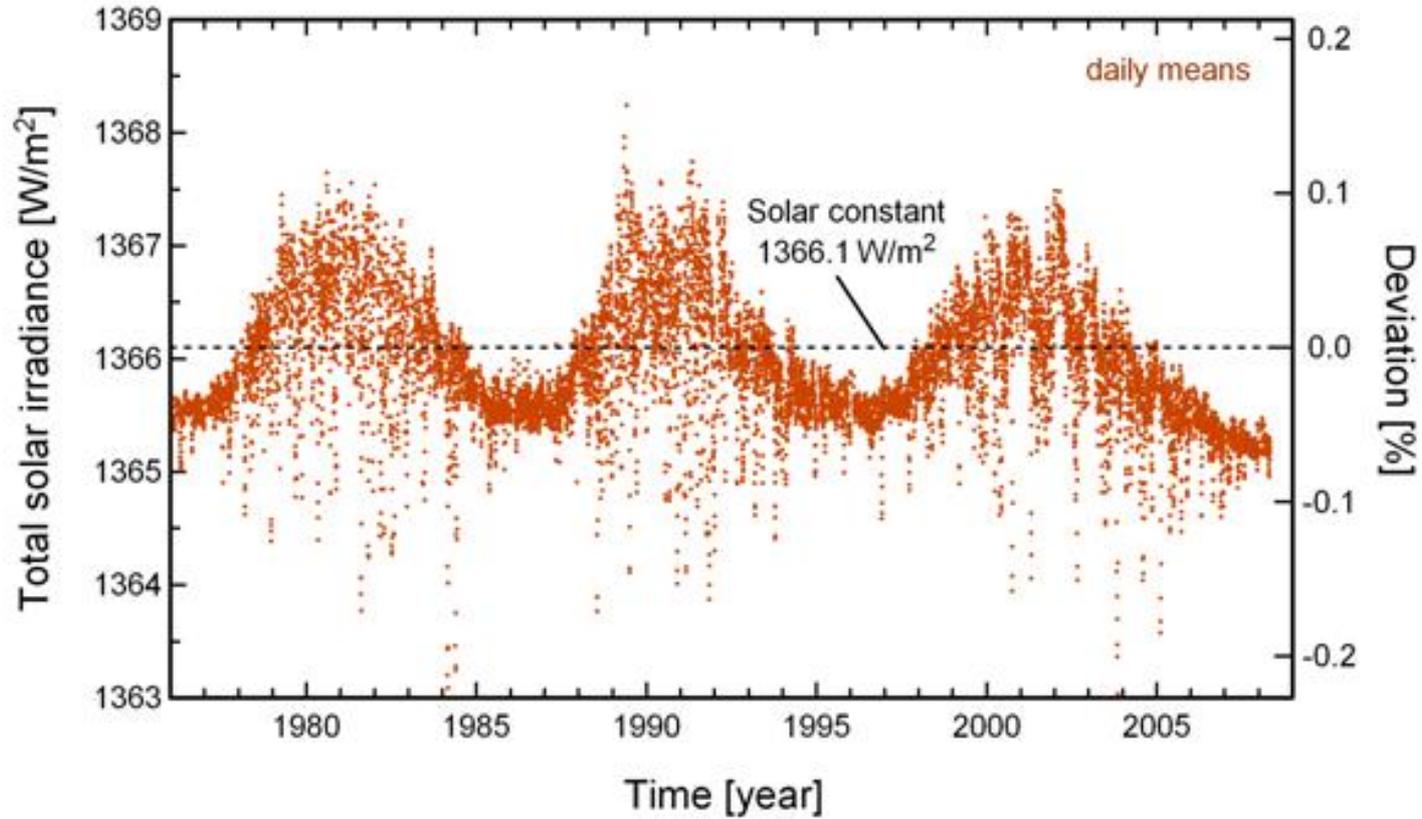
Napfelszín: 5-6000 K



Az egységnyi felületre jutó sugárzási teljesítmény a távolság négyzetével csökken.

A Vénusz a Nap-Föld távolság 0,7-szeresénél kering, vagyis kétszeres "kakaót" kap.

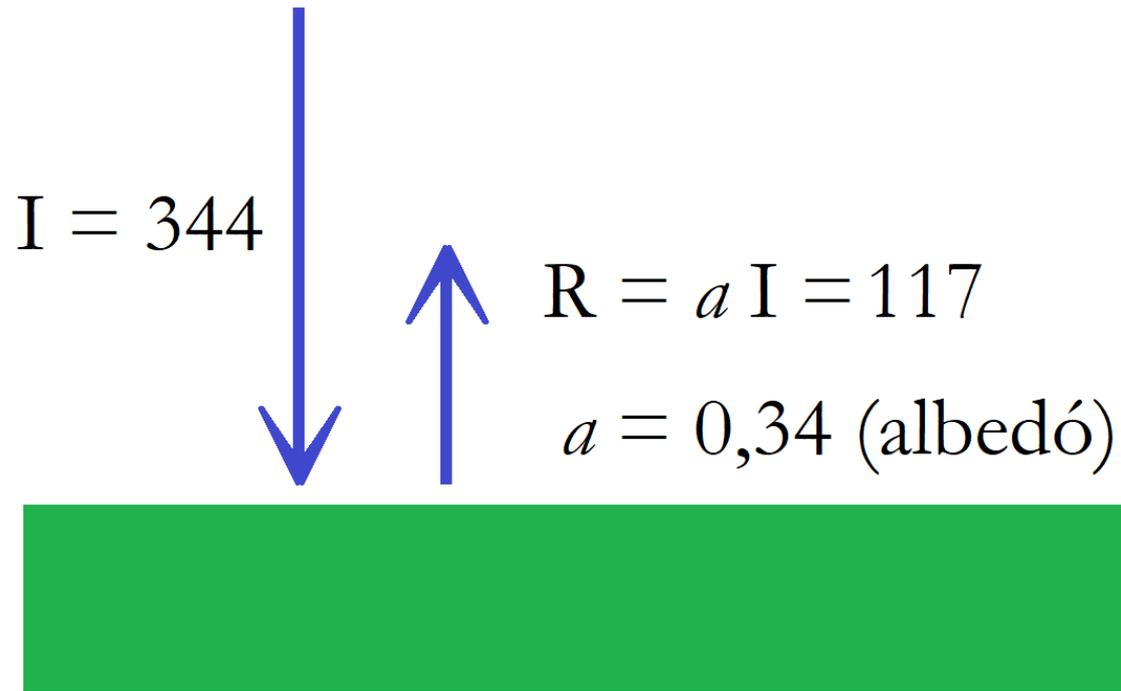
Valójában, a “napállandó” nem állandó

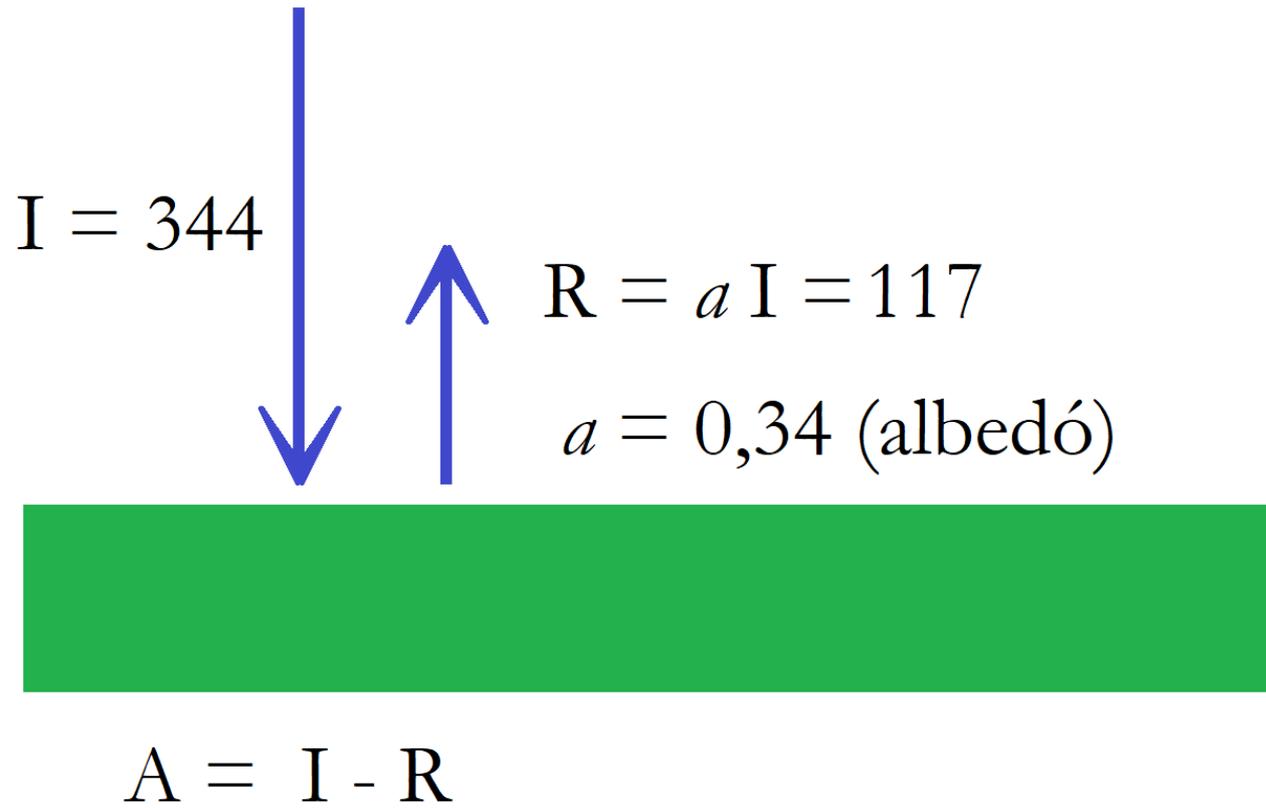


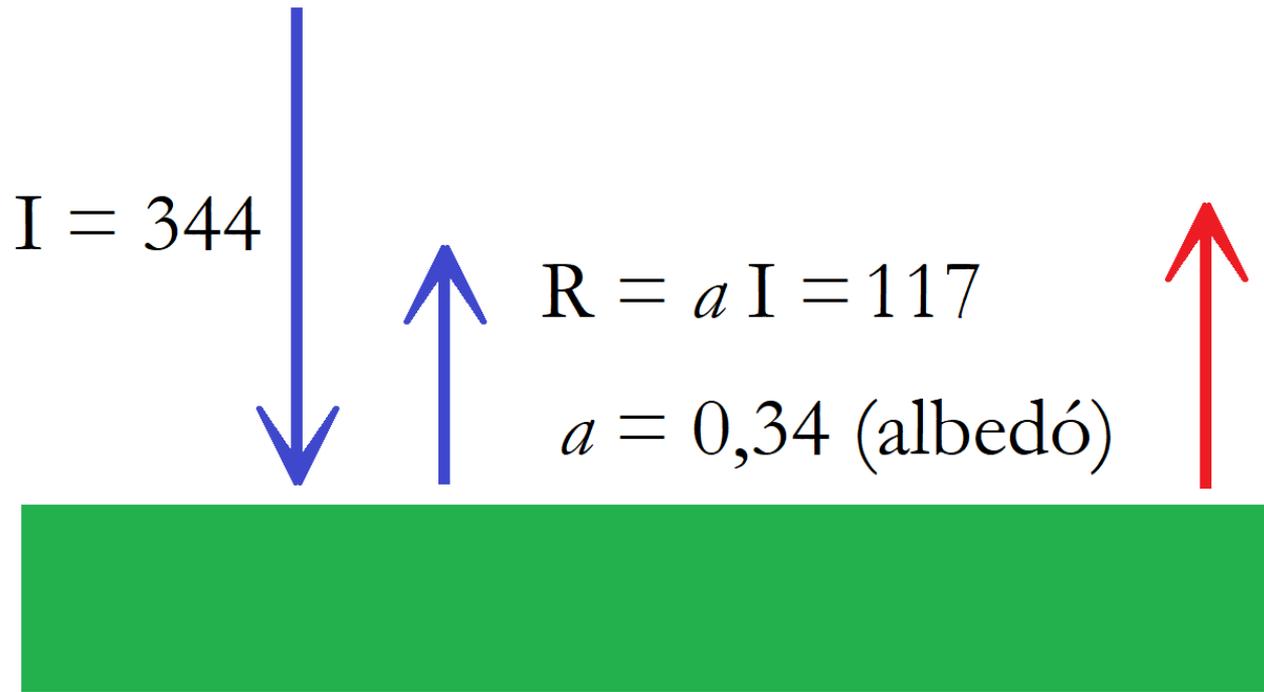
[forrás: NOAA]

