

# ATM 2106 TA Lecture

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  - B.S Department of Atmospheric Sciences, Yonsei University, Seoul, Korea
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  - 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.  
(Himawari-8(MTSAT-3))

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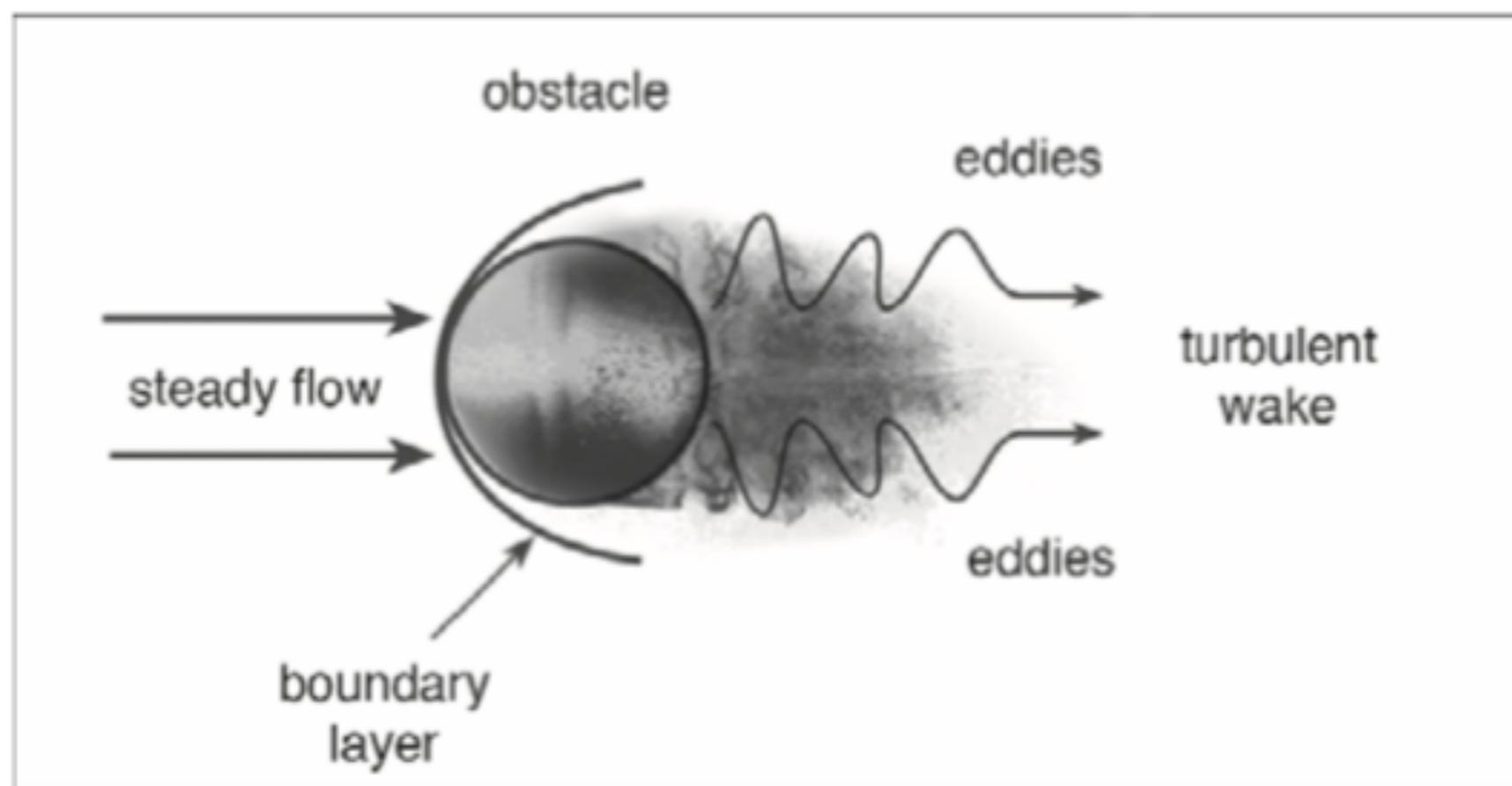
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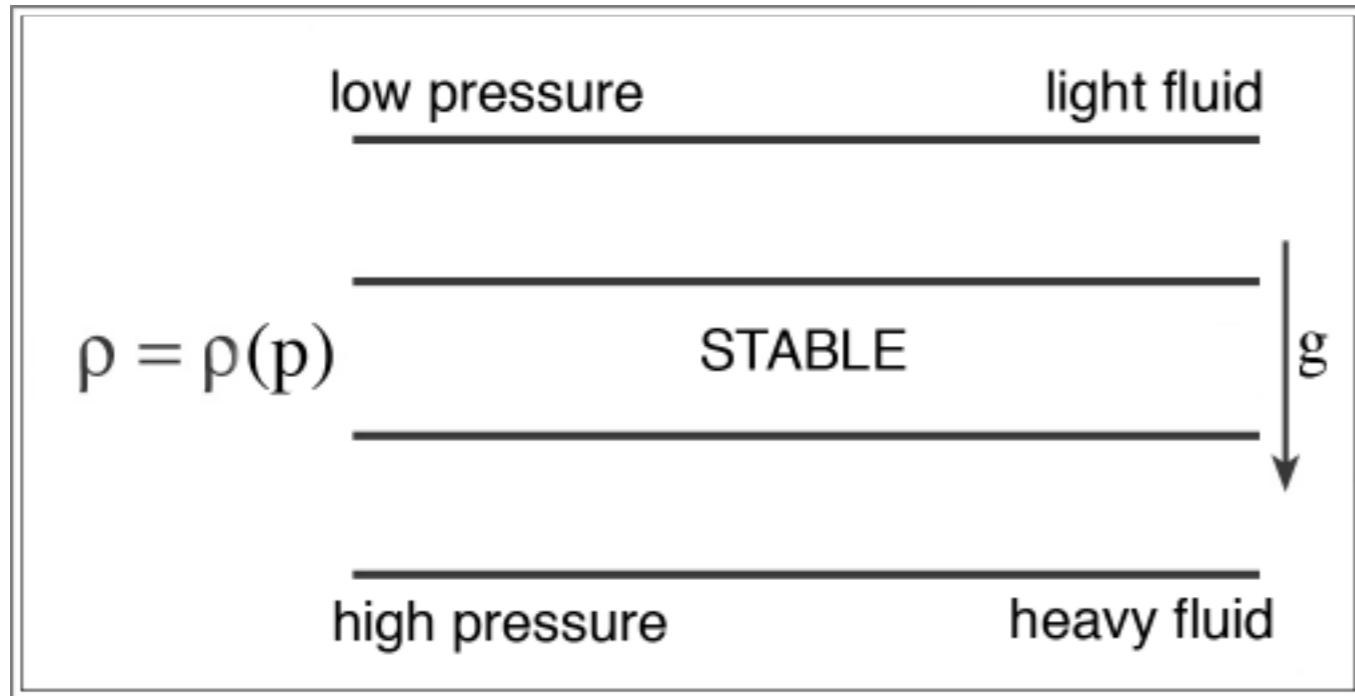
- 0 1      Fluid dynamics
- 0 2      Characteristics of the atmosphere
- 0 3      The global energy balance

