ATM 2106 TA Lecture

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Department of Atmospheric Sciences, Yonsei University
Air-Sea Modeling Laboratory

Introduce

Teaching assistant

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- Office hour : With email contact (Thursday ~ Friday)
- Education

  - B.S Department of Atmospheric Sciences, Yonsei University, Seoul, Korea
- Experiences

  - Weather Forecast Officer(Lieutenant), Satellite System Manager, Republic of Korea Air Force

  - Applied programming skills to maintain satellite reception system servers

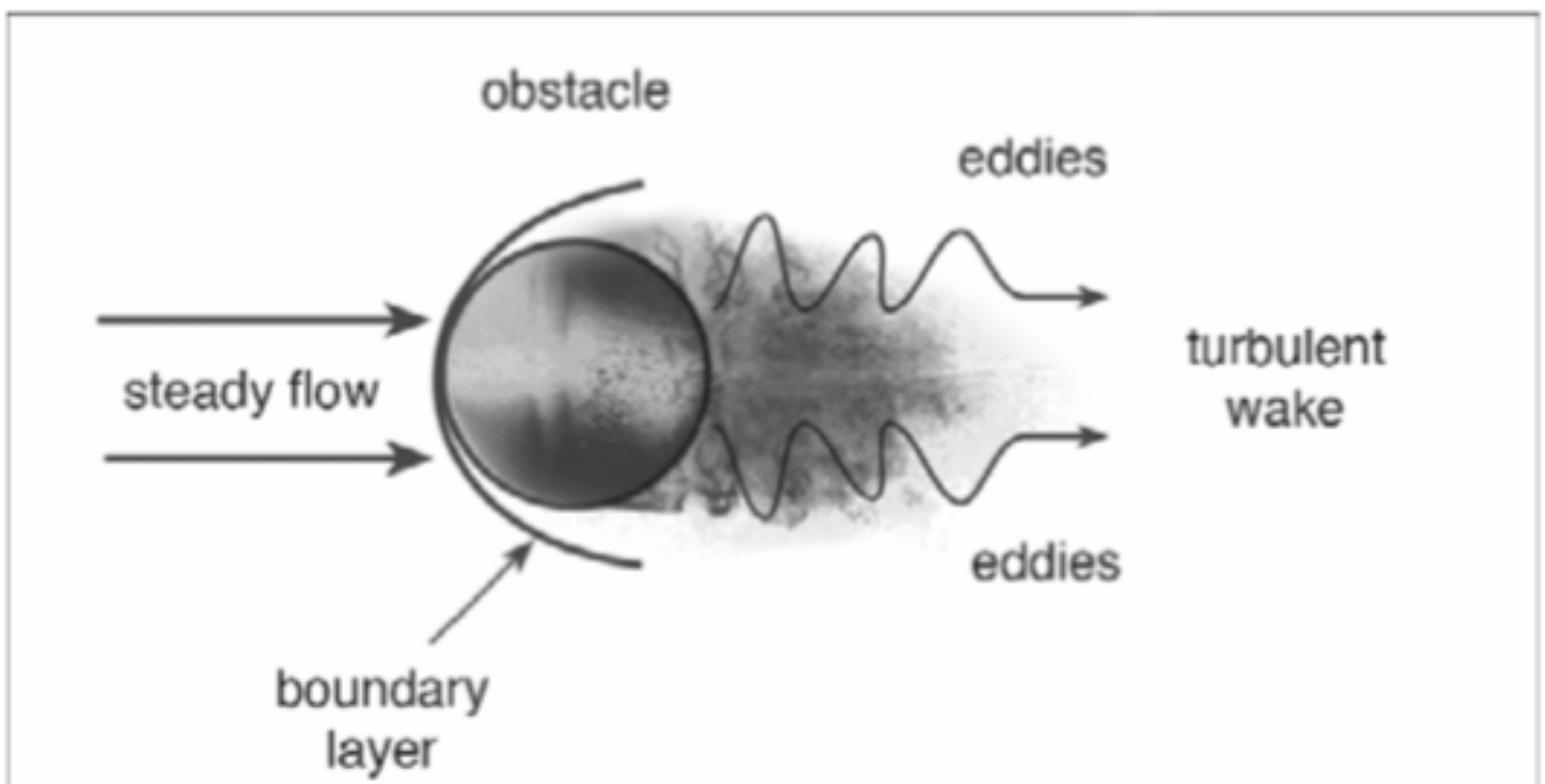
  - Produced highly optimized weather forecasts for each air mission and briefed pilots on weather conditions prior to missions