$$I = 344$$

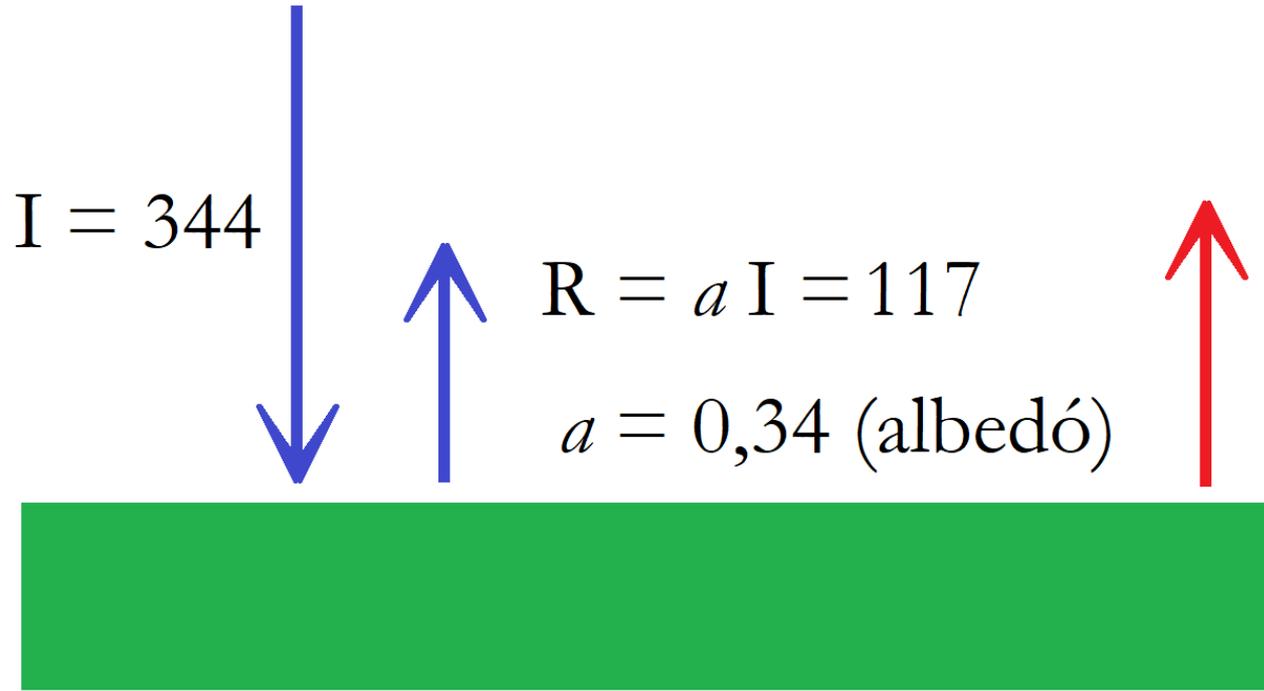




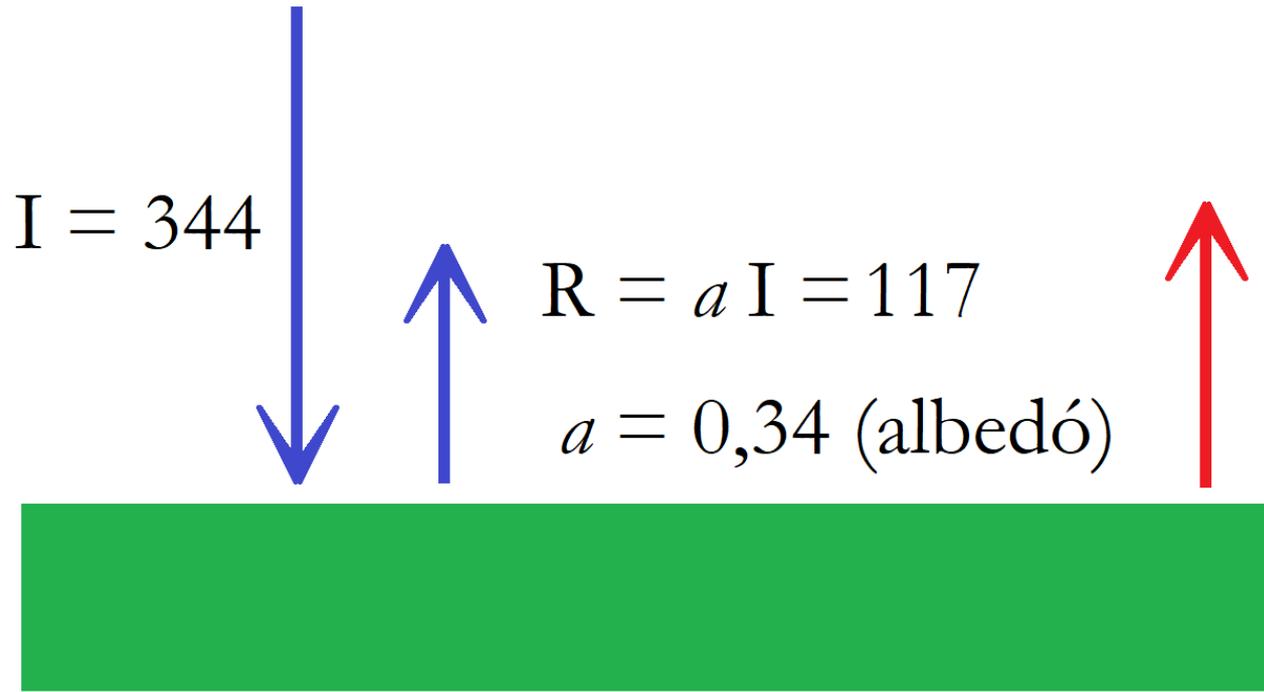




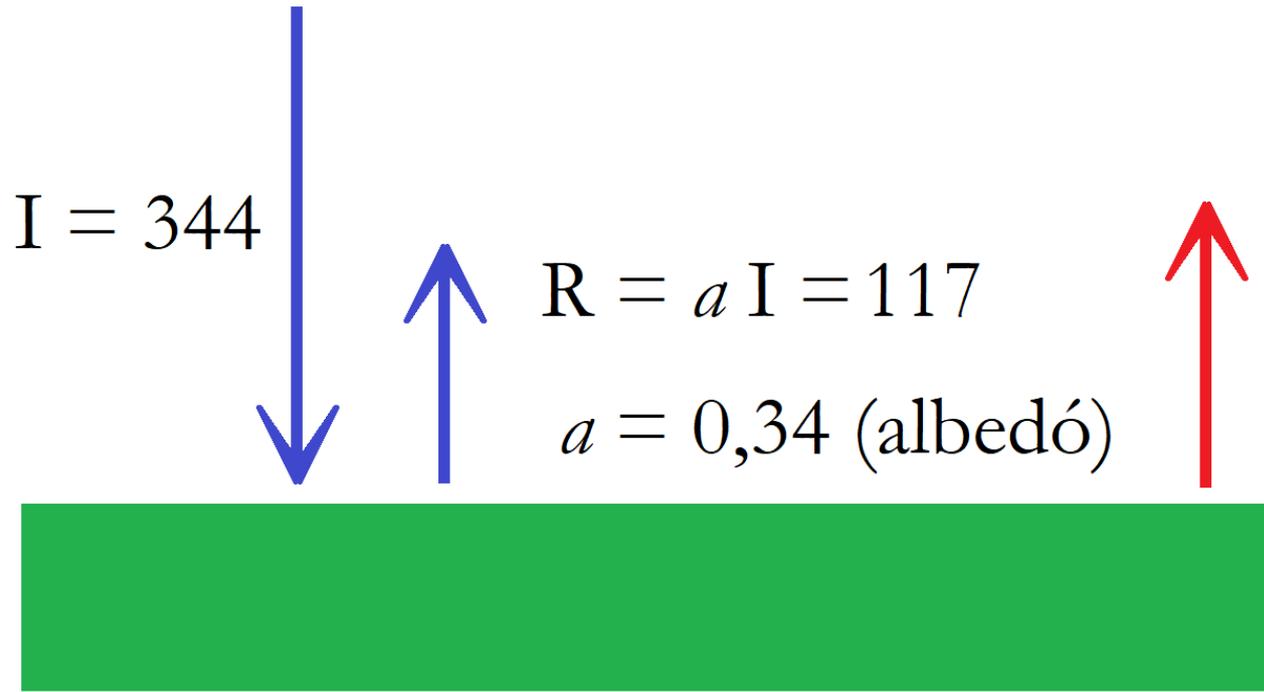
$$A = I - R$$



$$A = I - R = I (1 - a) = 227$$

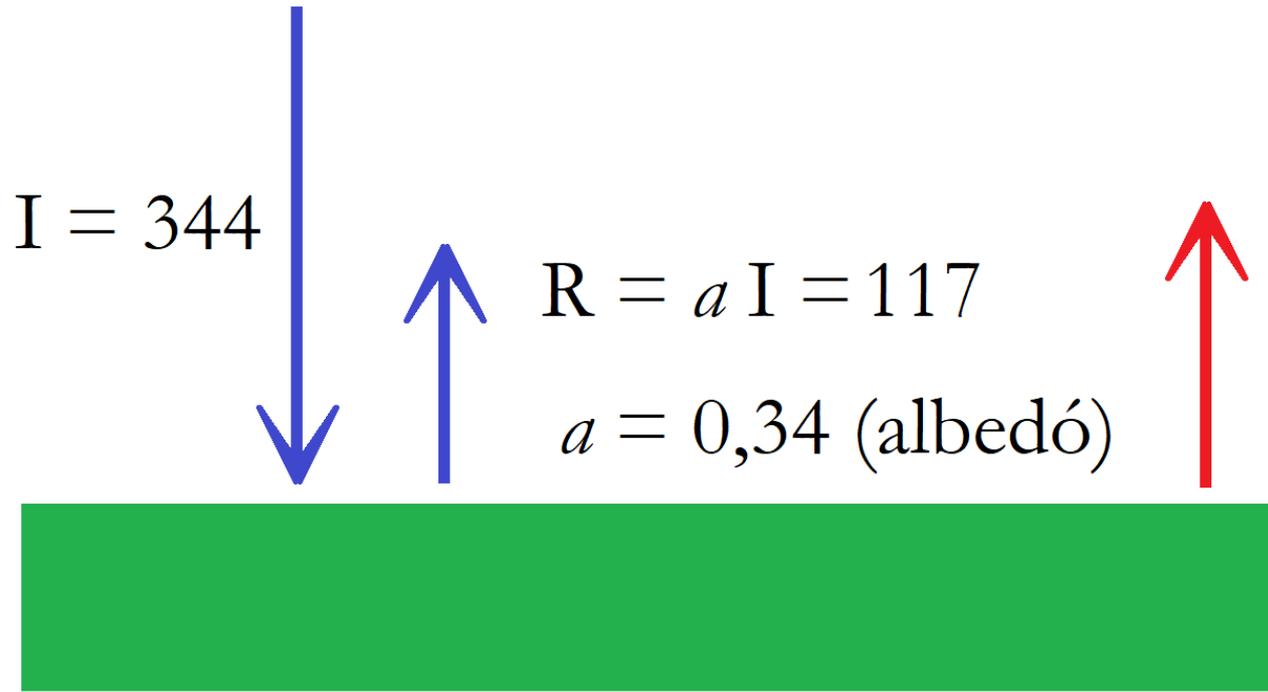


$$A = I - R = I (1 - a) = 227 = E$$



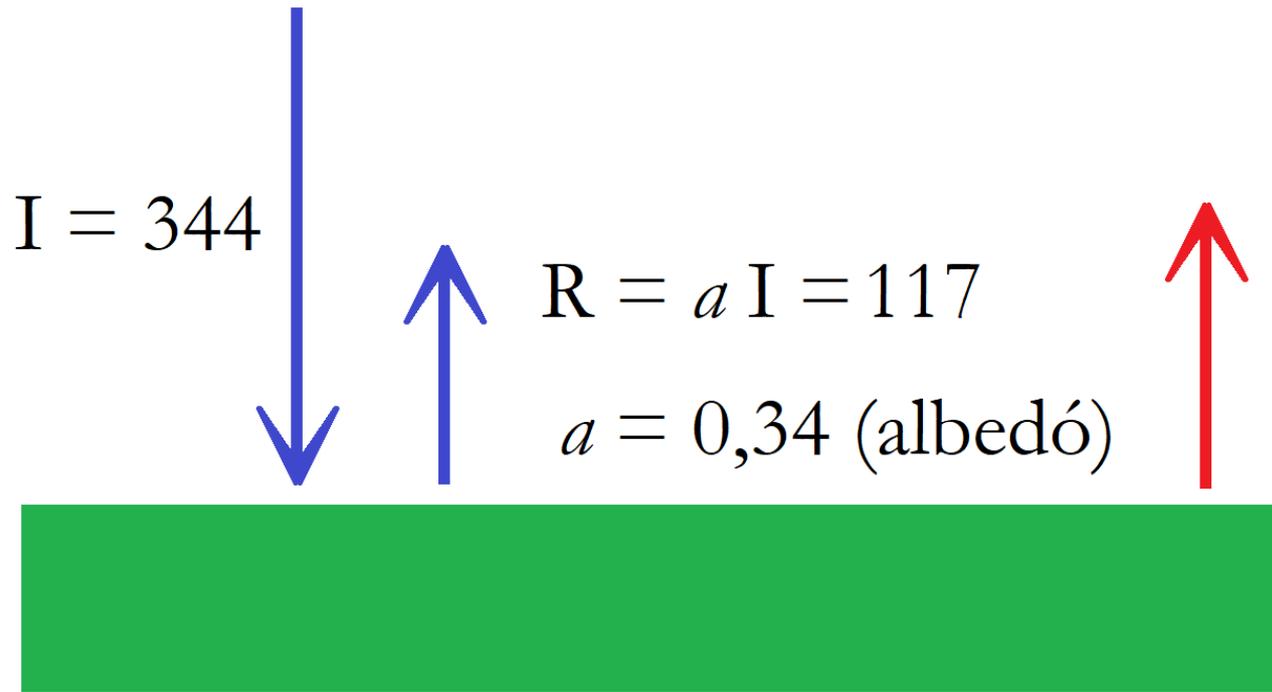
$$A = I - R = I (1 - a) = 227 = E$$

$$\sigma T^4 = E$$



$$A = I - R = I (1 - a) = 227 = E$$

$$\sigma T^4 = E \longrightarrow T = 251 \text{ K } (\sim -21^\circ\text{C})$$



$$A = I - R = I (1 - a) = 227 = E$$

$$\sigma T^4 = E \longrightarrow T = 251 \text{ K } (\sim -21^\circ\text{C}) \quad ?$$

Hold:

„ugyanitt” van (Nap sokkal messzebb), de légkör
nincs, $a = 0,12 \rightarrow$ helyes átlagos T



Fotó: NASA, Artemis I, 2022. decembere



Nobel-díj kémiából (1903)
NEM ezért!

Svante Arrhenius (1859–1927)

THE
LONDON, EDINBURGH, AND DUBLIN
PHILOSOPHICAL MAGAZINE
AND
JOURNAL OF SCIENCE.

[FIFTH SERIES.]

APRIL 1896.