## Fluid dynamics

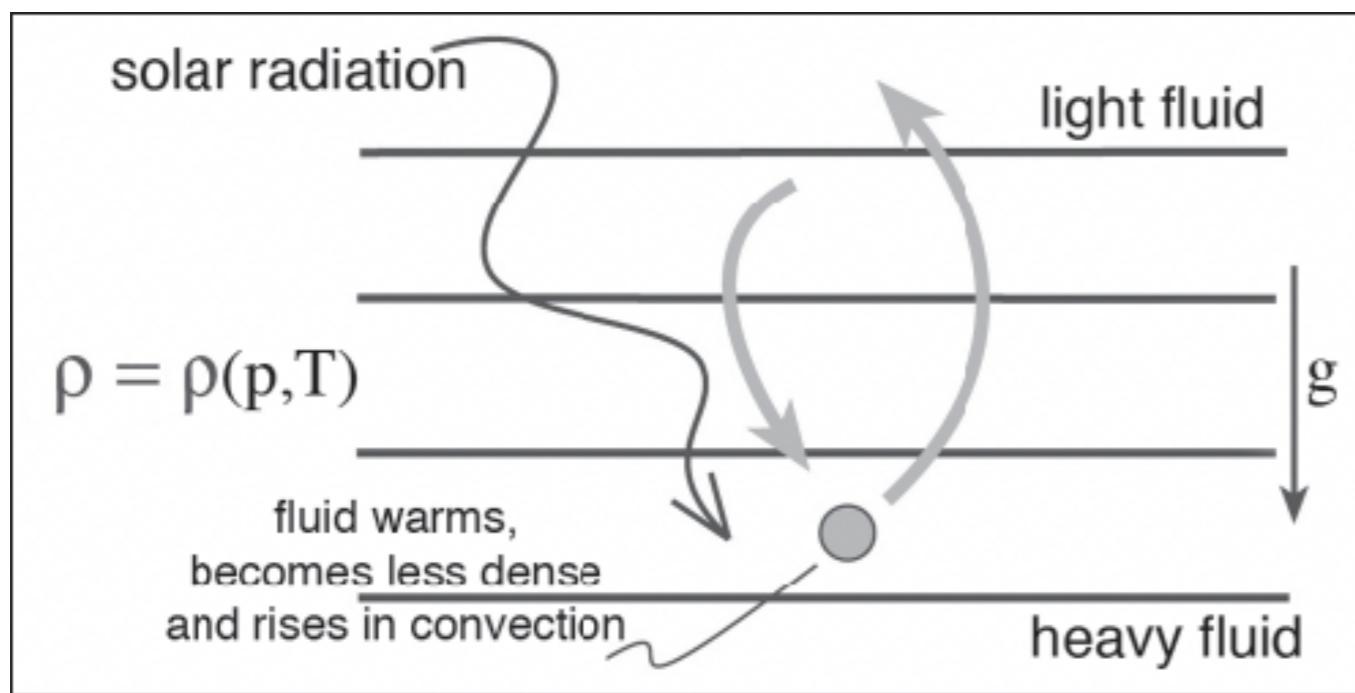
- Fluid dynamics is commonly studied in engineering.
- Atmosphere, Ocean has different compressibility.
- In geophysical fluid dynamics, we consider rotation effect