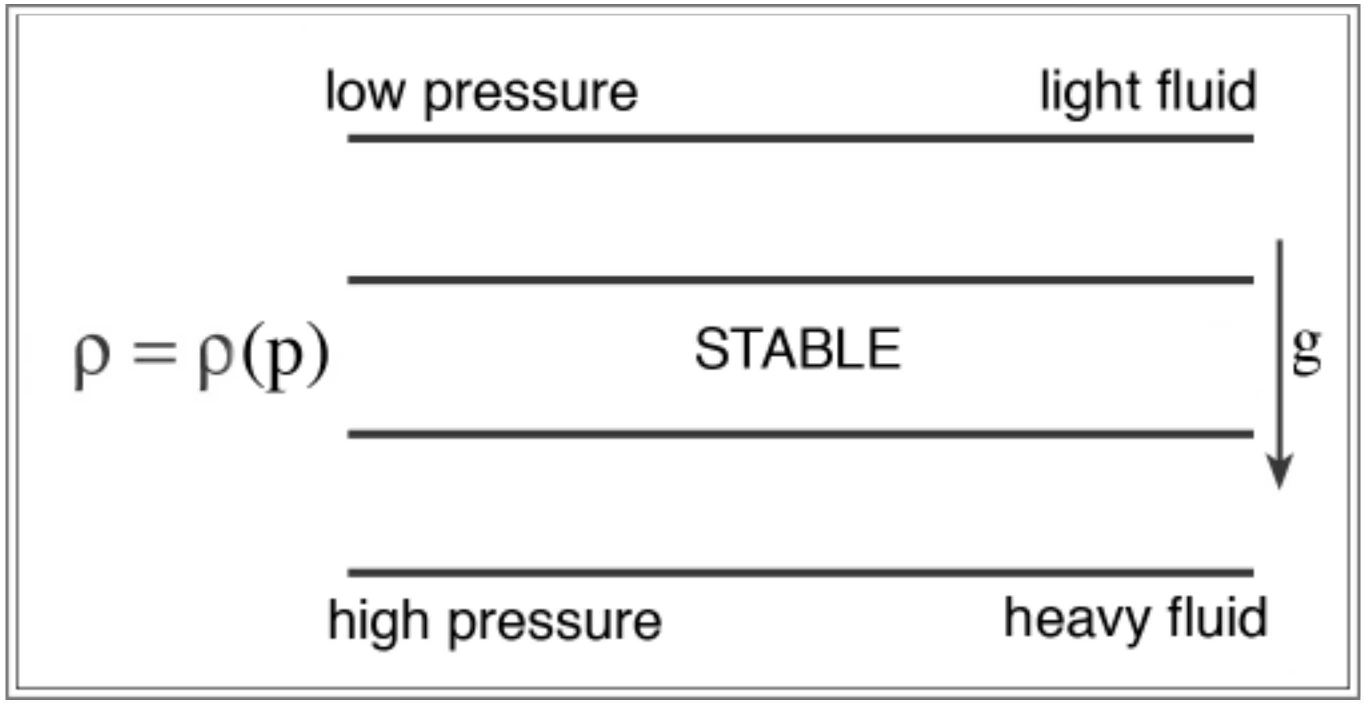
  - Planned and carried out satellite reception system upgrade projects worthy of $300,000. (Himawari-8(MTSAT-3))

Contents

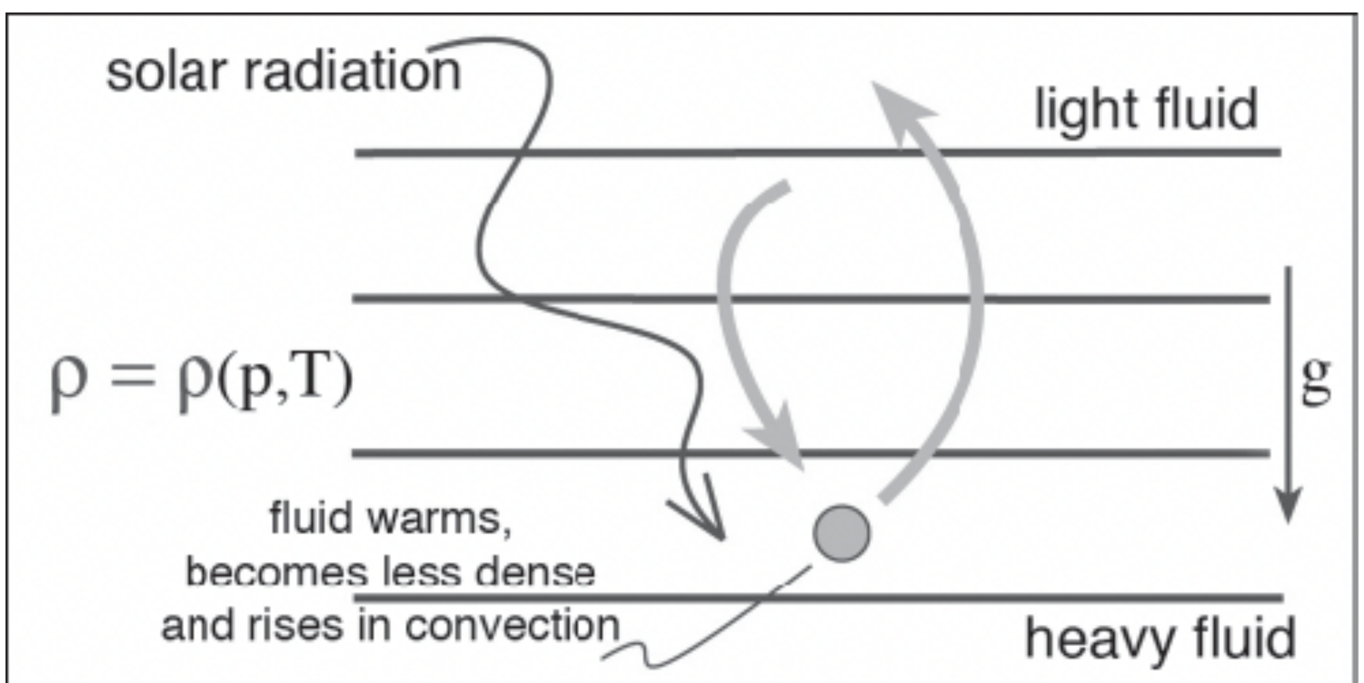
Fluid dynamics

- Fluid dynamics is commonly studied in engineering.
- Atmosphere, Ocean has different compressibility.
- In geophysical fluid dynamics, we consider rotation effect





- Barotropic Atmosphere
- if ρ does not depend on T,
- the fluid can't be brought in to motion by heating/cooling



- Baroclinic Atmosphere
- if ρ depends on both P and T, the fluid can convert by thermal energy