XXXI. *On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground.* By Prof. SVANTE ARRHENIUS*.



$$I = 344$$



①



②



$$I = 344$$

$$R_1 = a_1 I = 113,5$$

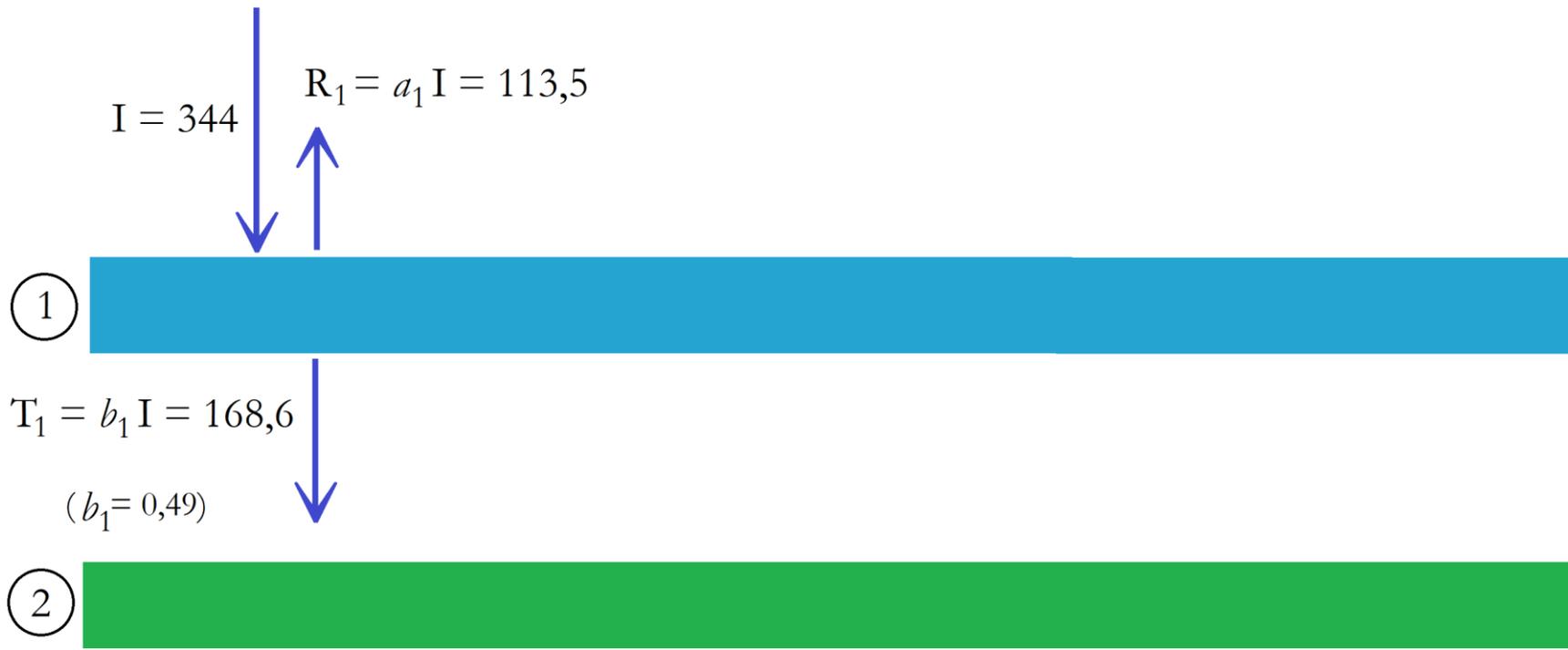
$$(a_1 = 0,33)$$

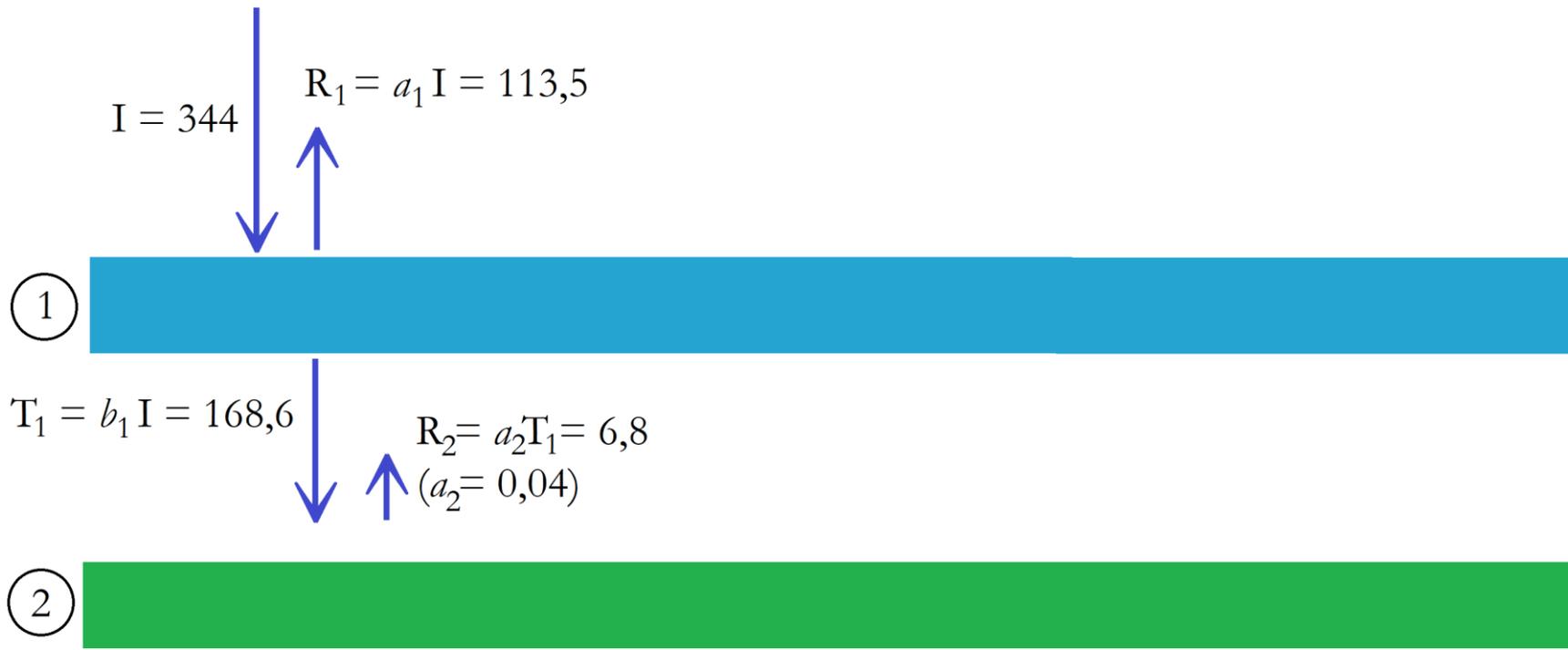
①

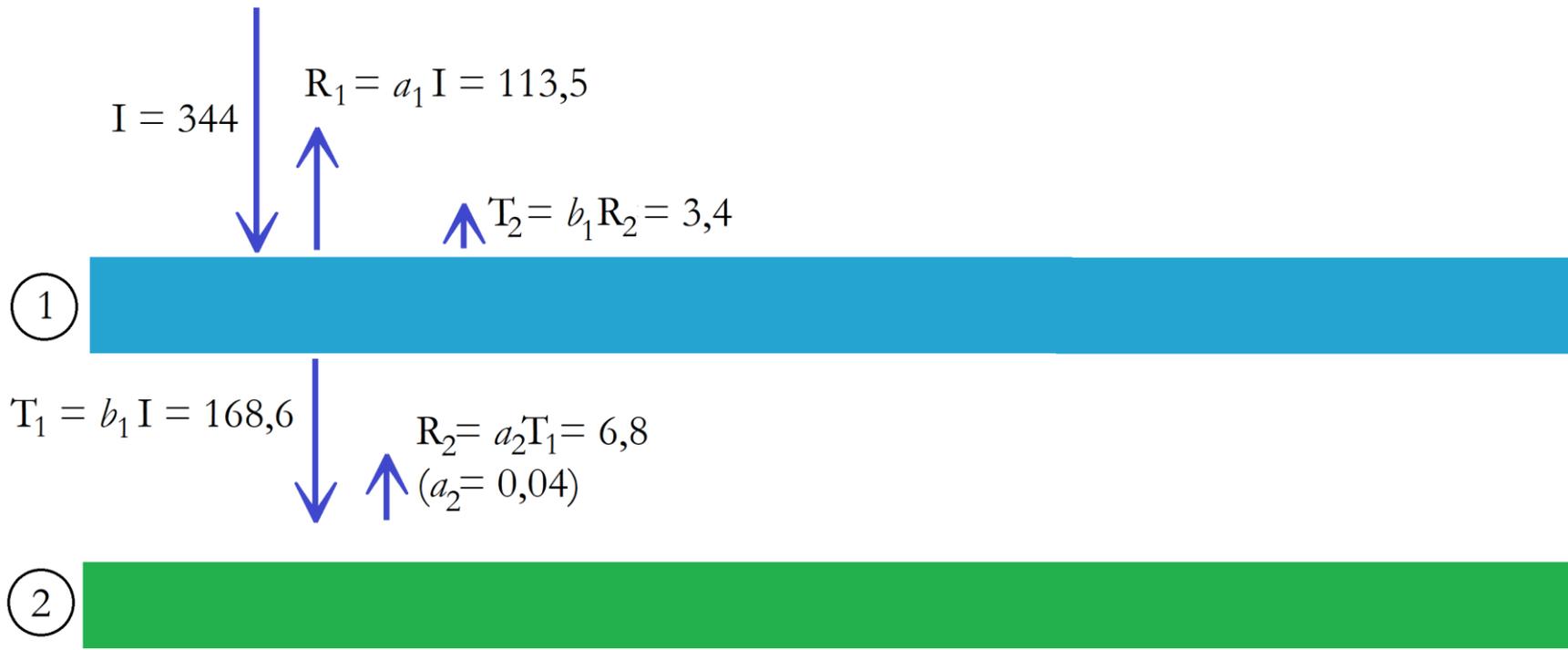


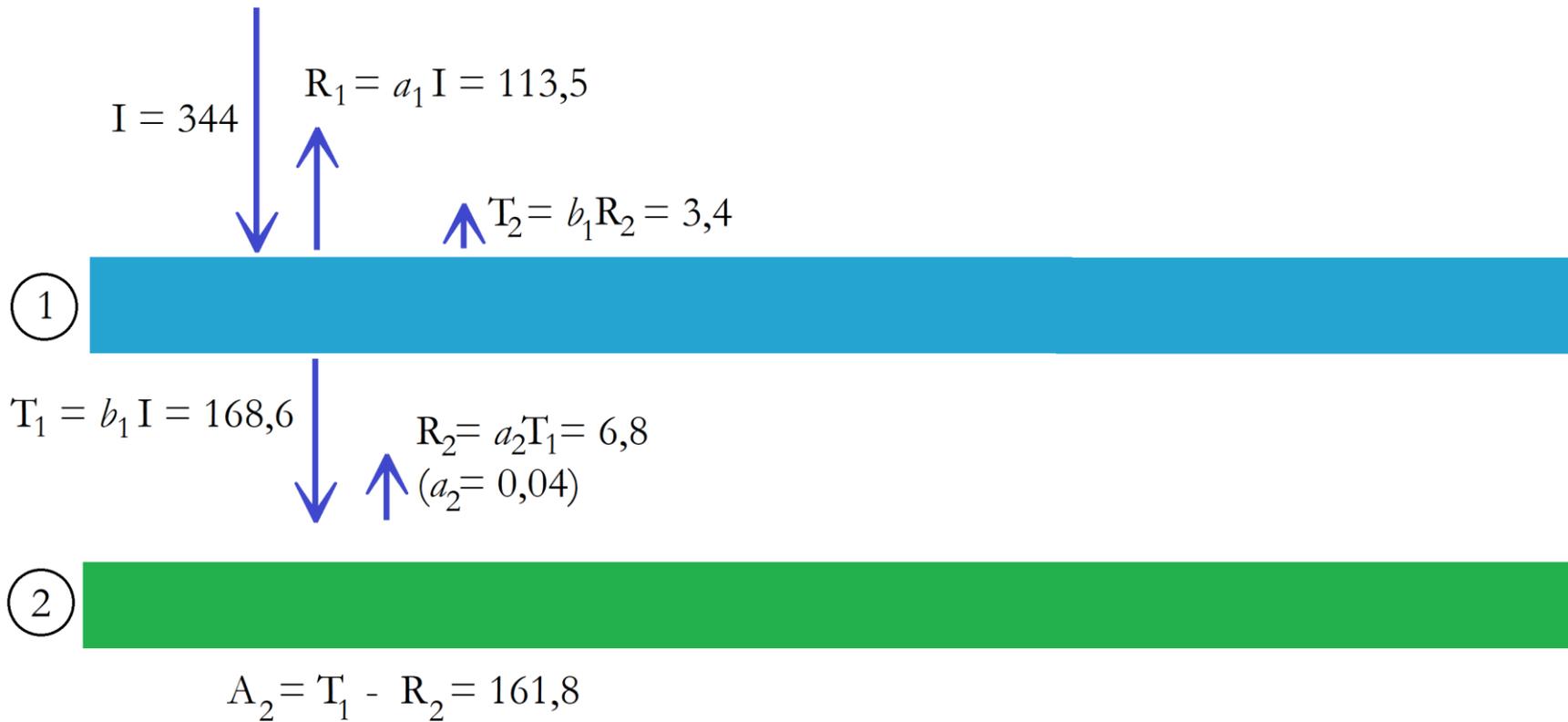
②

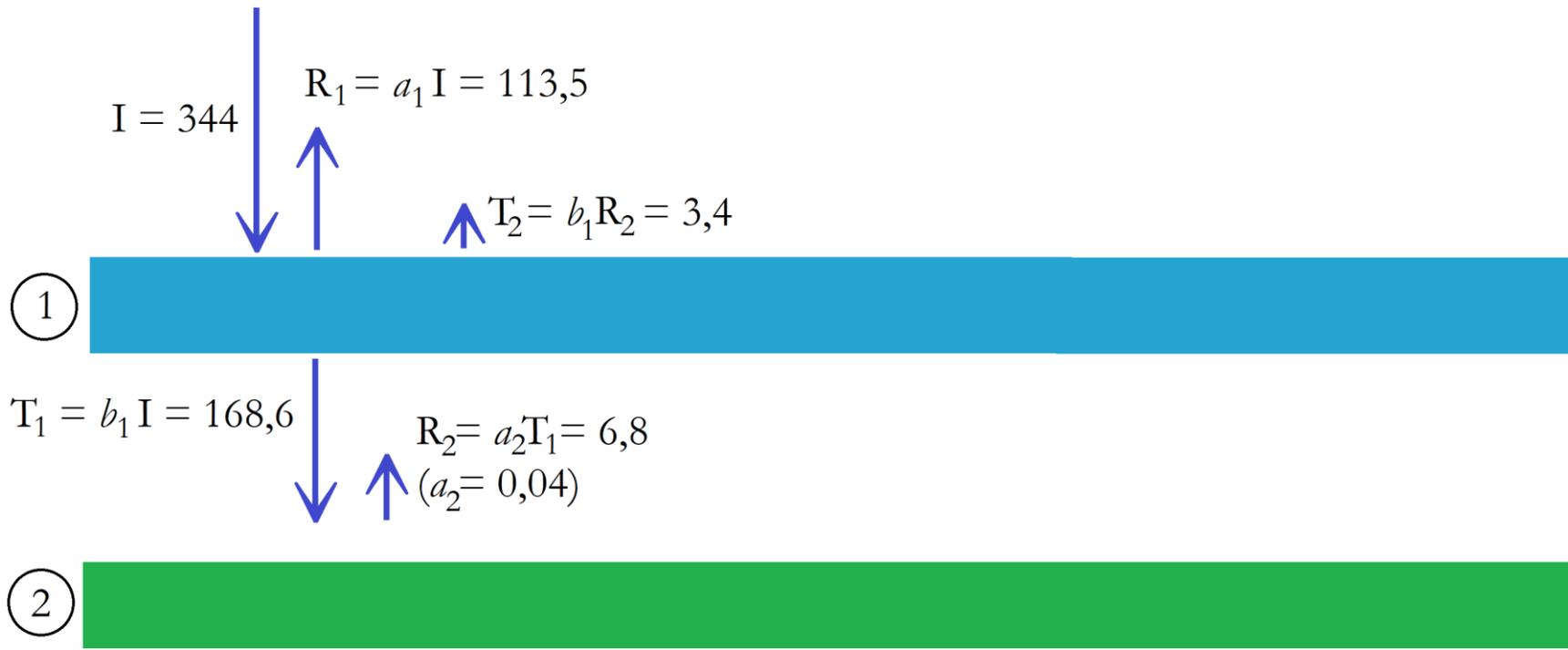






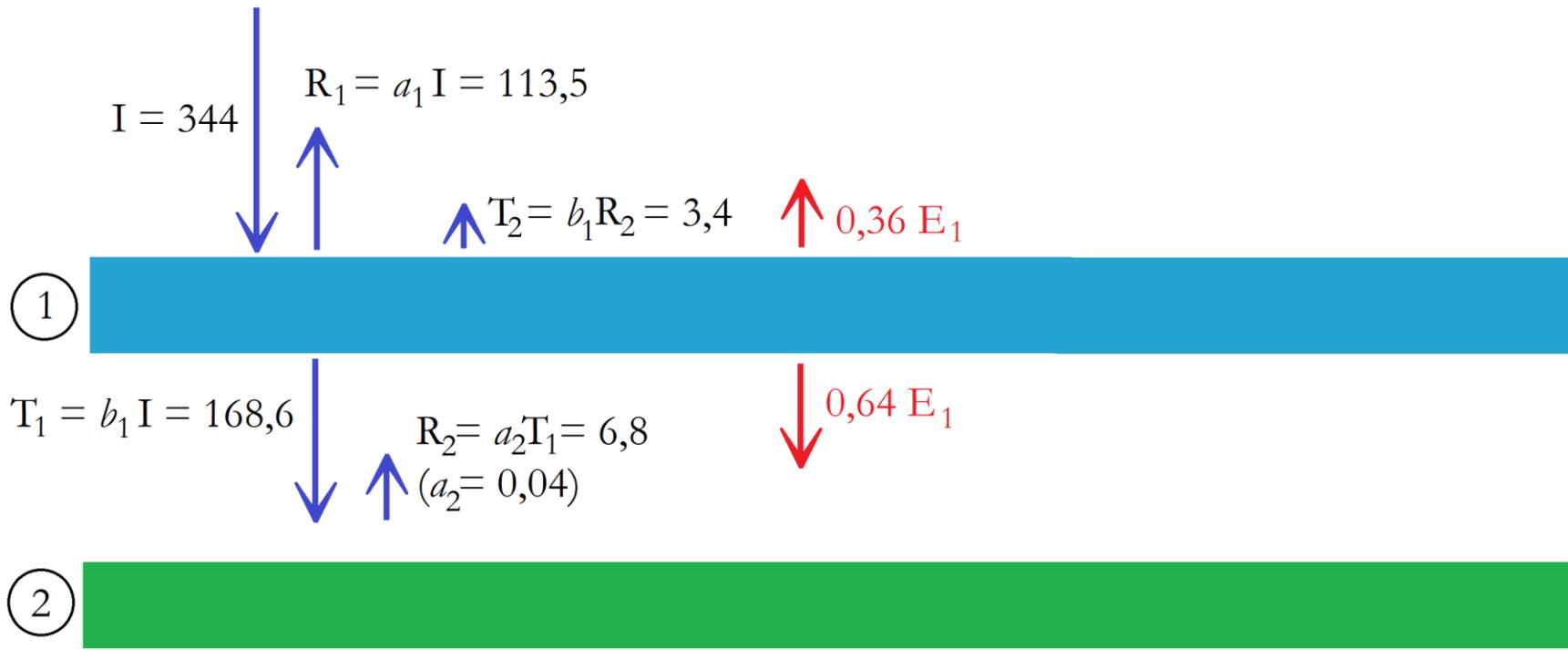






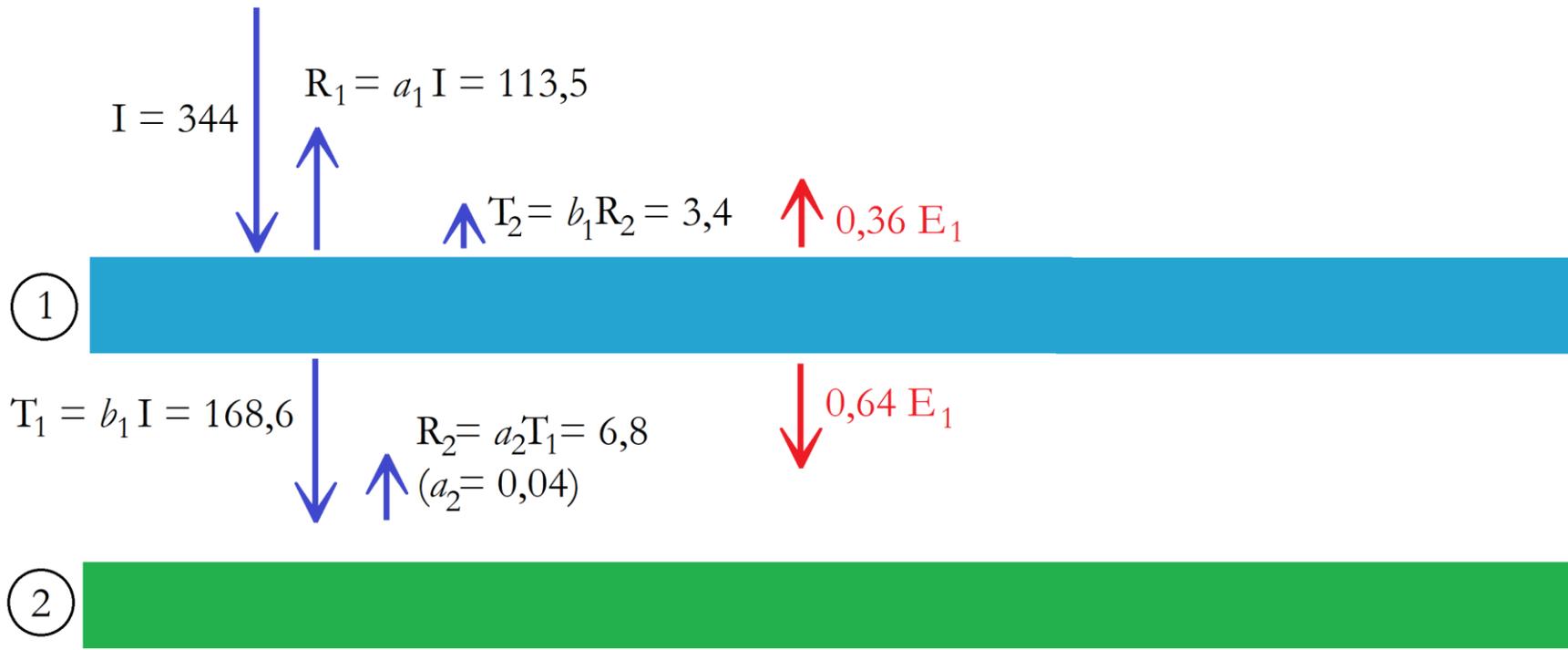
$$A_2 = T_1 - R_2 = 161,8$$

$$\begin{aligned}
 A_1 &= (I - R_1 - T_1) + (R_2 - T_2) = \\
 &= [1 - a_1 - b_1 + b_1 a_2 (1 - b_1)] I = 65,3
 \end{aligned}$$



$$A_2 = T_1 - R_2 = 161,8$$

$$\begin{aligned}
 A_1 &= (I - R_1 - T_1) + (R_2 - T_2) = \\
 &= [1 - a_1 - b_1 + b_1 a_2 (1 - b_1)] I = 65,3
 \end{aligned}$$

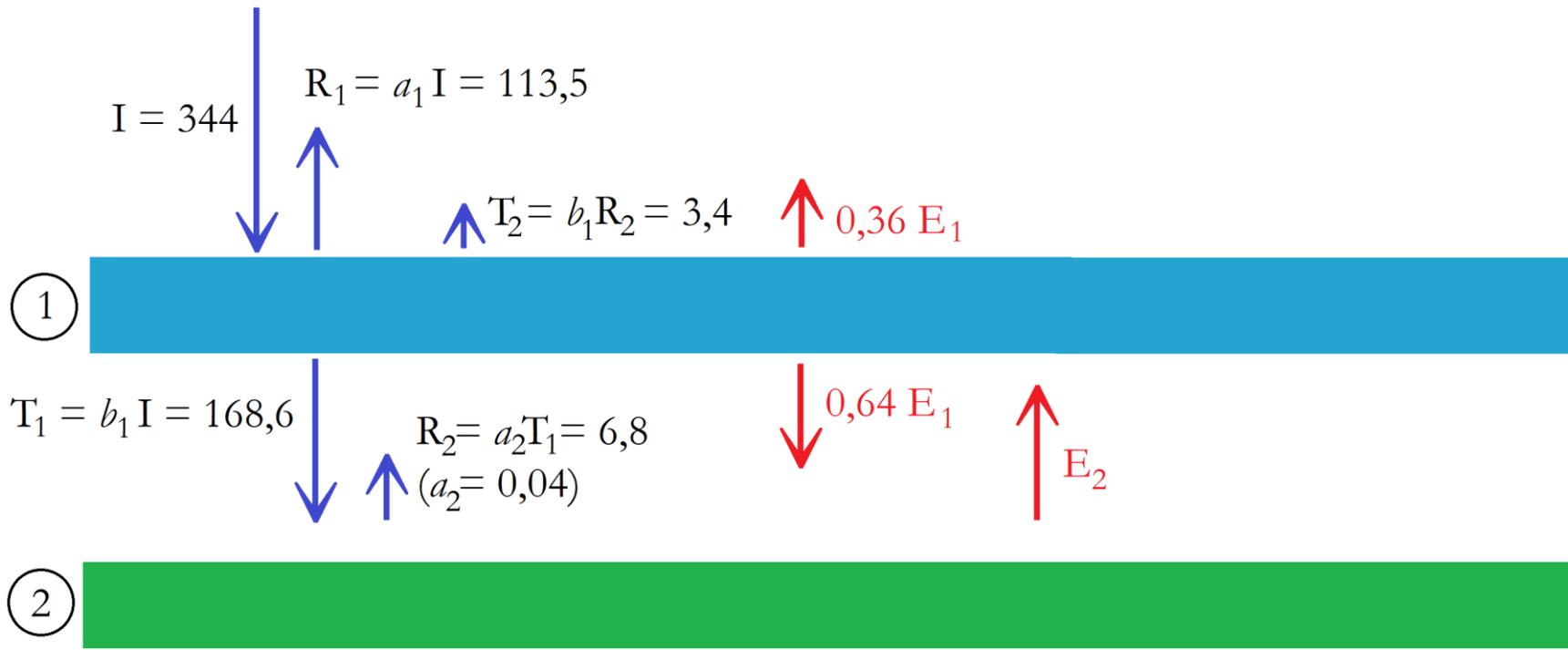


$$A_2 = T_1 - R_2 = 161,8$$

$$E_2 = A_2 + 0,64 E_1$$

$$A_1 = (I - R_1 - T_1) + (R_2 - T_2) =$$

$$= [1 - a_1 - b_1 + b_1 a_2 (1 - b_1)] I = 65,3$$

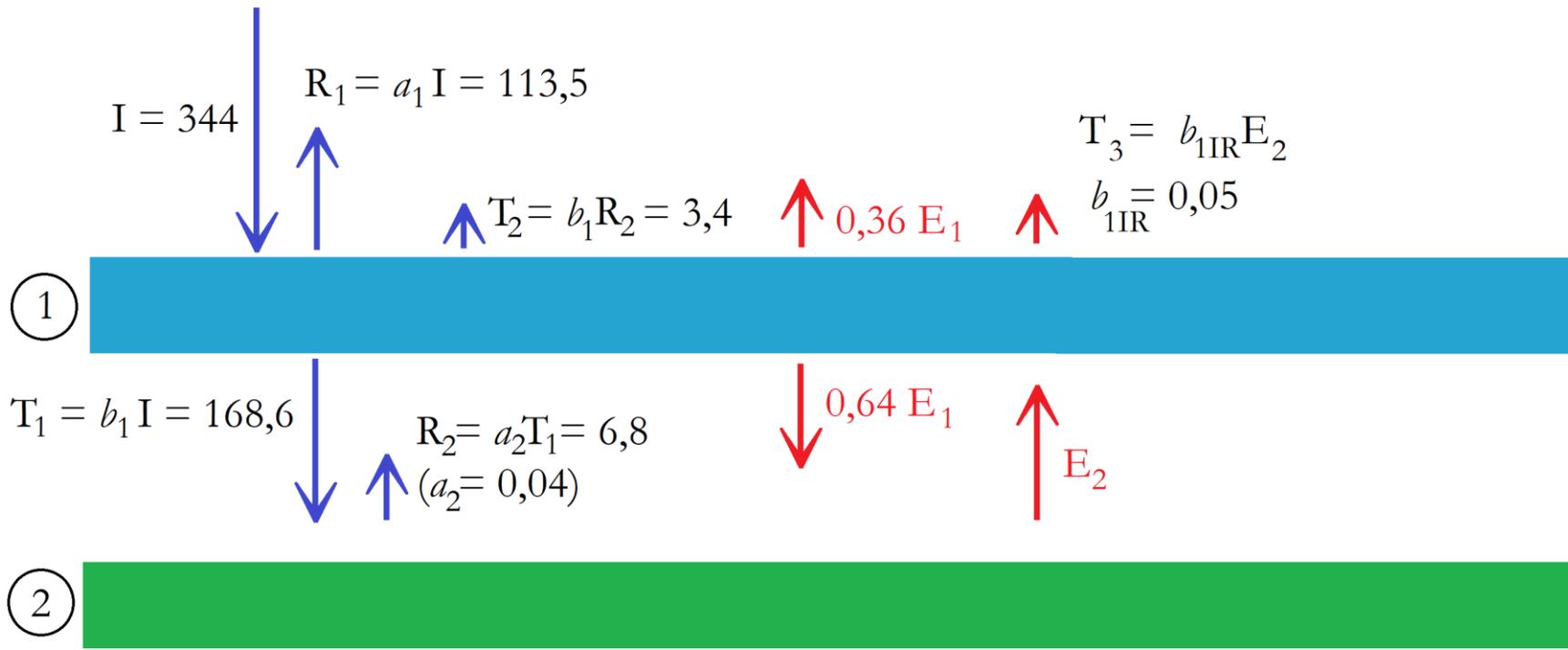


$$A_2 = T_1 - R_2 = 161,8$$

$$E_2 = A_2 + 0,64 E_1$$

$$A_1 = (I - R_1 - T_1) + (R_2 - T_2) =$$

$$= [1 - a_1 - b_1 + b_1 a_2 (1 - b_1)] I = 65,3$$

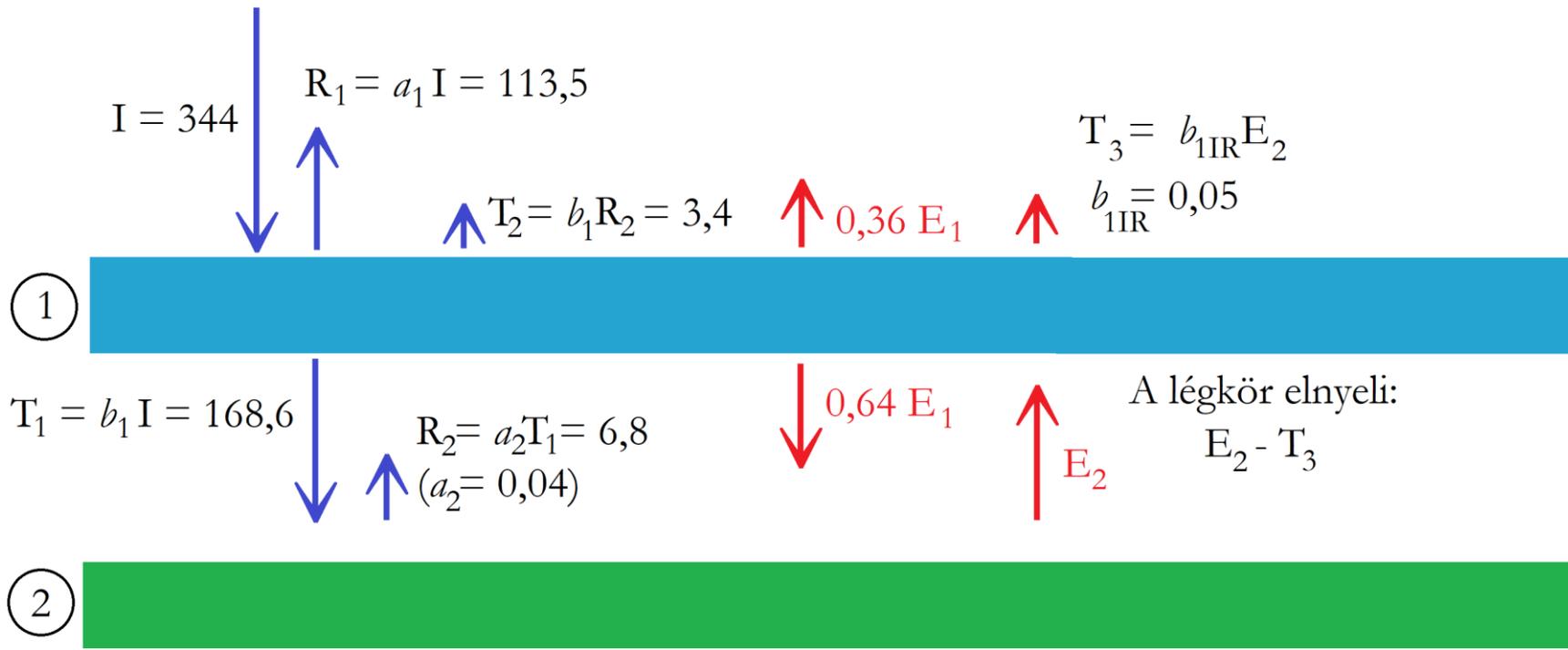


$$A_2 = T_1 - R_2 = 161,8$$

$$E_2 = A_2 + 0,64 E_1$$

$$A_1 = (I - R_1 - T_1) + (R_2 - T_2) =$$

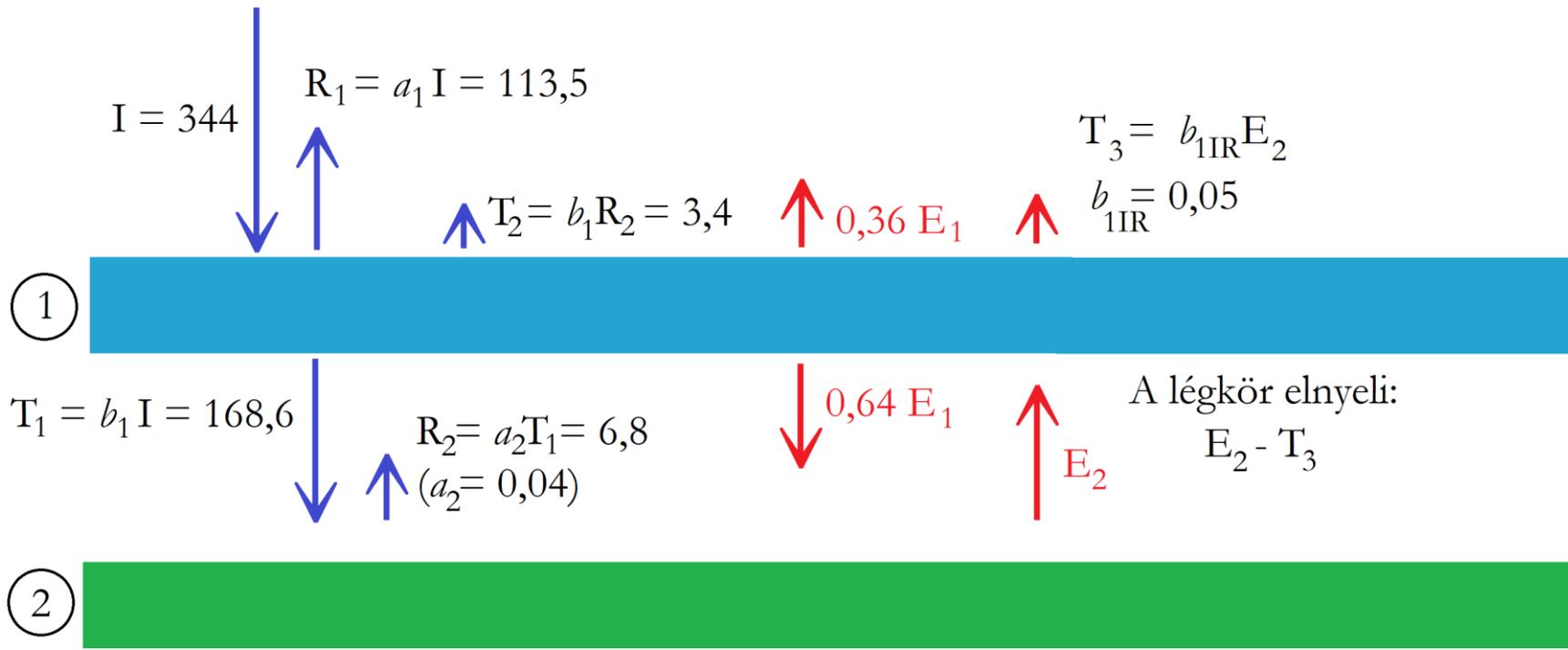
$$= [1 - a_1 - b_1 + b_1 a_2 (1 - b_1)] I = 65,3$$



$$A_2 = T_1 - R_2 = 161,8$$

$$E_2 = A_2 + 0,64 E_1$$

$$\begin{aligned}
 A_1 &= (I - R_1 - T_1) + (R_2 - T_2) = \\
 &= [1 - a_1 - b_1 + b_1 a_2 (1 - b_1)] I = 65,3
 \end{aligned}$$

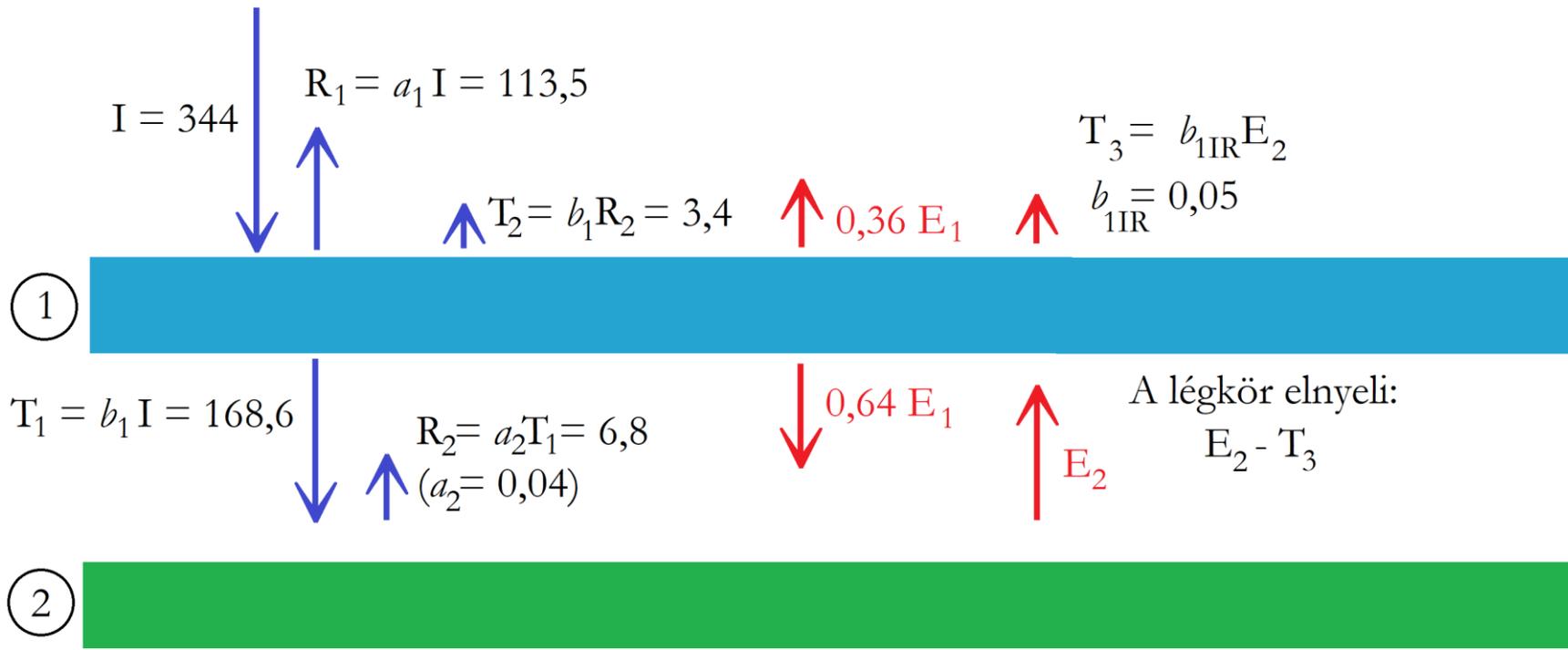


$$A_2 = T_1 - R_2 = 161,8$$

$$E_2 = A_2 + 0,64 E_1$$

$$\begin{aligned}
 A_1 &= (I - R_1 - T_1) + (R_2 - T_2) = \\
 &= [1 - a_1 - b_1 + b_1 a_2 (1 - b_1)] I = 65,3
 \end{aligned}$$

$$E_1 = A_1 + E_2 - T_3 = A_1 + (1 - b_{1IR}) E_2$$



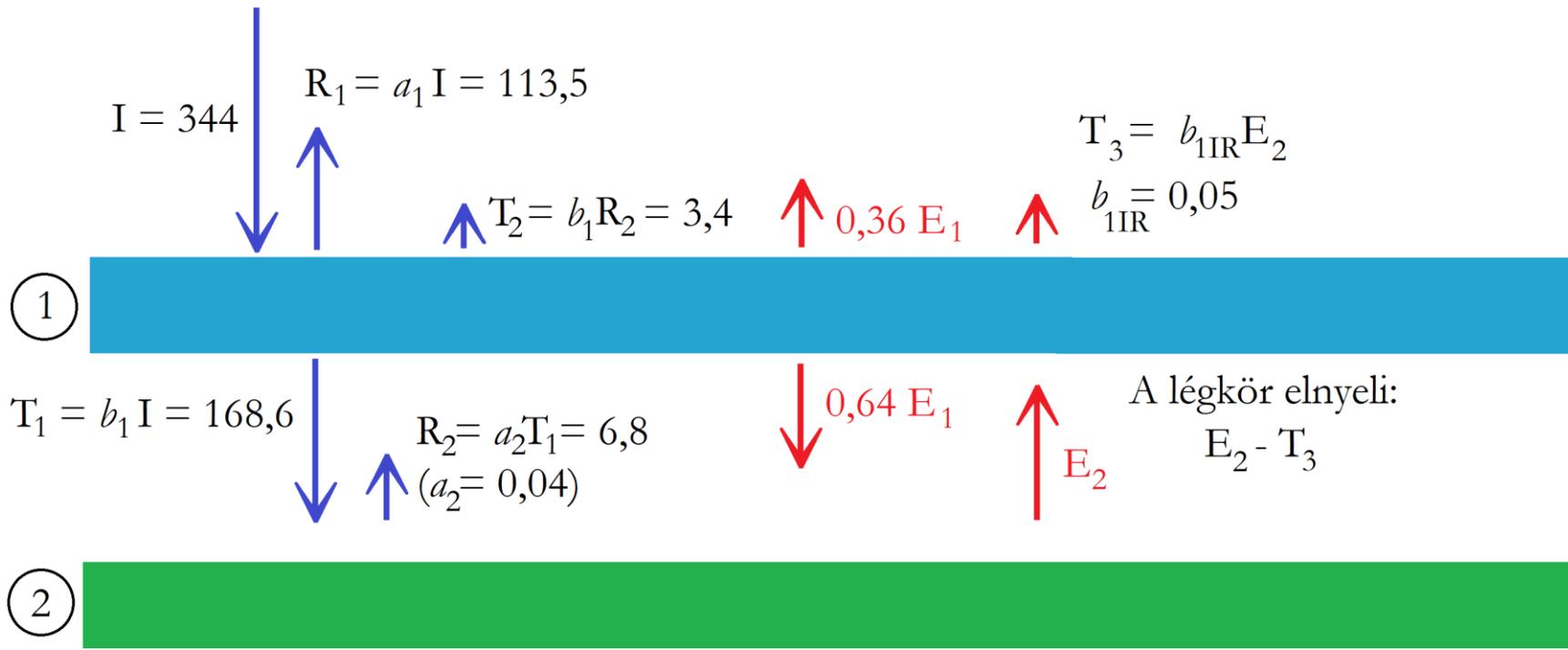
$$A_2 = T_1 - R_2 = 161,8$$

$$E_2 = A_2 + 0,64 E_1$$

$$A_1 = (I - R_1 - T_1) + (R_2 - T_2) = [1 - a_1 - b_1 + b_1 a_2 (1 - b_1)] I = 65,3$$

$$E_1 = A_1 + E_2 - T_3 = A_1 + (1 - b_{1IR}) E_2$$

$$E_1 = 558,7 \quad E_2 = 519,4$$



$$A_2 = T_1 - R_2 = 161,8$$

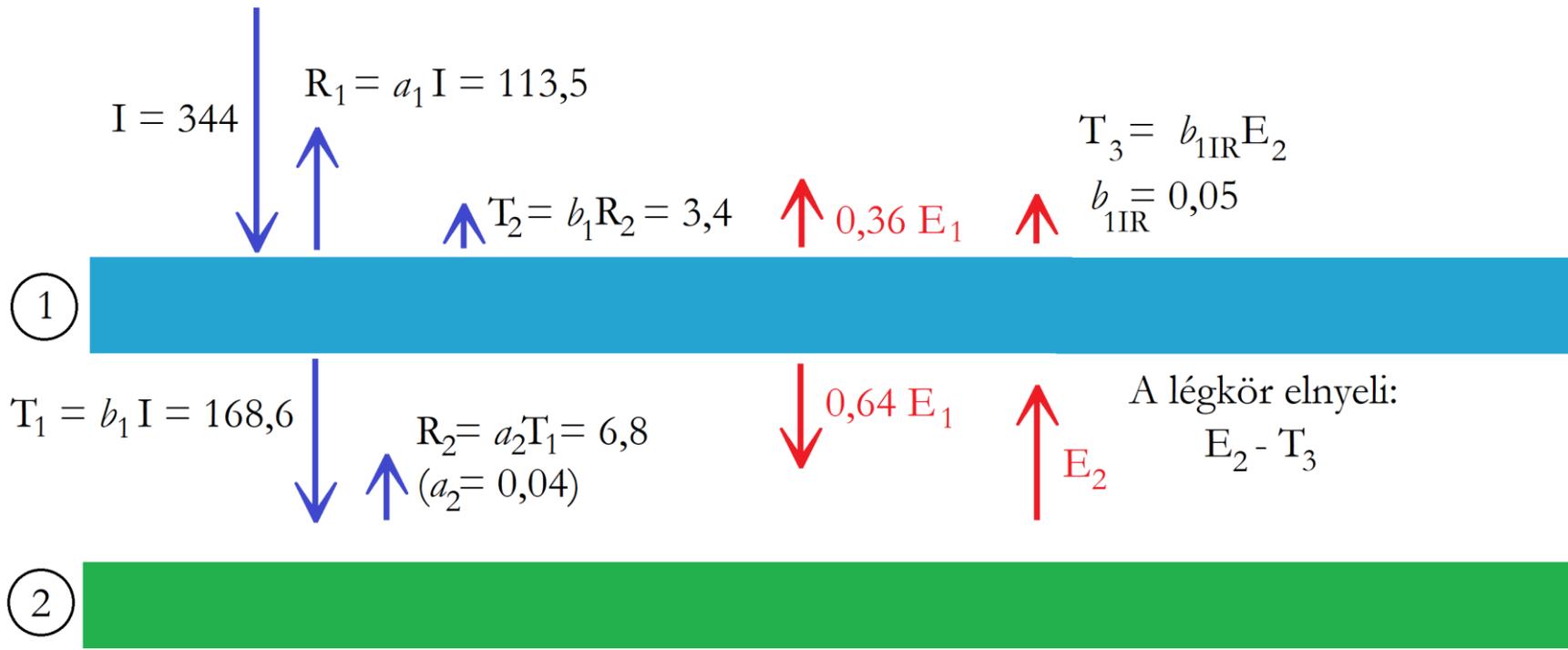
$$E_2 = A_2 + 0,64 E_1$$

$$A_1 = (I - R_1 - T_1) + (R_2 - T_2) = [1 - a_1 - b_1 + b_1 a_2 (1 - b_1)] I = 65,3$$