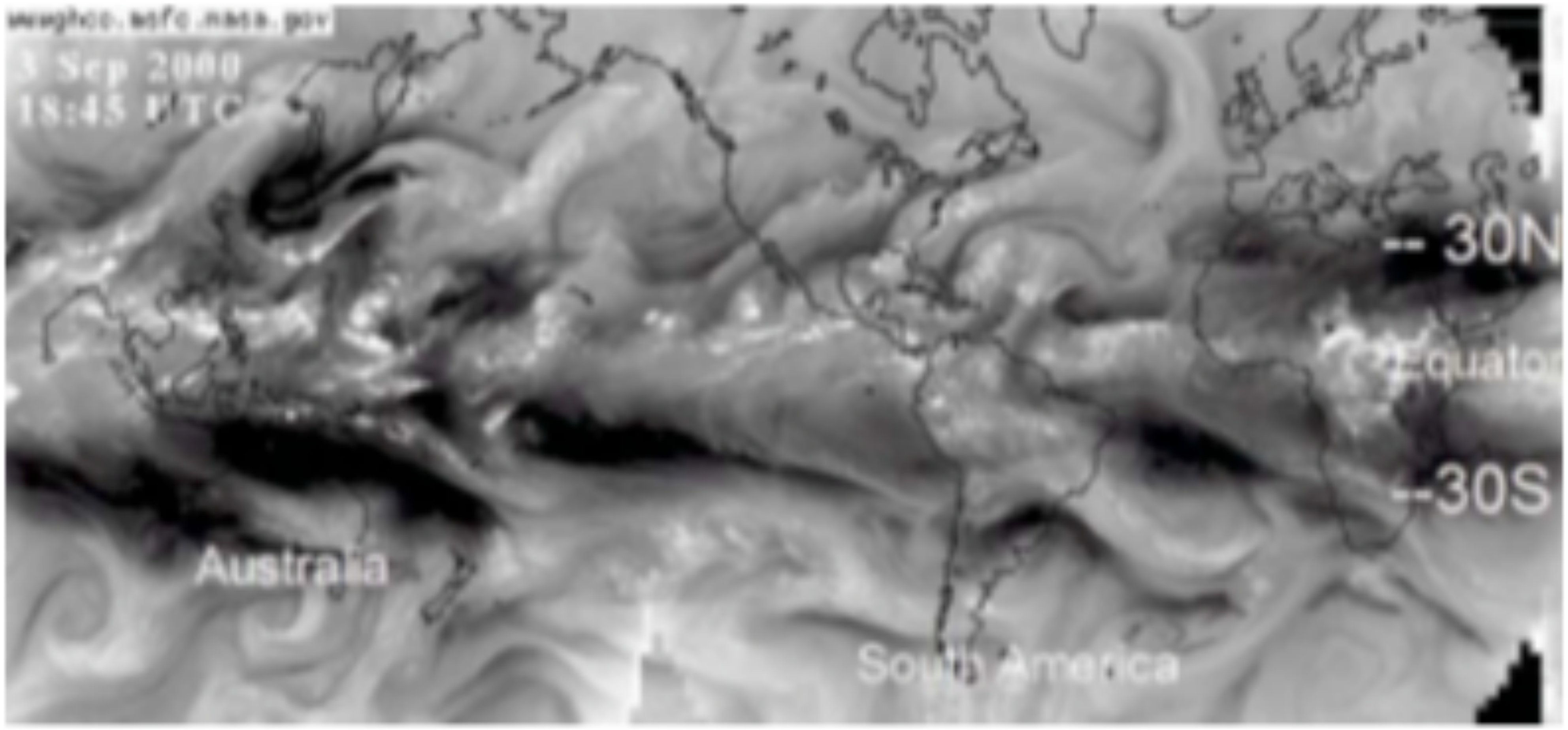


FIGURE 3. A mosaic of satellite images showing the water vapor distribution over the globe at a height of 6–10 km above the surface. We see the organization of H_2O by the circulation; dry (sinking) areas in the subtropics ($\pm 30°$) are dark, moist (upwelling) regions of the equatorial band are bright. Jet streams of the middle latitudes appear as elongated dark regions with adjacent clouds and bright regions. From NASA.

Fluid dynamics on earth

- Rotation does not always matter.
- Timescale of rotation: τ
- Timescale of the fluid: $\frac{L}{U}$

$$Ro = \tau \times \frac{U}{L}$$

Fluid dynamics on earth

$Ro >> 1$: **The fluid is faster than rotation.**

$Ro << 1$: **Rotation is faster than fluid.**

$$Ro = \tau \times \frac{U}{L}$$

Fluid dynamics on earth

Atmosphere :

$$\tau \sim 1 \text{ day} \approx 10^5 \text{ s}$$

$$U \sim 10 \text{ m s}^{-1}$$

$$L \sim 5000 \text{ km}$$

- Roatmos = 0.2

Ocean :

$$\tau \sim 1 \text{ day} \approx 10^5 \text{ s}$$

$$U \sim 0.1 \text{ m s}^{-1}$$

$$L \sim 1000 \text{ km}$$

- Roocean = 0.01

Rotation is important in determining the fluid motion on earth!

Atmosphere

- About 80% of the mass of the atmosphere in 10km
- Very thin : 10km << 6400km
- N_2, O_2 => strongly combined
- H_2O, CO_2, O_3(tri atomic molecules) => absorb radiation well
- Dry air(~29g/mol) > water vapor(18g/mol)

TABLE 1.2. The most important atmospheric constituents. The chlorofluorocarbons (CFCs) CCl_2F_2 and CCl_3F are also known as CFC-12 and CFC-11, respectively. [N.B. (ppm, ppb, ppt) = parts per (million, billion, trillion)] The concentrations of some constituents are increasing systematically because of human activity. For example, the CO_2 concentration of 380 ppm was measured in 2004 (see Fig. 1.3); CFCs are now decreasing in concentration following restrictions on their production.