$$E_1 = A_1 + E_2 - T_3 = A_1 + (1 - b_{1IR}) E_2$$

$$E_1 = 558,7 \quad E_2 = 519,4$$

$(E_1, E_2 > I)$



$$A_2 = T_1 - R_2 = 161,8$$

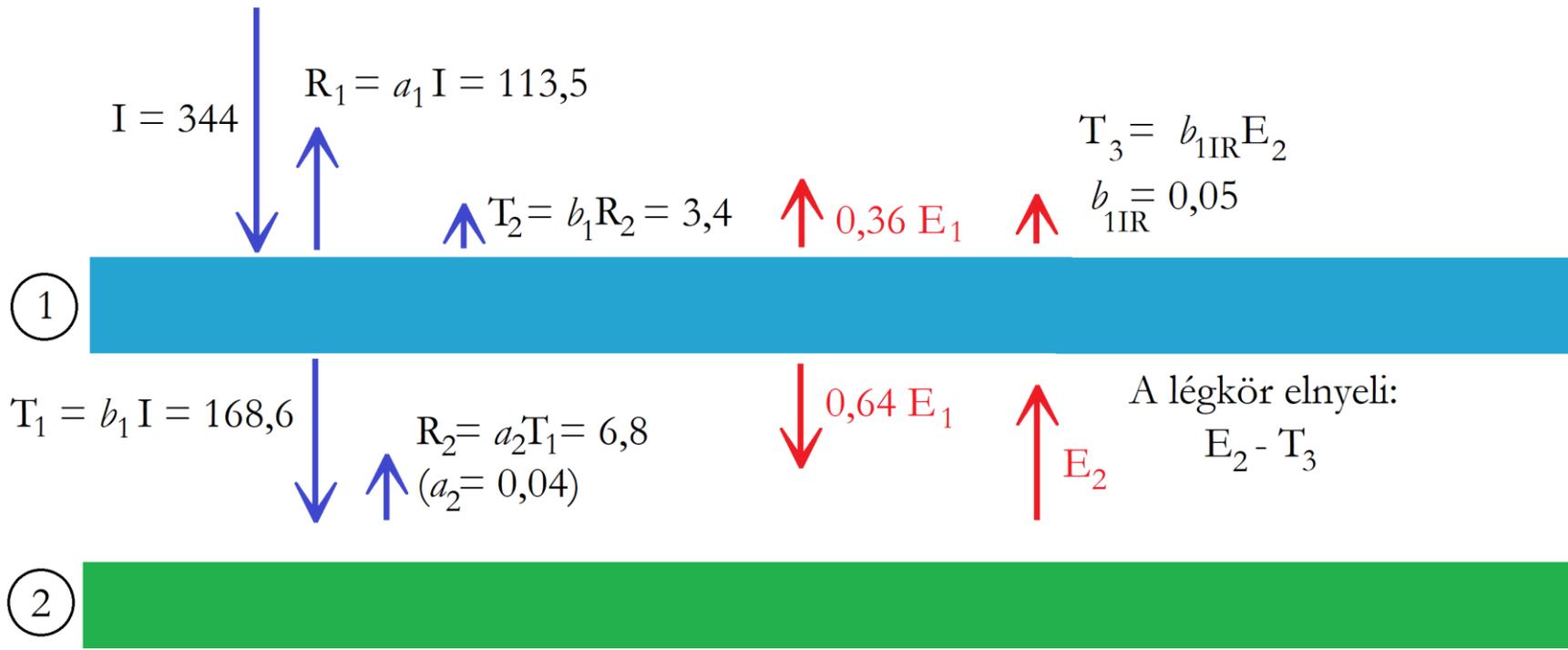
$$E_2 = A_2 + 0,64 E_1$$

$$A_1 = (I - R_1 - T_1) + (R_2 - T_2) = [1 - a_1 - b_1 + b_1 a_2 (1 - b_1)] I = 65,3$$

$$E_1 = A_1 + E_2 - T_3 = A_1 + (1 - b_{1IR}) E_2$$

$$E_1 = 558,7 \quad E_2 = 519,4 \quad \rightarrow \quad 36^\circ\text{C}$$

$(E_1, E_2 > I)$



$$A_2 = T_1 - R_2 = 161,8$$

$$E_2 = A_2 + 0,64 E_1$$

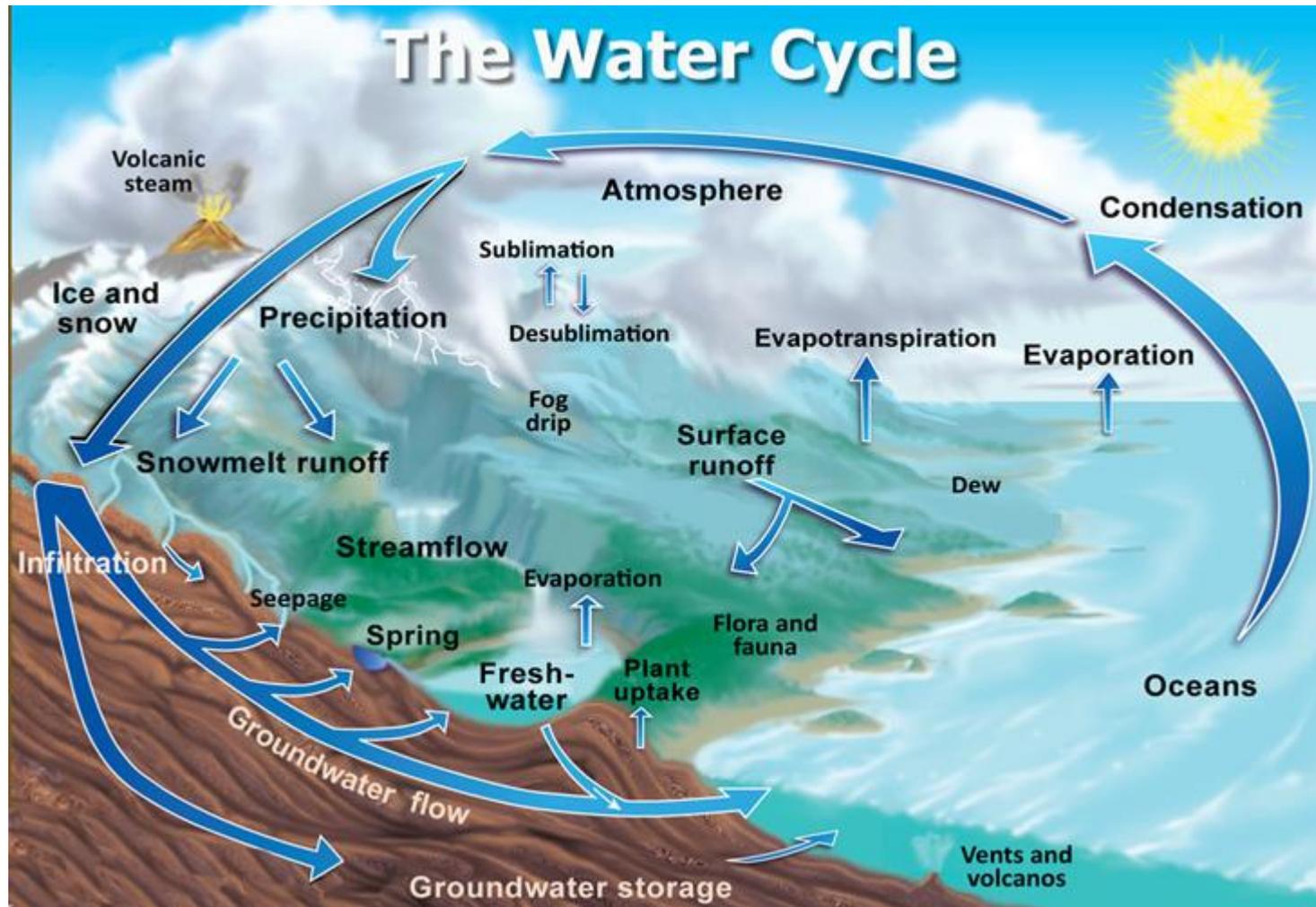
$$A_1 = (I - R_1 - T_1) + (R_2 - T_2) = [1 - a_1 - b_1 + b_1 a_2 (1 - b_1)] I = 65,3$$

$$E_1 = A_1 + E_2 - T_3 = A_1 + (1 - b_{1IR}) E_2$$

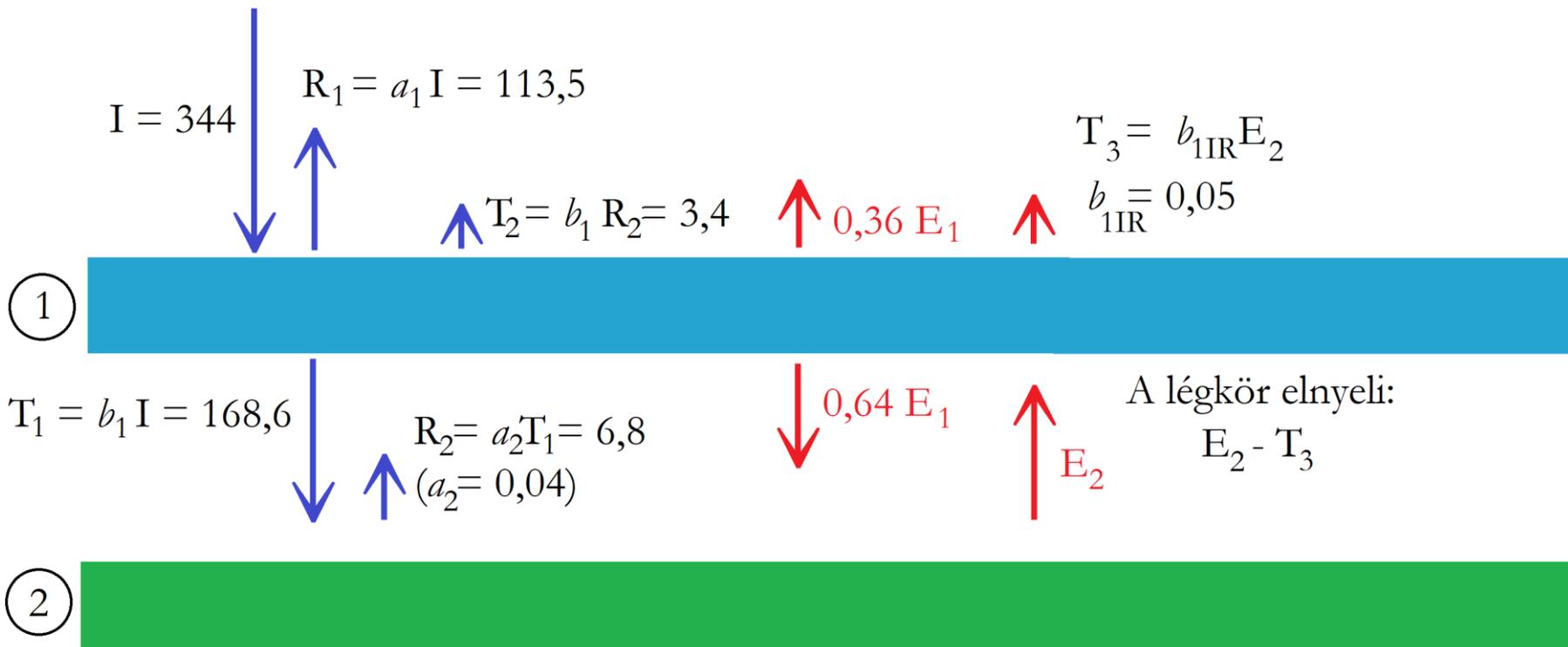
$$E_1 = 558,7 \quad E_2 = 519,4 \quad \rightarrow 36^\circ\text{C}$$

(E₁, E₂ > I) Ez azért túlzás! :)

A víz körforgása

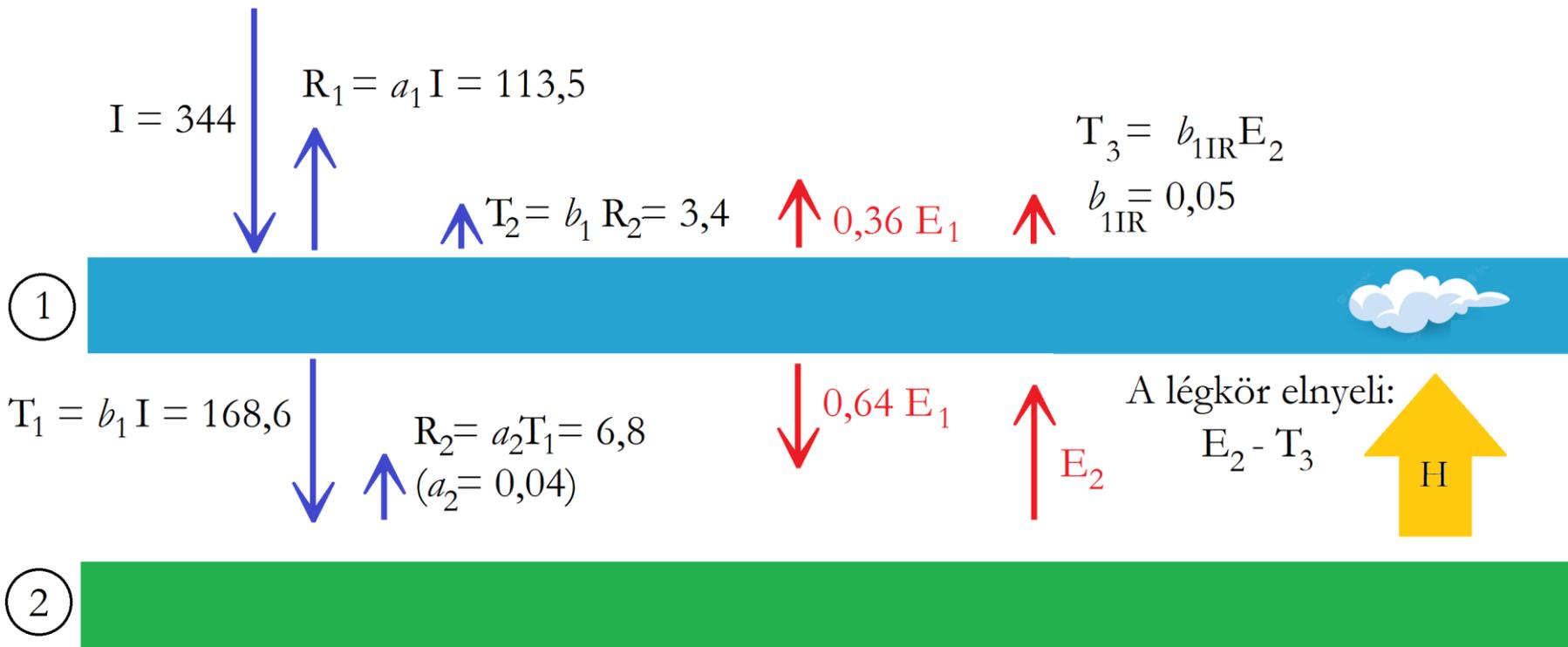


(kép: USGS)



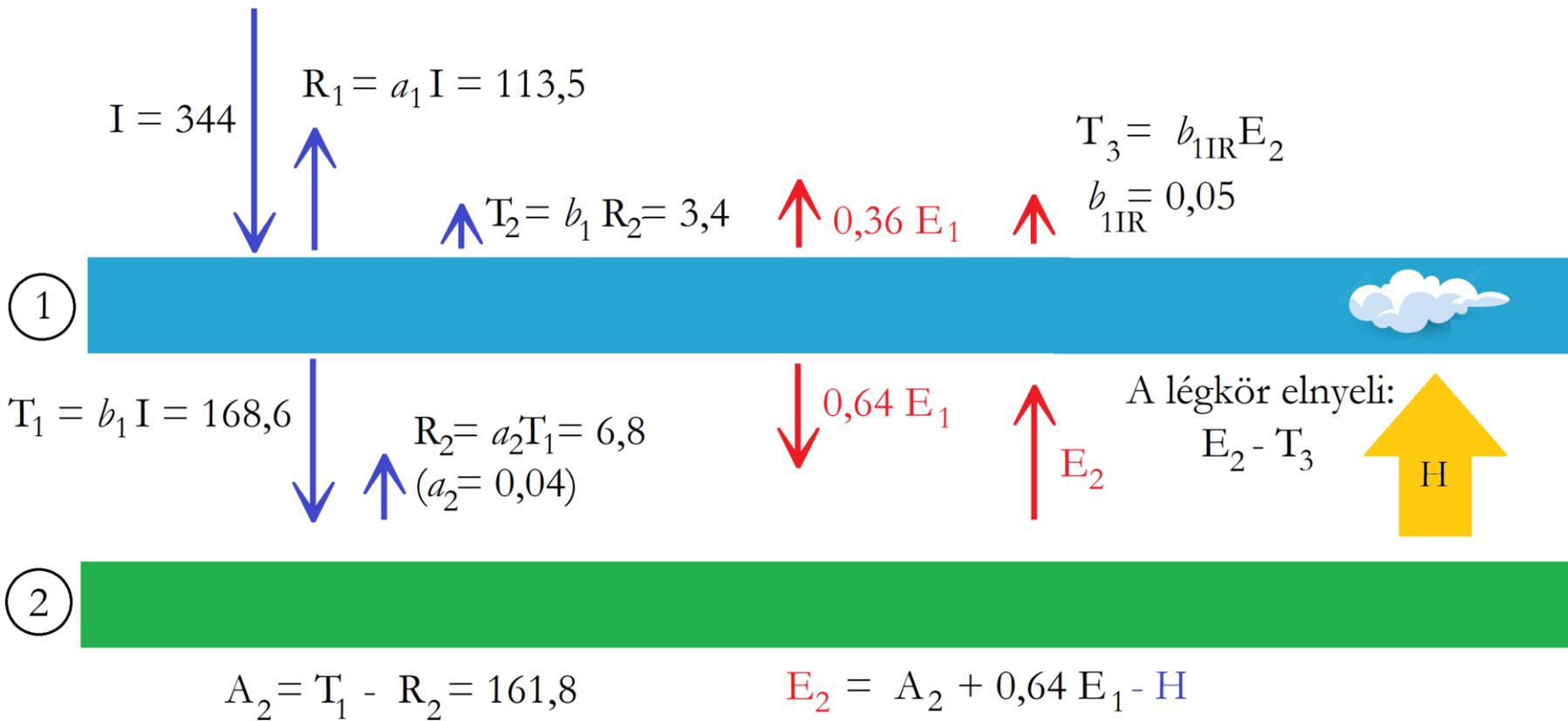
$$A_2 = T_1 - R_2 = 161,8$$

$$\begin{aligned}
 A_1 &= (I - R_1 - T_1) + (R_2 - T_2) = \\
 &= [1 - a_1 - b_1 + b_1 a_2 (1 - b_1)] I = 65,3
 \end{aligned}$$

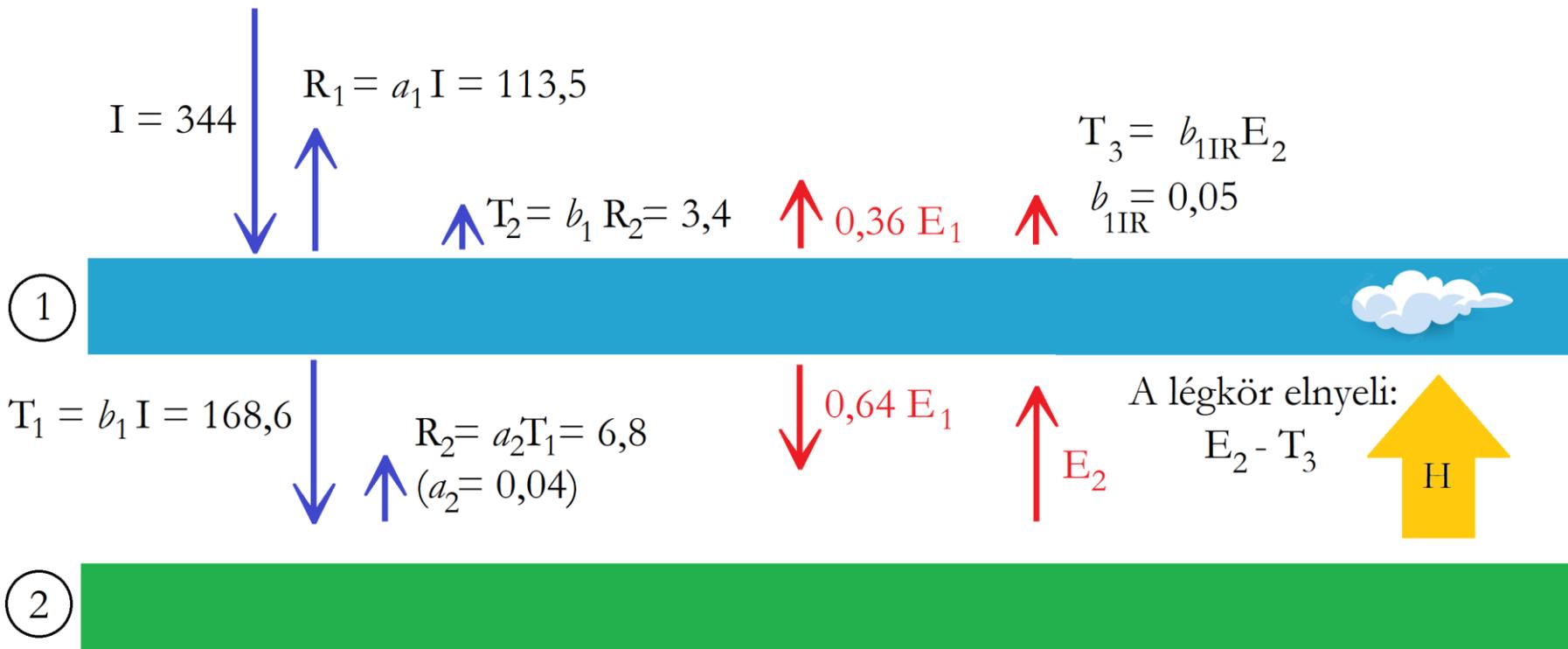


$$A_2 = T_1 - R_2 = 161,8$$

$$\begin{aligned}
 A_1 &= (I - R_1 - T_1) + (R_2 - T_2) = \\
 &= [1 - a_1 - b_1 + b_1 a_2 (1 - b_1)] I = 65,3
 \end{aligned}$$



$$\begin{aligned}
 A_1 &= (I - R_1 - T_1) + (R_2 - T_2) = \\
 &= [1 - a_1 - b_1 + b_1 a_2 (1 - b_1)] I = 65,3
 \end{aligned}$$



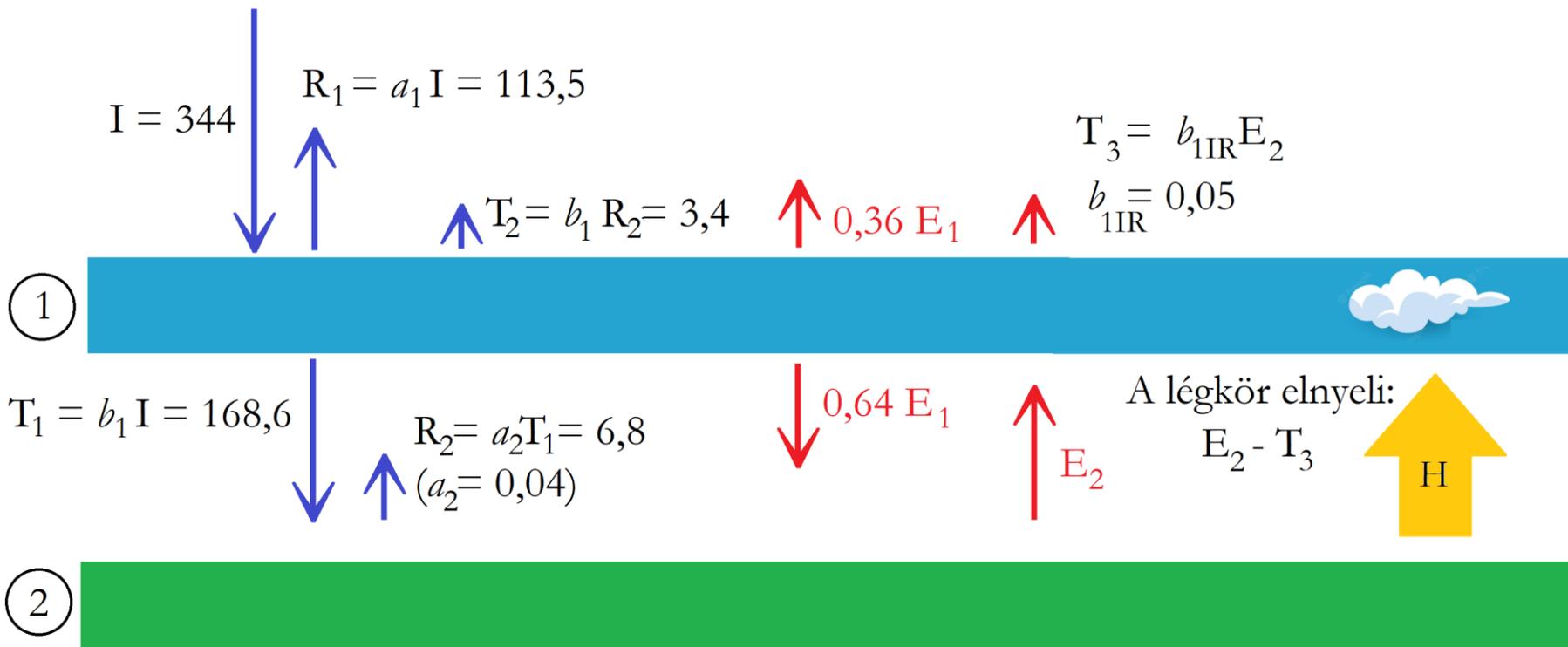
$$A_2 = T_1 - R_2 = 161,8$$

$$E_2 = A_2 + 0,64 E_1 - H$$

$$A_1 = (I - R_1 - T_1) + (R_2 - T_2) =$$

$$= [1 - a_1 - b_1 + b_1 a_2 (1 - b_1)] I = 65,3$$

$$E_1 = A_1 + E_2 - T_3 + H$$



$$A_2 = T_1 - R_2 = 161,8$$

$$E_2 = A_2 + 0,64 E_1 - H$$

$$A_1 = (I - R_1 - T_1) + (R_2 - T_2) =$$

$$= [1 - a_1 - b_1 + b_1 a_2 (1 - b_1)] I = 65,3$$

$$E_1 = A_1 + E_2 - T_3 + H$$

$$E_1 = 573,2 \quad E_2 = 415,0 \quad \rightarrow \quad 19^\circ\text{C}$$

$(E_1, E_2 > I)$





MODTRAN Infrared Light in the Atmosphere

Model Input

CO ₂ (ppm)	<input type="text" value="400"/>
CH ₄ (ppm)	<input type="text" value="1.7"/>
Trop. Ozone (ppb)	<input type="text" value="28"/>
Strat. Ozone scale	<input type="text" value="1"/>
Water Vapor Scale	<input type="text" value="1"/>
Freon Scale	<input type="text" value="1"/>

Temperature Offset, C

Locality Tropical Atmosphere ▼

No Clouds or Rain ▼

Altitude (km)

Looking down ▼

Save This Run to Background

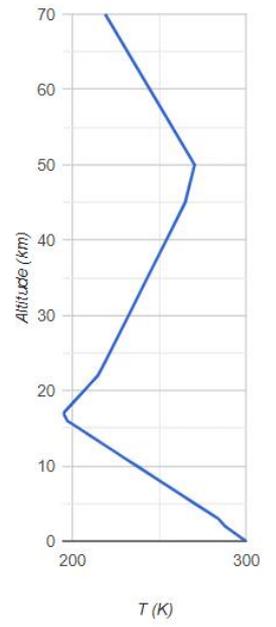
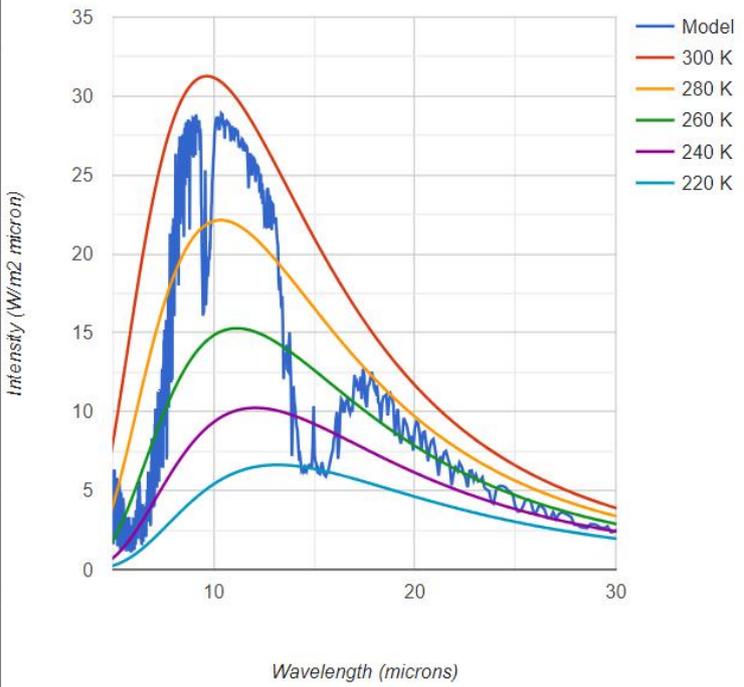
Show Raw Model Output

Model Output

Upward IR Heat Flux **298.52** W/m²

Ground Temperature **299.7** K

Spectrum expanded 5-11-17, changing the IR out value.



Wavelength ▼

T (K) ▼

MODTRAN Infrared Light in the Atmosphere

Model Input

CO ₂ (ppm)	<input type="text" value="400"/>
CH ₄ (ppm)	<input type="text" value="1.7"/>
Trop. Ozone (ppb)	<input type="text" value="28"/>
Strat. Ozone scale	<input type="text" value="1"/>
Water Vapor Scale	<input type="text" value="0"/>
Freon Scale	<input type="text" value="1"/>

Temperature Offset, C	<input type="text" value="0"/>
-----------------------	--------------------------------

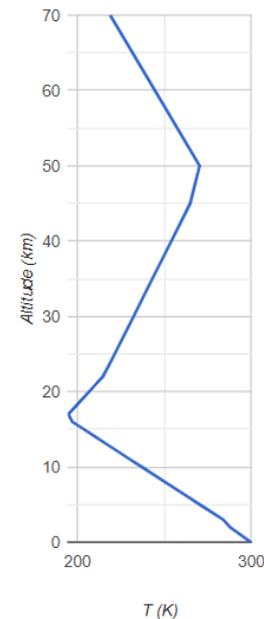
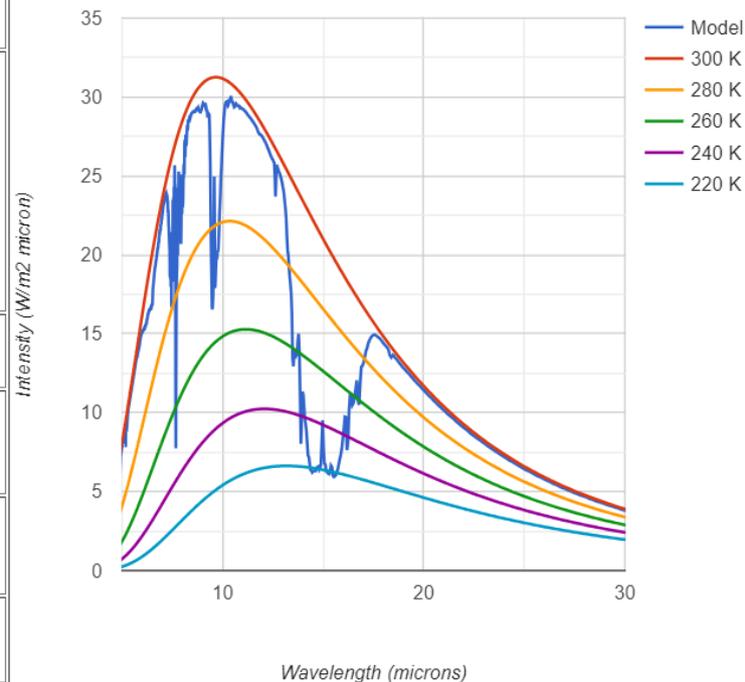
Locality	<input type="text" value="Tropical Atmosphere"/>
	<input type="text" value="No Clouds or Rain"/>

Altitude (km)	<input type="text" value="70"/>
	<input type="text" value="Looking down"/>

Model Output

Upward IR Heat Flux **389.36** W/m²
Ground Temperature **299.7** K

Spectrum expanded 5-11-17, changing the IR out value.



Wavelength

T (K)



MODTRAN Infrared Light in the Atmosphere

Model Input

CO ₂ (ppm)	<input type="text" value="400"/>
CH ₄ (ppm)	<input type="text" value="1.7"/>
Trop. Ozone (ppb)	<input type="text" value="28"/>
Strat. Ozone scale	<input type="text" value="1"/>
Water Vapor Scale	<input type="text" value="1"/>
Freon Scale	<input type="text" value="1"/>

Temperature Offset, C

Locality Tropical Atmosphere ▼

No Clouds or Rain ▼

Altitude (km)

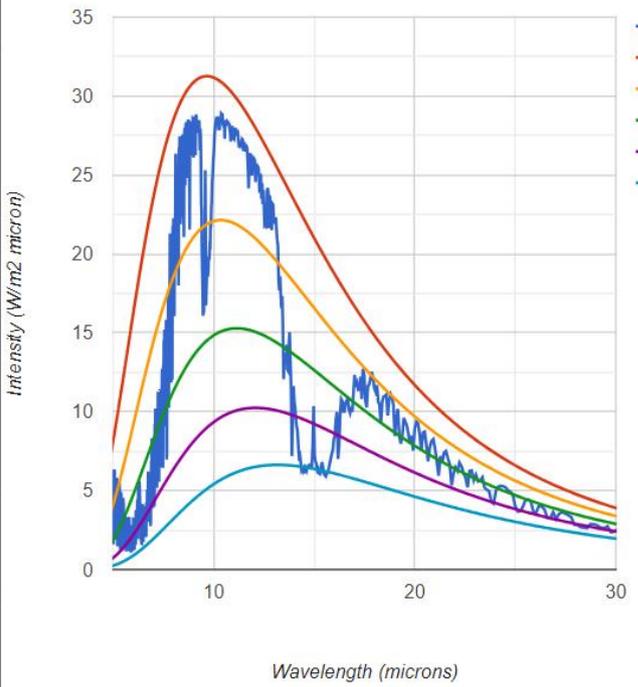
Looking down ▼

Model Output

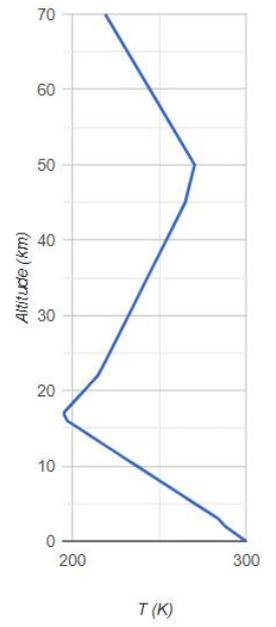
Upward IR Heat Flux **298.52** W/m²

Ground Temperature **299.7** K

Spectrum expanded 5-11-17, changing the IR out value.



Wavelength ▼



T (K) ▼

MODTRAN Infrared Light in the Atmosphere

Model Input

CO ₂ (ppm)	<input type="text" value="0"/>
CH ₄ (ppm)	<input type="text" value="1.7"/>
Trop. Ozone (ppb)	<input type="text" value="28"/>
Strat. Ozone scale	<input type="text" value="1"/>
Water Vapor Scale	<input type="text" value="0"/>
Freon Scale	<input type="text" value="1"/>

Temperature Offset, C

Locality

Altitude (km)

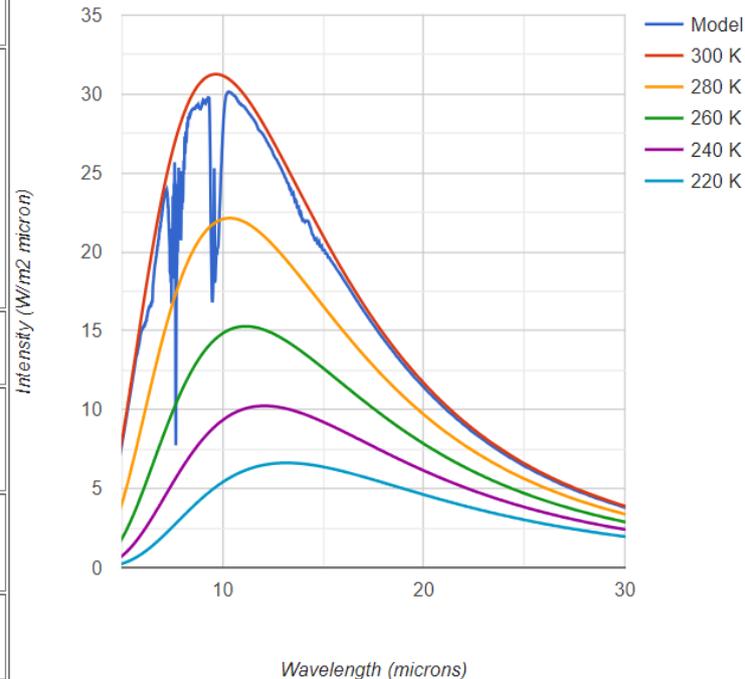
Save This Run to Background

Show Raw Model Output

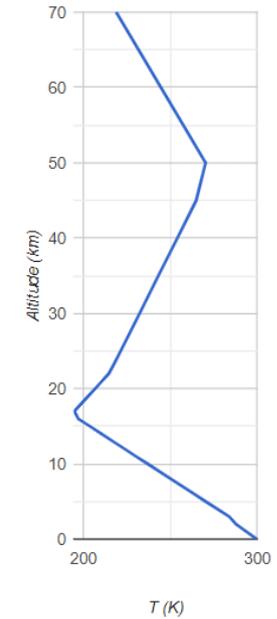
Model Output

Upward IR Heat Flux **431.436** W/m²
 Ground Temperature **299.7** K

Spectrum expanded 5-11-17, changing the IR out value.