Chemical species	Molecular weight (g mol^{-1})	Proportion by volume	Chemical species	Molecular weight	Proportion by volume
N_2	28.01	78%	O_3	48.00	~500 ppb
O_2	32.00	21%	N_2O	44.01	310 ppb
Ar	39.95	0.93%	CO	28.01	120 ppb
H_2O (vapor)	18.02	~0.5%	NH_3	17.03	~100 ppb
CO_2	44.01	380 ppm	NO_2	46.00	~1 ppb
Ne	20.18	19 ppm	CCl_2F_2	120.91	480 ppt
He	4.00	5.2 ppm	CCl_3F	137.37	280 ppt
CH_4	16.04	1.7 ppm	SO_2	64.06	~200 ppt
Kr	83.8	1.1 ppm	H_2S	34.08	~200 ppt
H_2	2.02	~500 ppb	AIR	28.97	

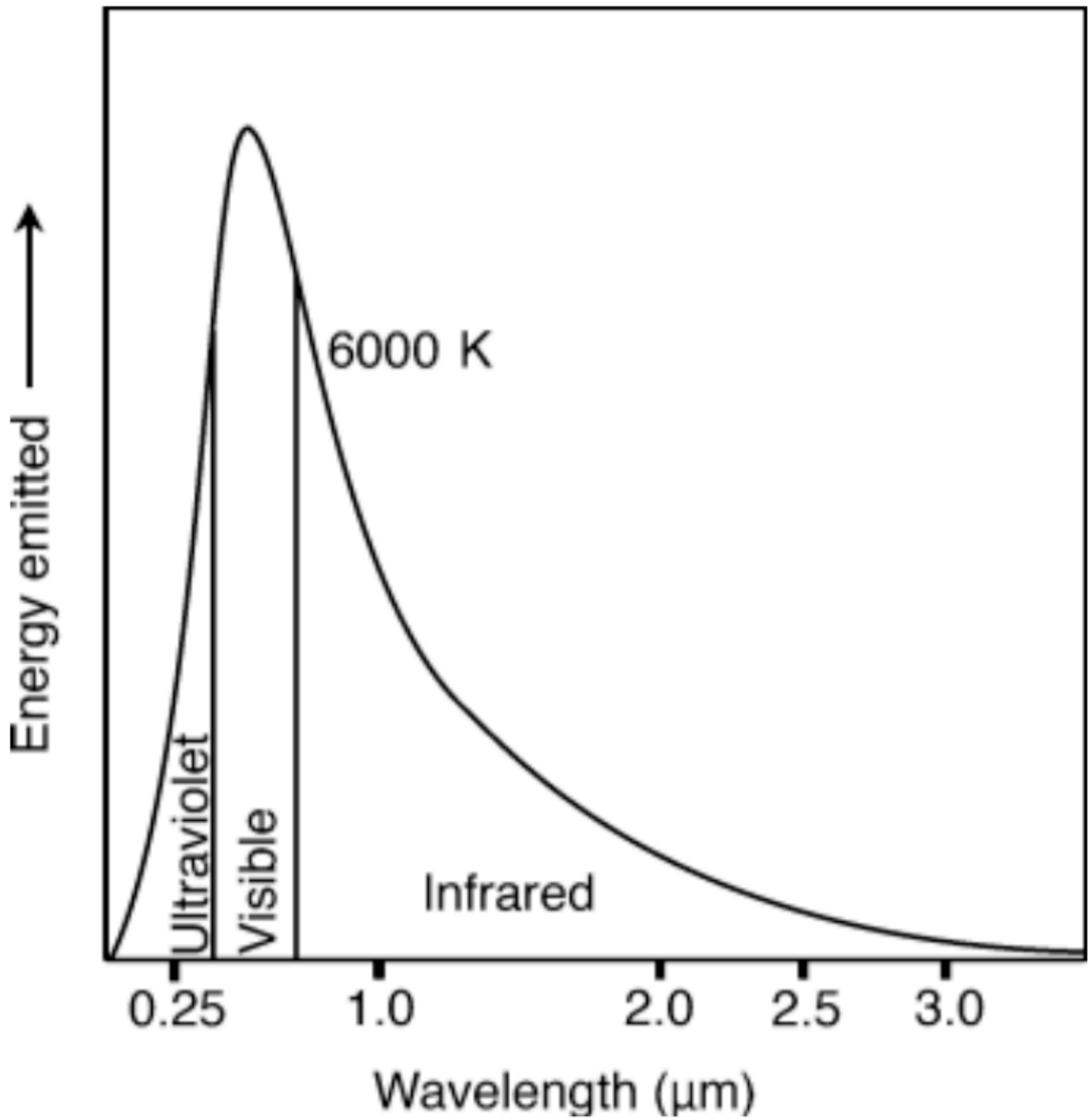
Planetary emission temperature

- Black Body
- Plank’s Law
- Stefan-Boltzman Law
- Wien’s displacement Law
- Planetary emission temperature

Black Body

- BlackBody is an idealized physical body that absorbs all incident electronomagnetic radiaiton
- a = e = 1

Plank’s Law



- The black body having a specific temperature emits light with arbitrary wavelength at a certain radiation intensity

2.3.4 Stefan-Boltzman Law

- Radiance(복사휘도) emitted from blackbody for all wavelengths,

$$B(T)=\int_0^\infty B_\lambda(T)d\lambda=\int_0^\infty \frac{2hc^2\lambda^{-5}}{e^{hc/k\lambda T}-1}d\lambda \quad \text{@ given T}$$