Wavelength



T (K)



MODTRAN Infrared Light in the Atmosphere

Model Input

CO ₂ (ppm)	<input type="text" value="400"/>
CH ₄ (ppm)	<input type="text" value="1.7"/>
Trop. Ozone (ppb)	<input type="text" value="28"/>
Strat. Ozone scale	<input type="text" value="1"/>
Water Vapor Scale	<input type="text" value="1"/>
Freon Scale	<input type="text" value="1"/>

Temperature Offset, C

Locality Tropical Atmosphere ▼

No Clouds or Rain ▼

Altitude (km)

Looking down ▼

Save This Run to Background

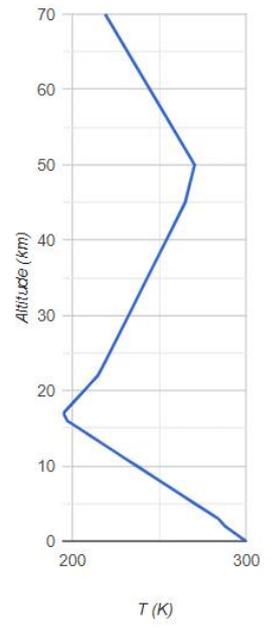
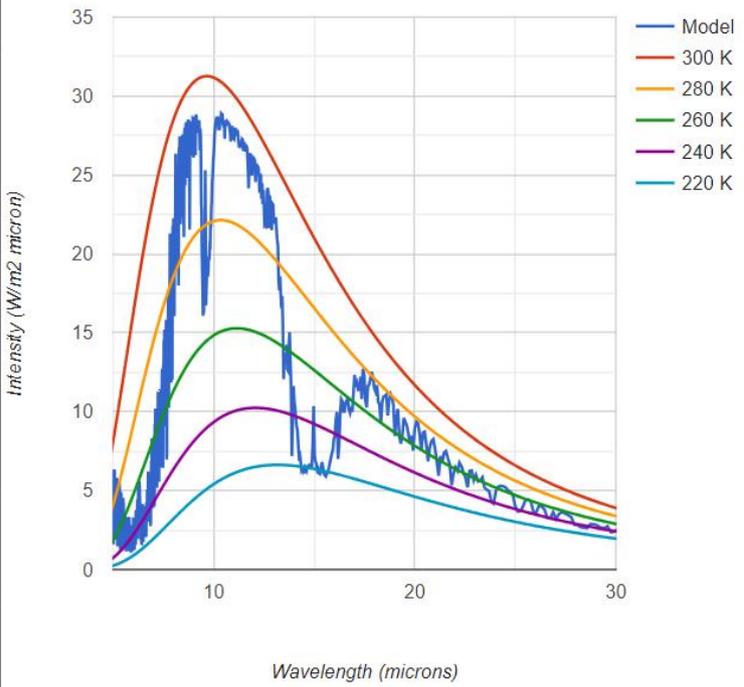
Show Raw Model Output

Model Output

Upward IR Heat Flux **298.52** W/m²

Ground Temperature **299.7** K

Spectrum expanded 5-11-17, changing the IR out value.



Wavelength ▼

T (K) ▼

MODTRAN Infrared Light in the Atmosphere

Model Input

CO ₂ (ppm)	<input type="text" value="1000"/>
CH ₄ (ppm)	<input type="text" value="1.7"/>
Trop. Ozone (ppb)	<input type="text" value="28"/>
Strat. Ozone scale	<input type="text" value="1"/>
Water Vapor Scale	<input type="text" value="1"/>
Freon Scale	<input type="text" value="1"/>

Temperature Offset, C	<input type="text" value="0"/>
-----------------------	--------------------------------

Locality	<input type="text" value="Tropical Atmosphere"/>
	<input type="text" value="No Clouds or Rain"/>

Altitude (km)	<input type="text" value="70"/>
	<input type="text" value="Looking down"/>

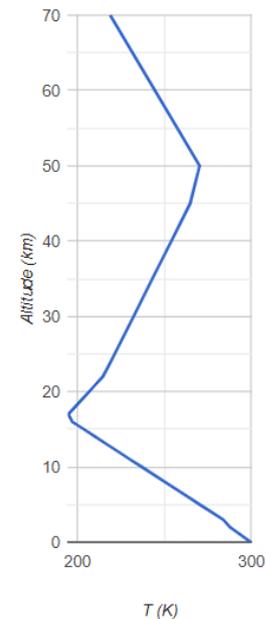
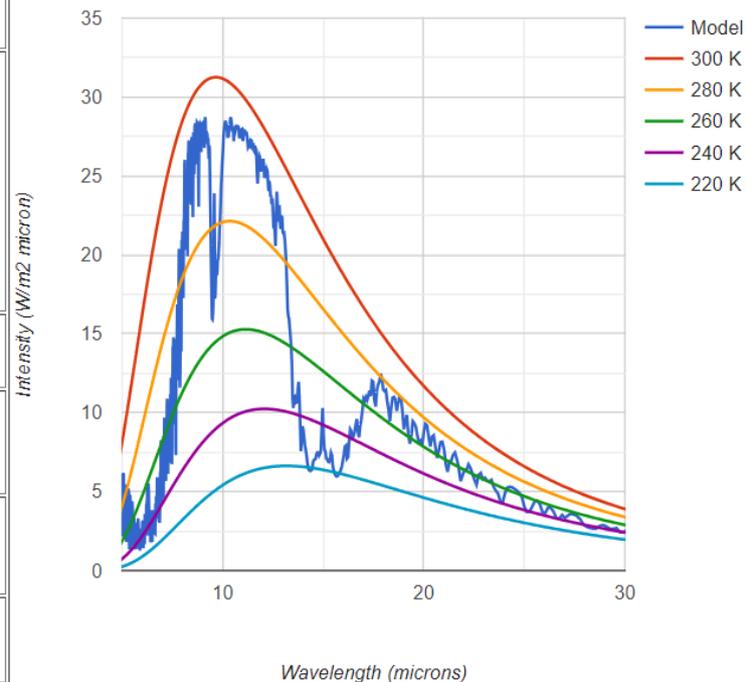
Save This Run to Background

Show Raw Model Output

Model Output

Upward IR Heat Flux **294.092** W/m²
Ground Temperature **299.7** K

Spectrum expanded 5-11-17, changing the IR out value.



Wavelength

T (K)

MODTRAN Infrared Light in the Atmosphere

Model Input

CO₂ (ppm)

CH₄ (ppm)

Trop. Ozone (ppb)

Strat. Ozone scale

Water Vapor Scale

Freon Scale

Temperature Offset, C

Locality

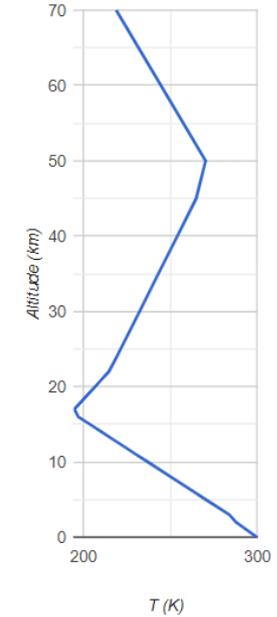
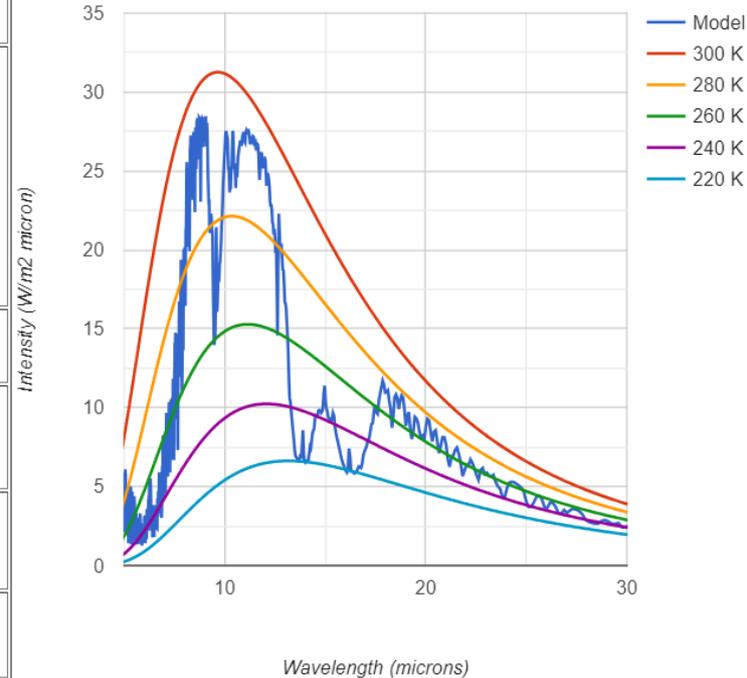
Altitude (km)

Model Output

Upward IR Heat Flux **281.501** W/m²

Ground Temperature **299.7** K

Spectrum expanded 5-11-17, changing the IR out value.



MODTRAN Infrared Light in the Atmosphere

Model Input

CO₂ (ppm)

CH₄ (ppm)

Trop. Ozone (ppb)

Strat. Ozone scale

Water Vapor Scale

Freon Scale

Temperature Offset, C

Locality

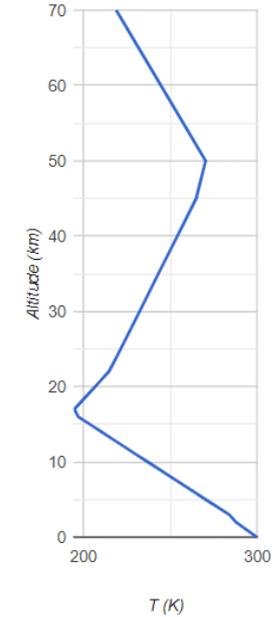
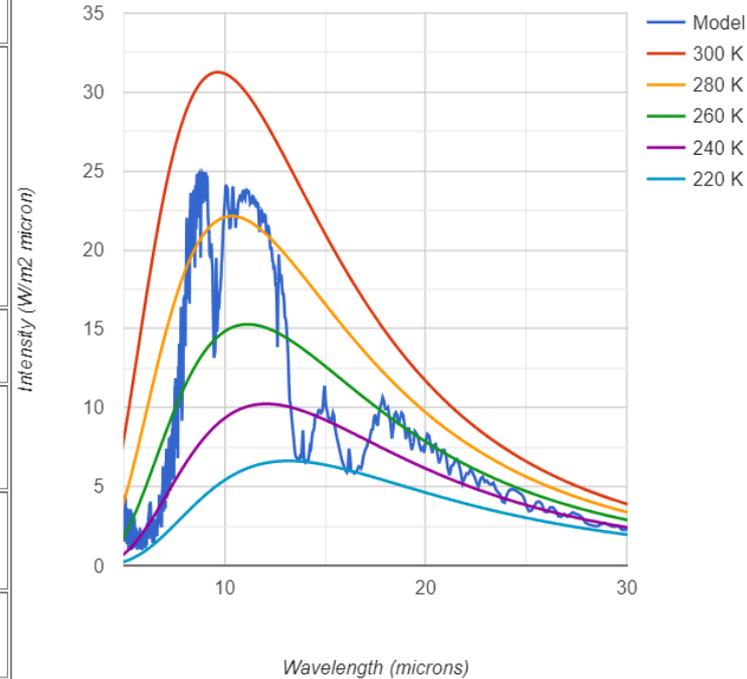
Altitude (km)

Model Output

Upward IR Heat Flux **254.685** W/m²

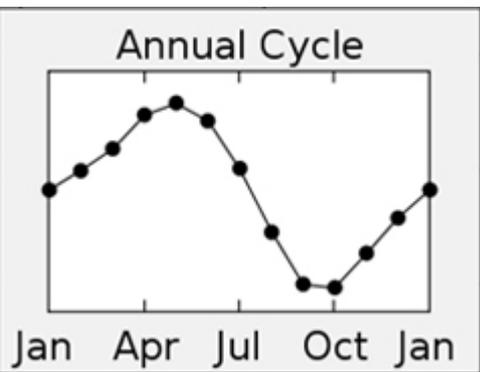
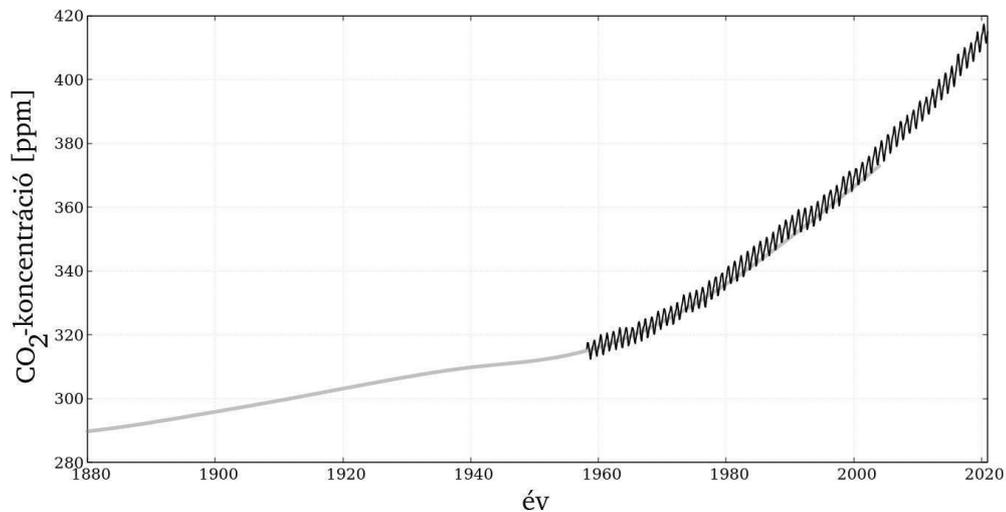
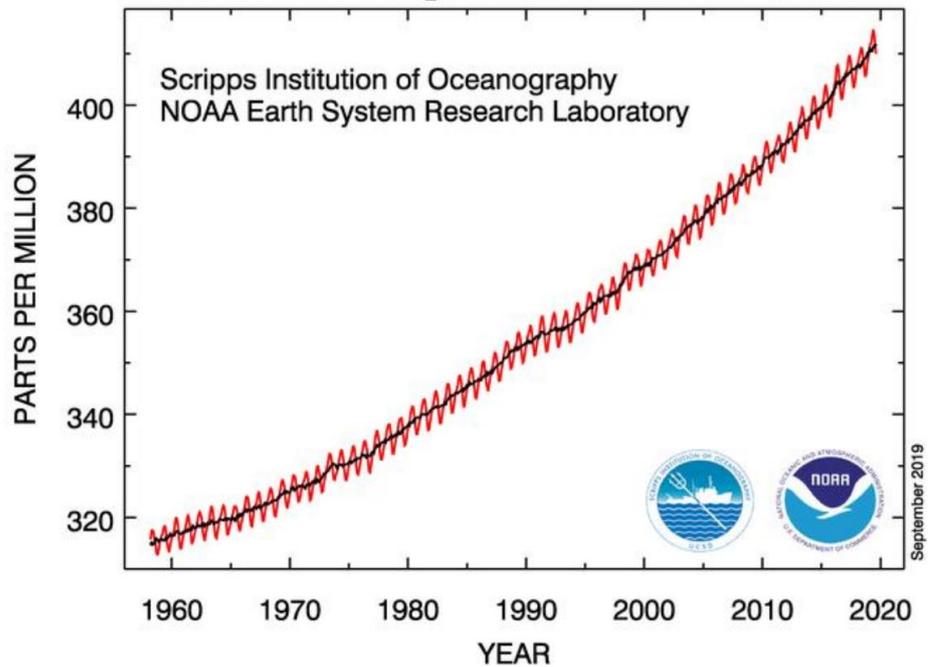
Ground Temperature **299.7** K

Spectrum expanded 5-11-17, changing the IR out value.

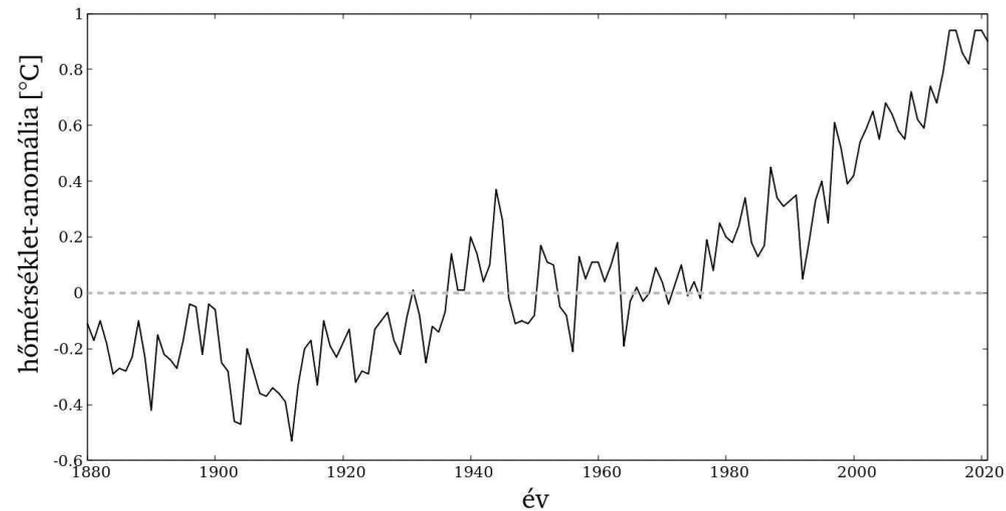


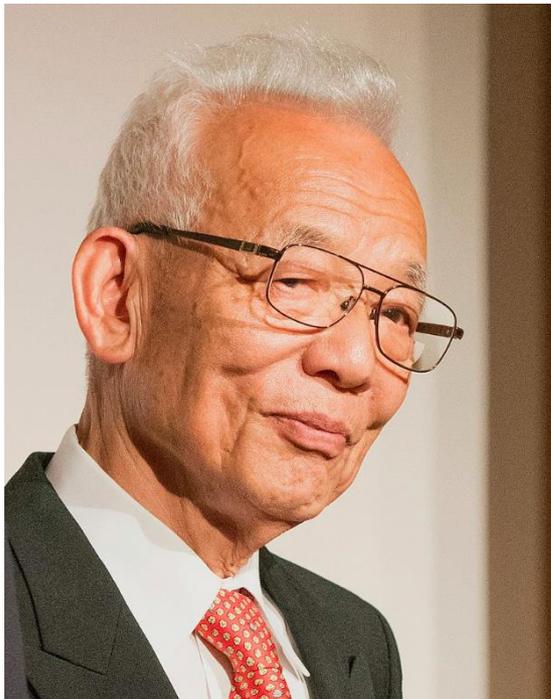


Atmospheric CO₂ at Mauna Loa Observatory



A Keeling-görbe

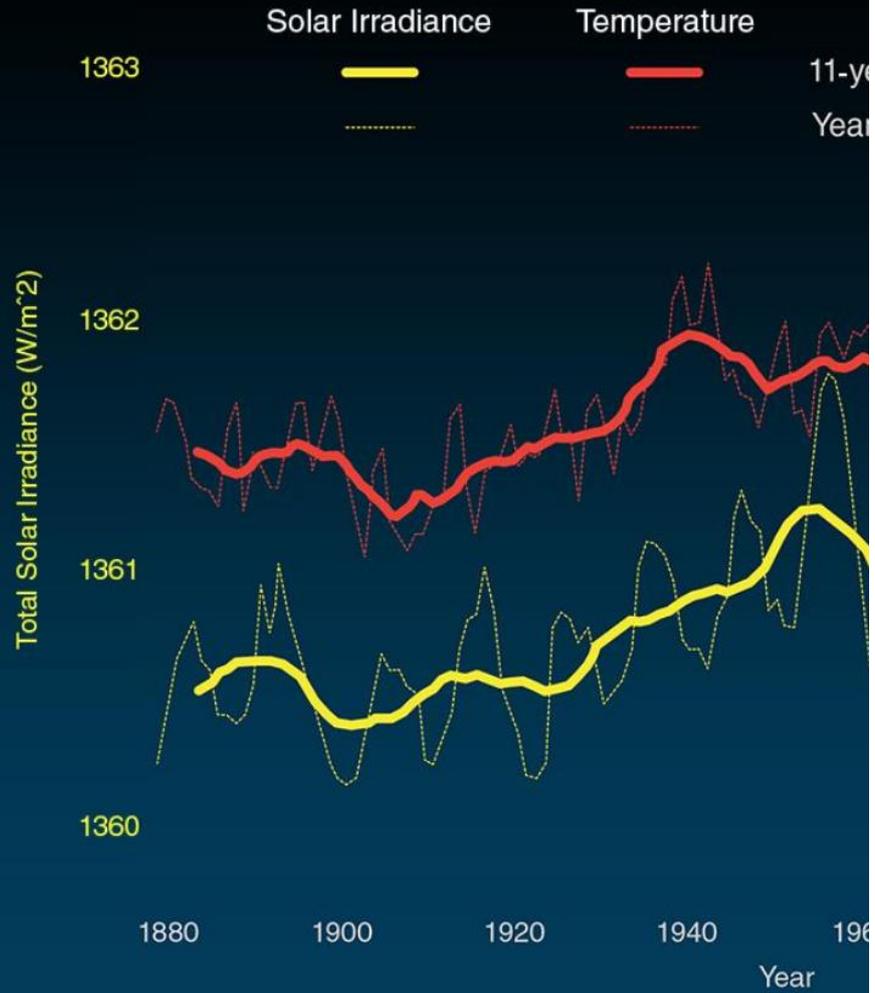




Syukuro Manabe (真鍋 淑郎) *1931,
Princeton, USA



Temperature vs Solar Activity



Thermal Equilibrium of the Atmosphere with a Given Distribution of Relative Humidity

SYUKURO MANABE AND RICHARD T. WETHERALD

Geophysical Fluid Dynamics Laboratory, ESSA, Washington, D. C.