- let $x=\dfrac{hc}{k\lambda T}$

$$\begin{cases} \lambda=\dfrac{hc}{xkT} \\ dx=\dfrac{-hckT}{(k\lambda T)^2}d\lambda \end{cases} \longrightarrow d\lambda=\frac{-(k\lambda T)^2}{hckT}dx=-\frac{-hc}{x^2kT}dx$$

$$B(T)=2\frac{k^5T^4}{h^4c^3}\left(-\frac{hc}{kT}\right)\int_\infty^0\frac{x^3}{e^x-1}dx$$

$$=\frac{2k^4T^4}{h^3c^2}\underbrace{\int_0^\infty\frac{x^3}{e^x-1}dx}_{\pi^4/15}$$

$$=\underbrace{\frac{2\pi^4k^4}{15h^3c^2}}_{b}T^4$$

- Wien's displacement law

$$\lambda_m T = constant$$

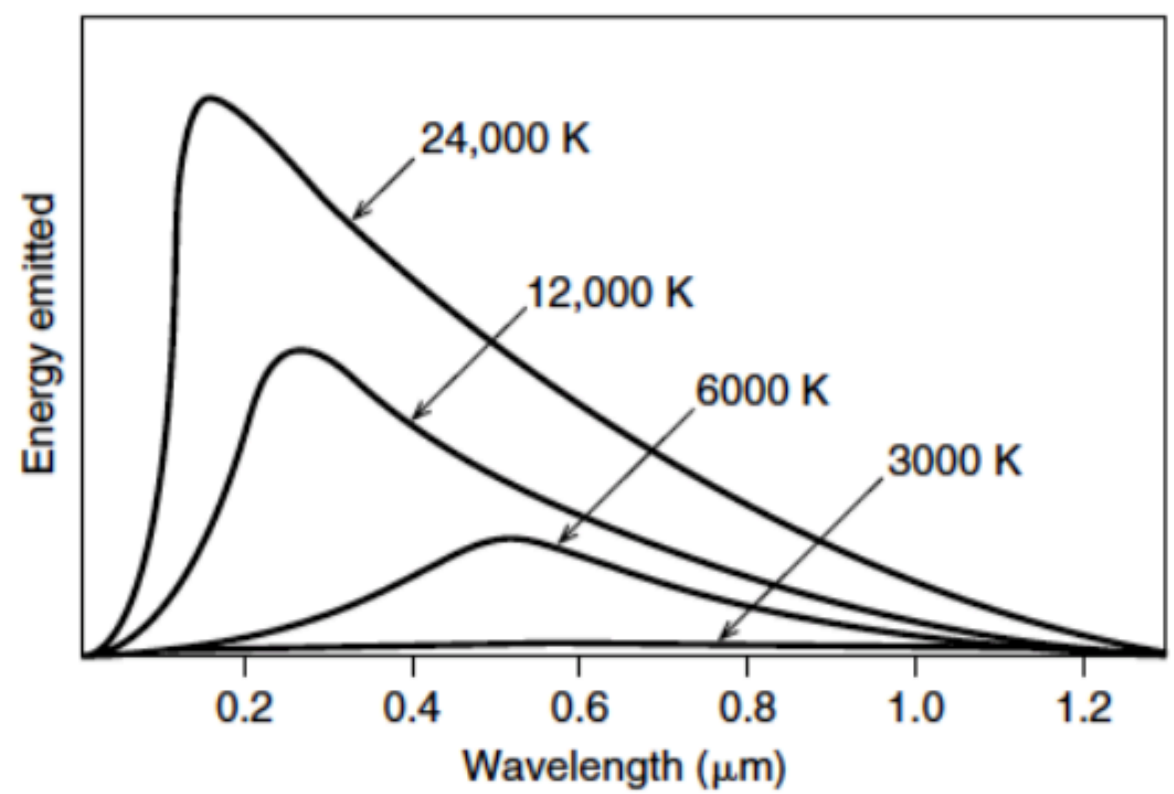
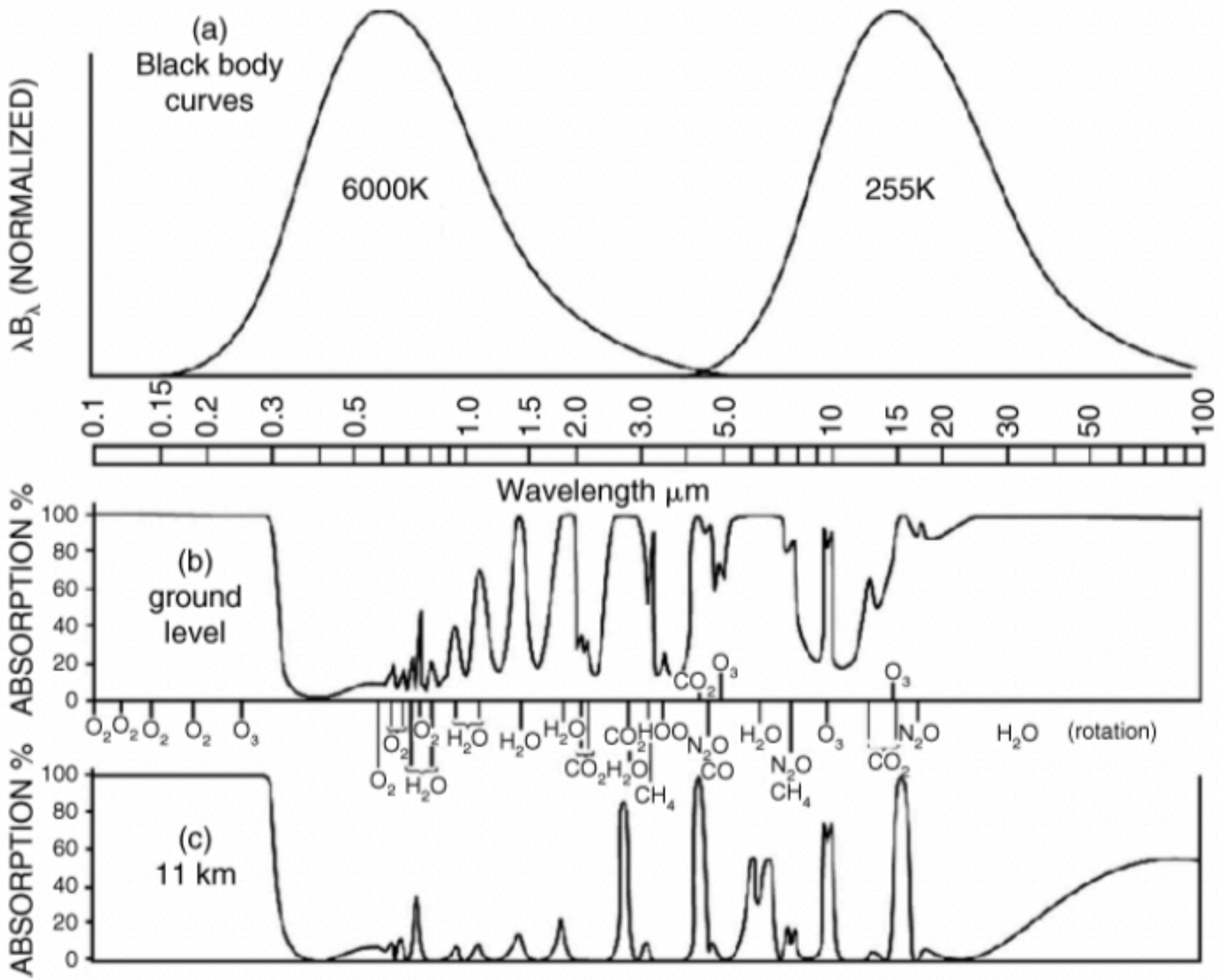
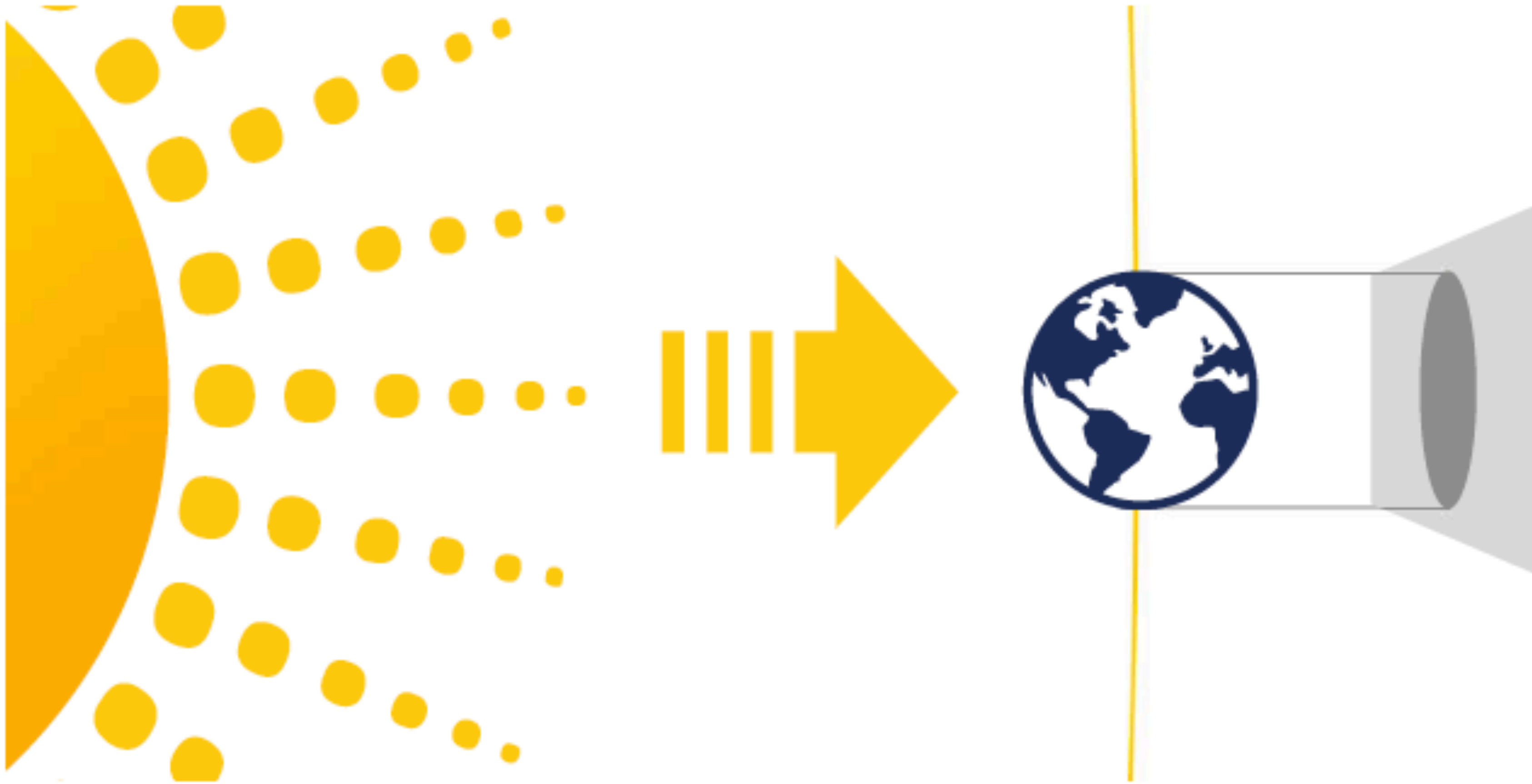
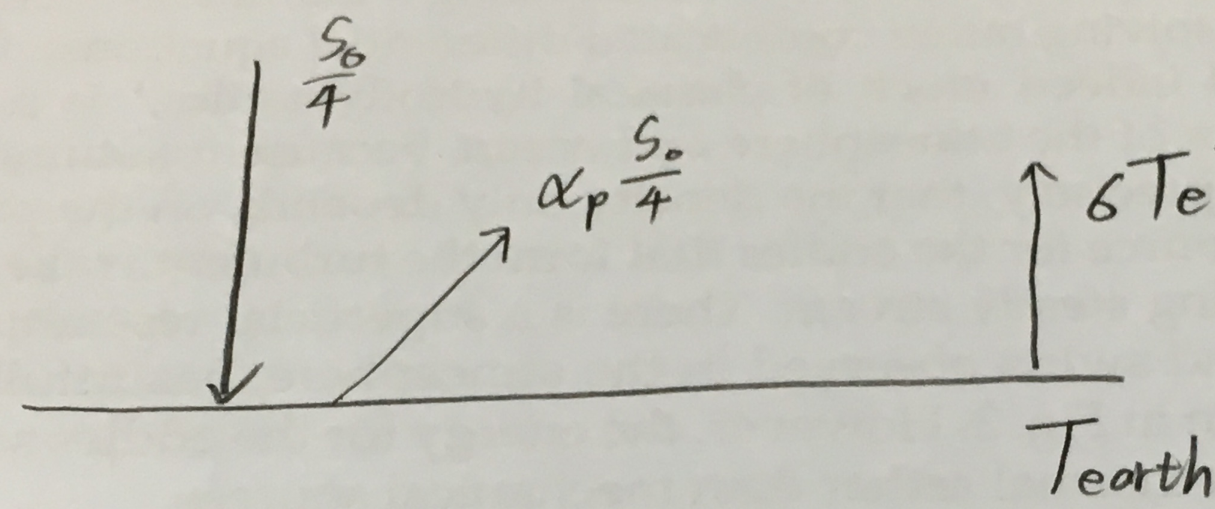


FIGURE 2.3. The energy emitted at different wavelengths for blackbodies at several temperatures. The function $B_\lambda(T)$, Eq. A-1, is plotted.


(a)
Black body curves
λB_λ (NORMALIZED)
6000K
255K
0.1 0.15 0.2 0.3 0.5 1.0 1.5 2.0 3.0 5.0 10 15 20 30 50 100
Wavelength μm
ABSORPTION %
(b)
ground level
O2 O2 O2 O2 O3
H2O (rotation)
(c)
11 km
0 20 40 60 80 100



$$\text{average solar energy flux} = \frac{\text{intercepted incoming radiation}}{\text{Earth's surface area}} = \frac{S_0 \pi a^2}{4\pi a^2} = \frac{S_0}{4}.$$



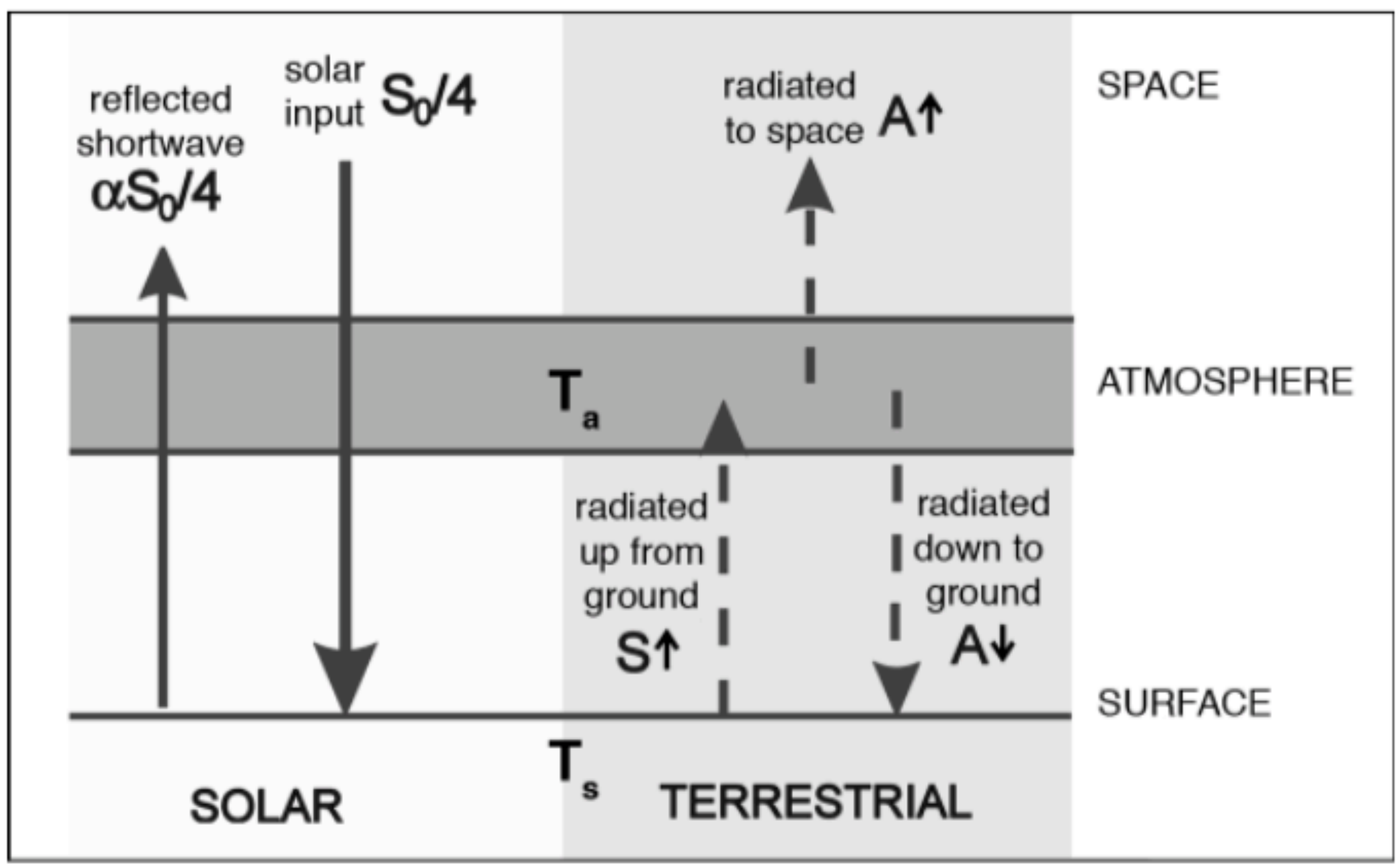
$$E_{in} = E_{out}$$

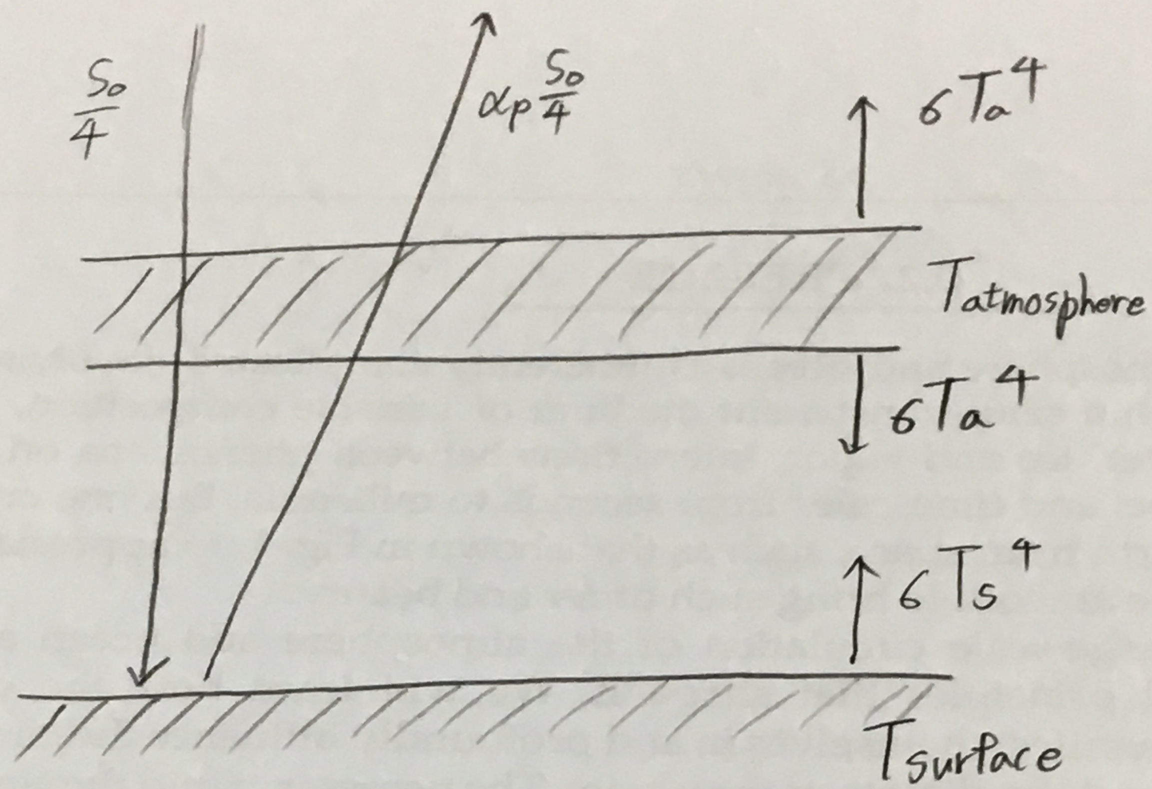
$$(1-\alpha_p)\frac{S_0}{4} = \sigma T_e^4$$

$$T_e = \left[\frac{(1-\alpha_p)S_0}{4\sigma}\right]^{1/4} \simeq 255K$$

3. The greenhouse effect: a. An opaque model

- Assumption
  - Completely transparent to shortwave solar radiation
  - Completely opaque to outgoing longwave radiation





$$E_{in} = E_{out}$$

$$\underbrace{(1-\alpha_p)\frac{S_0}{4}}_{= \sigma T_a^4} + \sigma T_a^4 = \sigma T_s^4$$

$$2\sigma T_a^4 = \sigma T_s^4$$