(Manuscript received 2 November 1966)

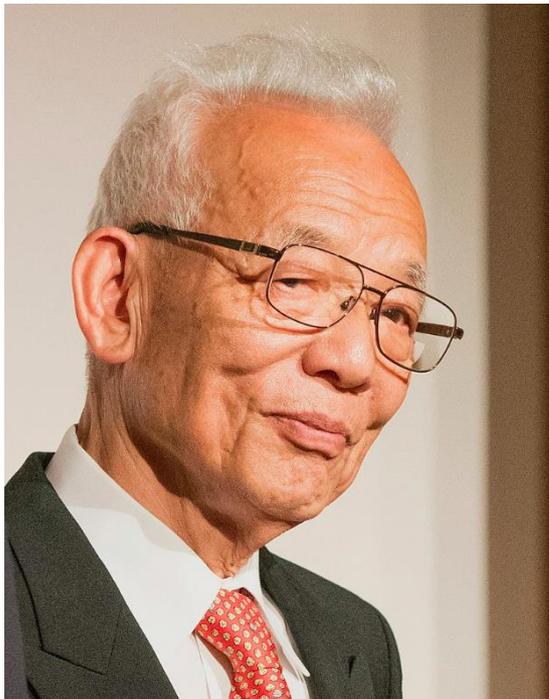
ABSTRACT

Radiative convective equilibrium of the atmosphere with a given distribution of relative humidity is computed as the asymptotic state of an initial value problem.

The results show that it takes almost twice as long to reach the state of radiative convective equilibrium for the atmosphere with a given distribution of relative humidity than for the atmosphere with a given distribution of absolute humidity.

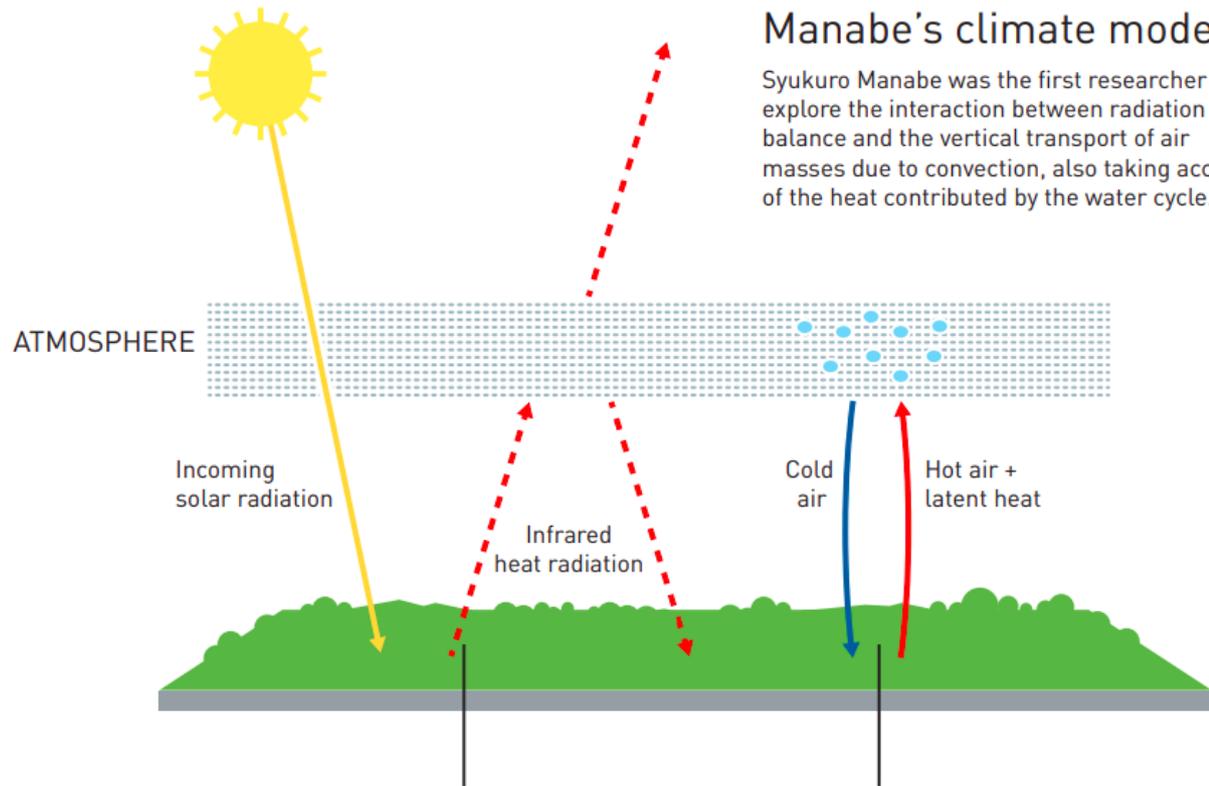
Also, the surface equilibrium temperature of the former is almost twice as sensitive to change of various factors such as solar constant, CO_2 content, O_3 content, and cloudiness, than that of the latter, due to the adjustment of water vapor content to the temperature variation of the atmosphere.

According to our estimate, a doubling of the CO_2 content in the atmosphere has the effect of raising the temperature of the atmosphere (whose relative humidity is fixed) by about 2°C . Our model does not have the extreme sensitivity of atmospheric temperature to changes of CO_2 content which was adduced by Möller.



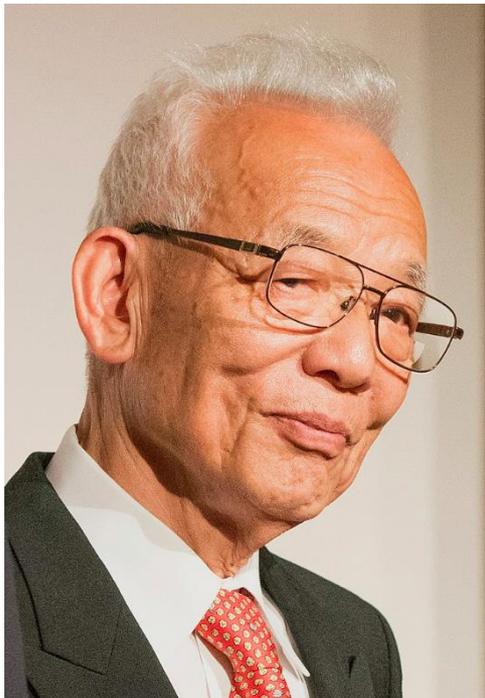
Manabe's climate model

Syukuro Manabe was the first researcher to explore the interaction between radiation balance and the vertical transport of air masses due to convection, also taking account of the heat contributed by the water cycle.

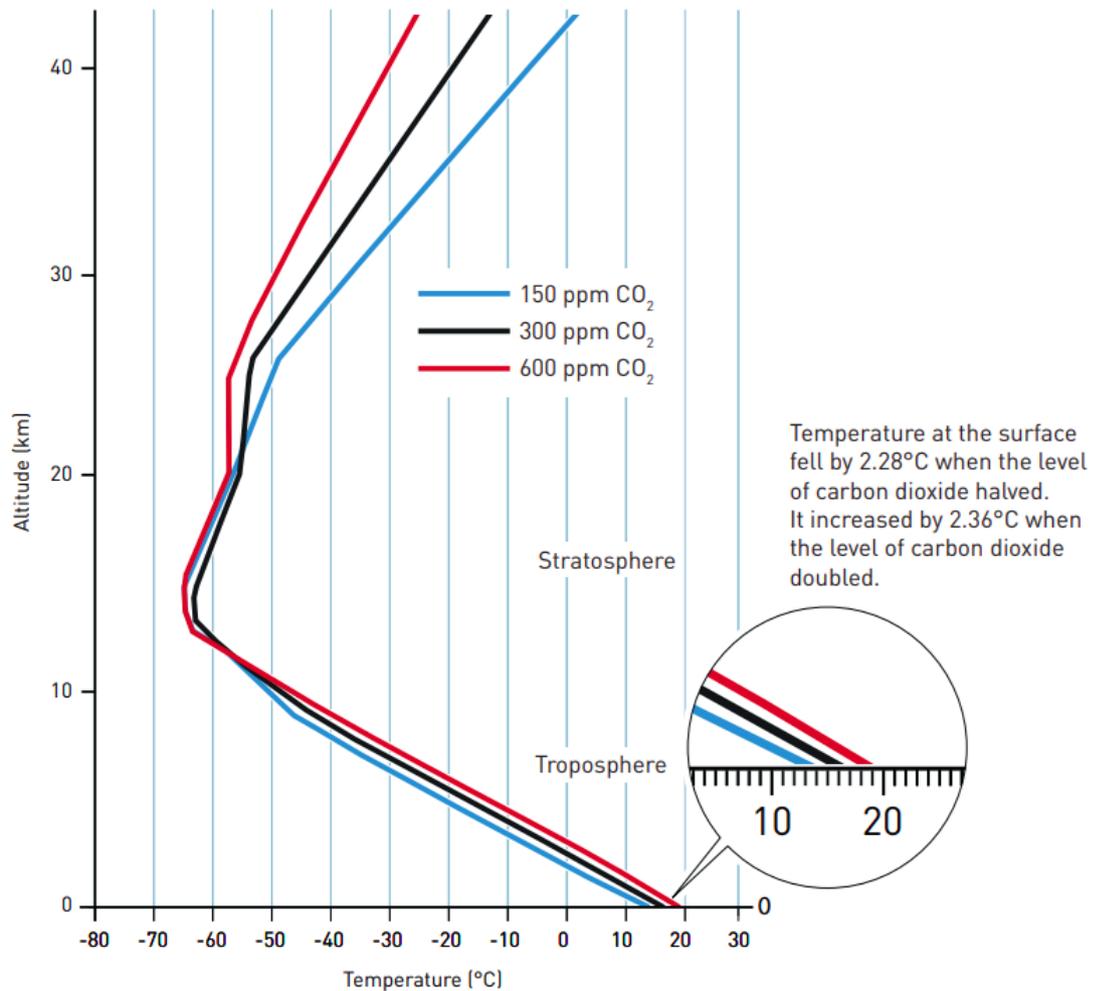


Infrared heat radiation from the ground is partially absorbed in the atmosphere, warming the air and the ground, while some radiates out into space.

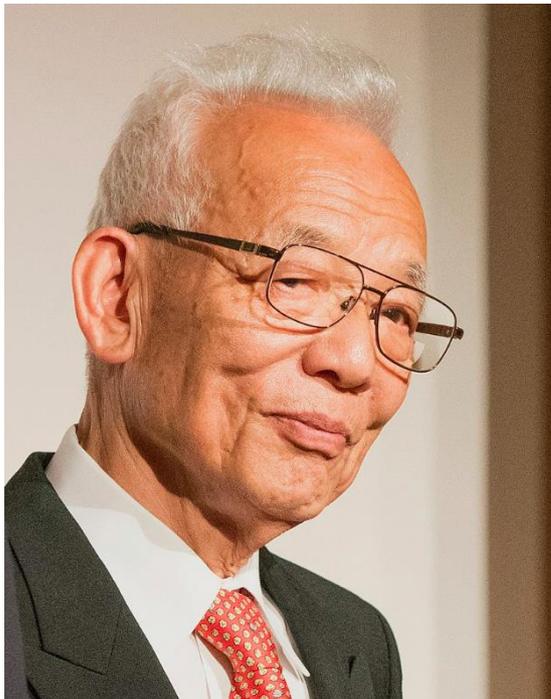
Hot air is lighter than cold air, so it rises through convection. It also carries water vapour, which is a powerful greenhouse gas. The warmer the air, the higher the concentration of water vapour. Further up, where the atmosphere is colder, cloud drops form, releasing the latent heat stored in the water vapour.



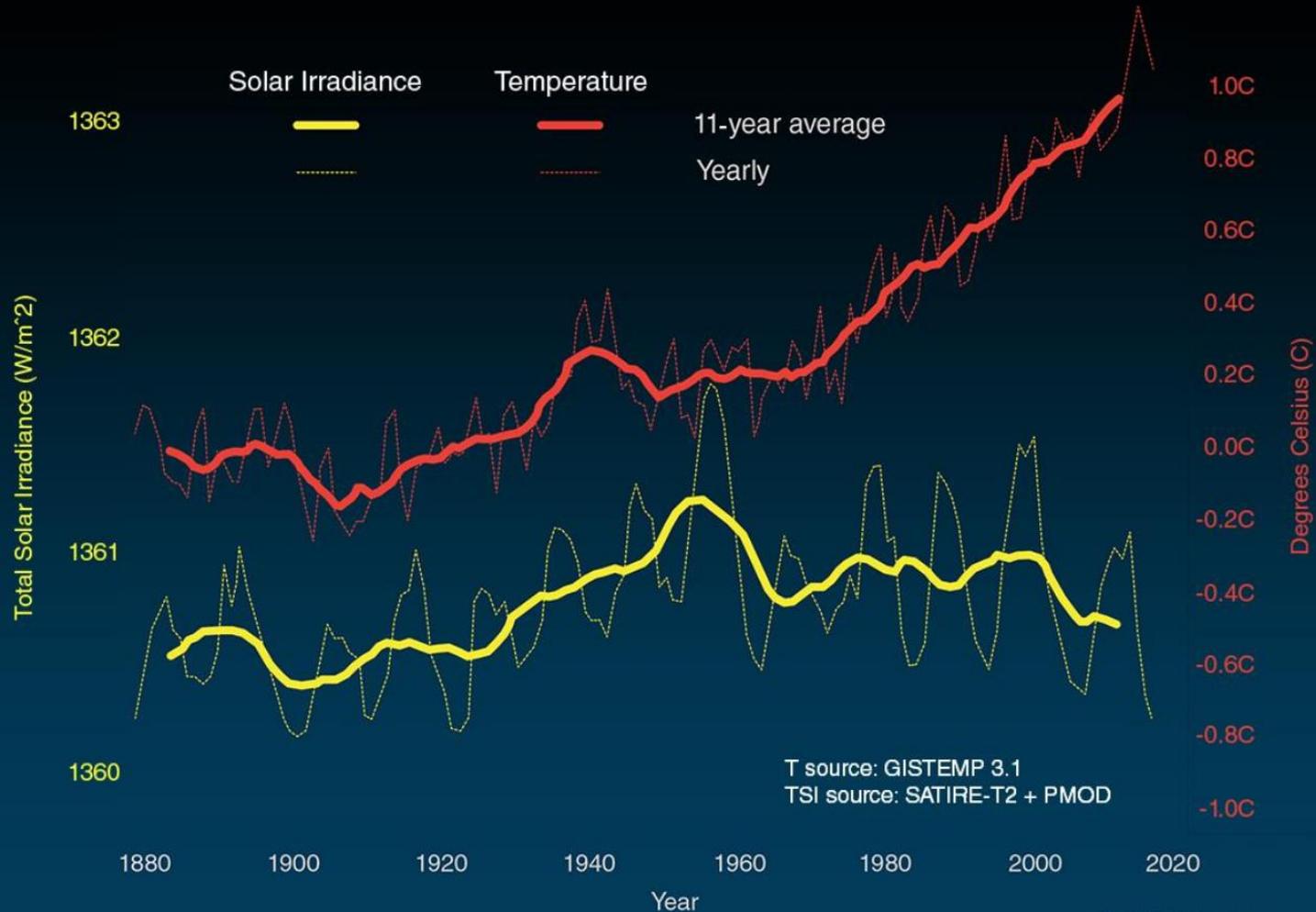
Increased levels of carbon dioxide lead to higher temperatures in the lower atmosphere, while the upper atmosphere gets colder. Manabe thus confirmed that the variation in temperature is due to increased levels of carbon dioxide; if it was caused by increased solar radiation, the entire atmosphere should have warmed up.



Source: Manabe and Wetherald (1967) Thermal equilibrium of the atmosphere with a given distribution of relative humidity, *Journal of the atmospheric sciences*, Vol. 24, Nr 3, May.



Temperature vs Solar Activity



Miért lett ilyen a Vénusz?

- A korai Naprendszerben a fiatal (~ 4,5 milliárd éves) Nap a mostani luminozitásának 70%-át adta le
- Ekkor a Vénuszon sekély óceánok alakulhattak ki
- Beindulhatott a megszaladó üvegházhatás (runaway greenhouse effect), amely egy nemegyensúlyi állapot, melynek során a teljes vízkészlet elpárolog, mert a légkör magasabb rétegeiben sem tud lecsapódni.
- UV miatt a vízmolekulák odafönt szétesnek, a hidrogén elszökik (deutérium nem annyira, azért ma 150-szeres arányban van ott jelen).
- Szegény bolygót az ág is húzza: a szén-dioxid nem tud kivonódni légkörből, mert (talán a víz hiánya miatt is) nincsen lemeztectonika. (Inorganic carbonate-silicate cycle hiányzik.)
- Félmilliárd évente szupervulkán-kitörések(?) → Relatív fiatal felszín





Ez vár ránk is?

A széndioxid-termelésünk miatt biztosan **NEM**. Legalábbis egyelőre.

Lokálisan nálunk is van ilyen megszaladás (Super Greenhouse Effect), pozitív visszacsatolás. Ausztráliától északkeletre, a Csendes-óceánon, de a légközrészünk miatt ez csak lokális jelenség.

De sajnos egymilliárd év múlva a Nap 10%-kal „fényesebb” lesz, a becslések szerint 47°C -ra növelve a Föld átlaghőmérsékletét, ami már egy belépő a visszacsatolásba, a végén a Vénuszt megszégyenítő 900°C -os felszíni hőmérséklettel...

De addig még lesz néhány szép körünk a Nap körül. ☺



Köszönöm a megtisztelő figyelmet!