$$T_s = 2^{1/4} T_a \approx 1.19 \times 255\text{K} \approx 303\text{K}$$

TABLE 2.1. Properties of some of the planets. S_0 is the solar constant at a distance r from the Sun, α_p is the planetary albedo, T_e is the emission temperature computed from Eq. 2-4, T_m is the measured emission temperature, and T_s is the global mean surface temperature. The rotation period, τ, is given in Earth days.

	r 10^9 m	S_0 W m^{-2}	α_p	T_e K	T_m K	T_s K	τ Earth days
Venus	108	2632	0.77	227	230	760	243
Earth	150	1367	0.30	255	250	288	1.00
Mars	228	589	0.24	211	220	230	1.03
Jupiter	780	51	0.51	103	130	134	0.41

제 1 문. 다음 표는 세 행성의 태양상수, 행성알베도, 실제 평균지표면온도를 나타낸다. 물음에 답하시오. (총 25점)

	태양상수(Wm^{-2})	행성알베도	평균지표면온도(K)
금성	2,620	0.71	750
지구	1,372	0.30	288
화성	593	0.17	220

1) 행성에 입사하는 태양 복사 에너지와 행성이 방출하는 복사 에너지가 균형을 이루는 평형상태에 있다고 가정할 때, 행성이 가지는 상당흑체온도(equivalent blackbody temperature)를 각각 구하시오. (단, 스테판-볼쯔만 상수는 $5.67 \times 10^{-8}\ \mathrm{W\,m^{-2}K^{-4}}$이다) (10점)

2) 위 표와 1)의 결과를 이용하여 각 행성에서의 온실효과(greenhouse effect)를 계산하시오. (5점)

3) 세 행성 간 온실효과의 차이에 대해 주요 온실기체를 고려하여 설명하시오. (10점)

Thank You

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