# 01 Fluid dynamics

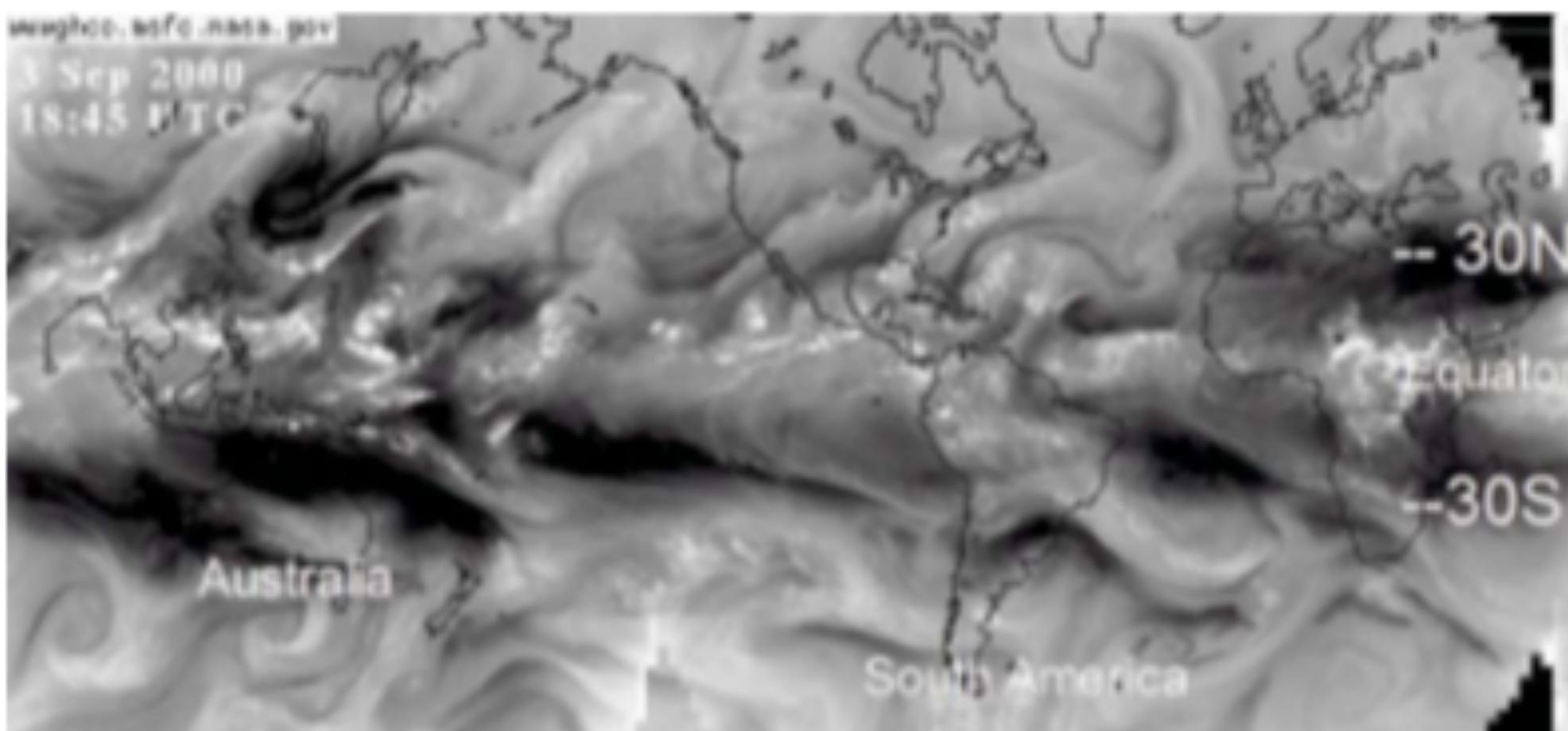


- Barotropic Atmosphere
- if  $\rho$  does not depend on  $T$ ,
- the fluid can't be brought in to motion by heating/cooling



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

# 01 Fluid dynamics



**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<sub>2</sub>O by the circulation; dry (sinking) areas in the subtropics ( $\pm 30^\circ$ ) 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

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

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

## Fluid dynamics on earth

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$Ro \gg 1$  : The fluid is faster than rotation.

$Ro \ll 1$  : Rotation is faster than fluid.

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

## Fluid dynamics on earth

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**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 :  $10\text{km} \ll 6400\text{km}$
- $\text{N}_2, \text{O}_2 \Rightarrow$  strongly combined
- $\text{H}_2\text{O}, \text{CO}_2, \text{O}_3$ (tri atomic molecules)  $\Rightarrow$  absorb radiation well
- Dry air( $\sim 29\text{g/mol}$ ) > water vapor( $18\text{g/mol}$ )

## 02 Characteristics of the atmosphere

**TABLE 1.2.** The most important atmospheric constituents. The chlorofluorocarbons (CFCs)  $\text{CCl}_2\text{F}_2$  and  $\text{CCl}_3\text{F}$  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  $\text{CO}_2$  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 ( $\text{g mol}^{-1}$ )	Proportion by volume	Chemical species	Molecular weight	Proportion by volume
$\text{N}_2$	28.01	78%	$\text{O}_3$	48.00	~500 ppb
$\text{O}_2$	32.00	21%	$\text{N}_2\text{O}$	44.01	310 ppb
Ar	39.95	0.93%	CO	28.01	120 ppb
$\text{H}_2\text{O}$ (vapor)	18.02	~0.5%	$\text{NH}_3$	17.03	~100 ppb
$\text{CO}_2$	44.01	380 ppm	$\text{NO}_2$	46.00	~1 ppb
Ne	20.18	19 ppm	$\text{CCl}_2\text{F}_2$	120.91	480 ppt
He	4.00	5.2 ppm	$\text{CCl}_3\text{F}$	137.37	280 ppt
$\text{CH}_4$	16.04	1.7 ppm	$\text{SO}_2$	64.06	~200 ppt
Kr	83.8	1.1 ppm	$\text{H}_2\text{S}$	34.08	~200 ppt
$\text{H}_2$	2.02	~500 ppb	AIR	28.97	

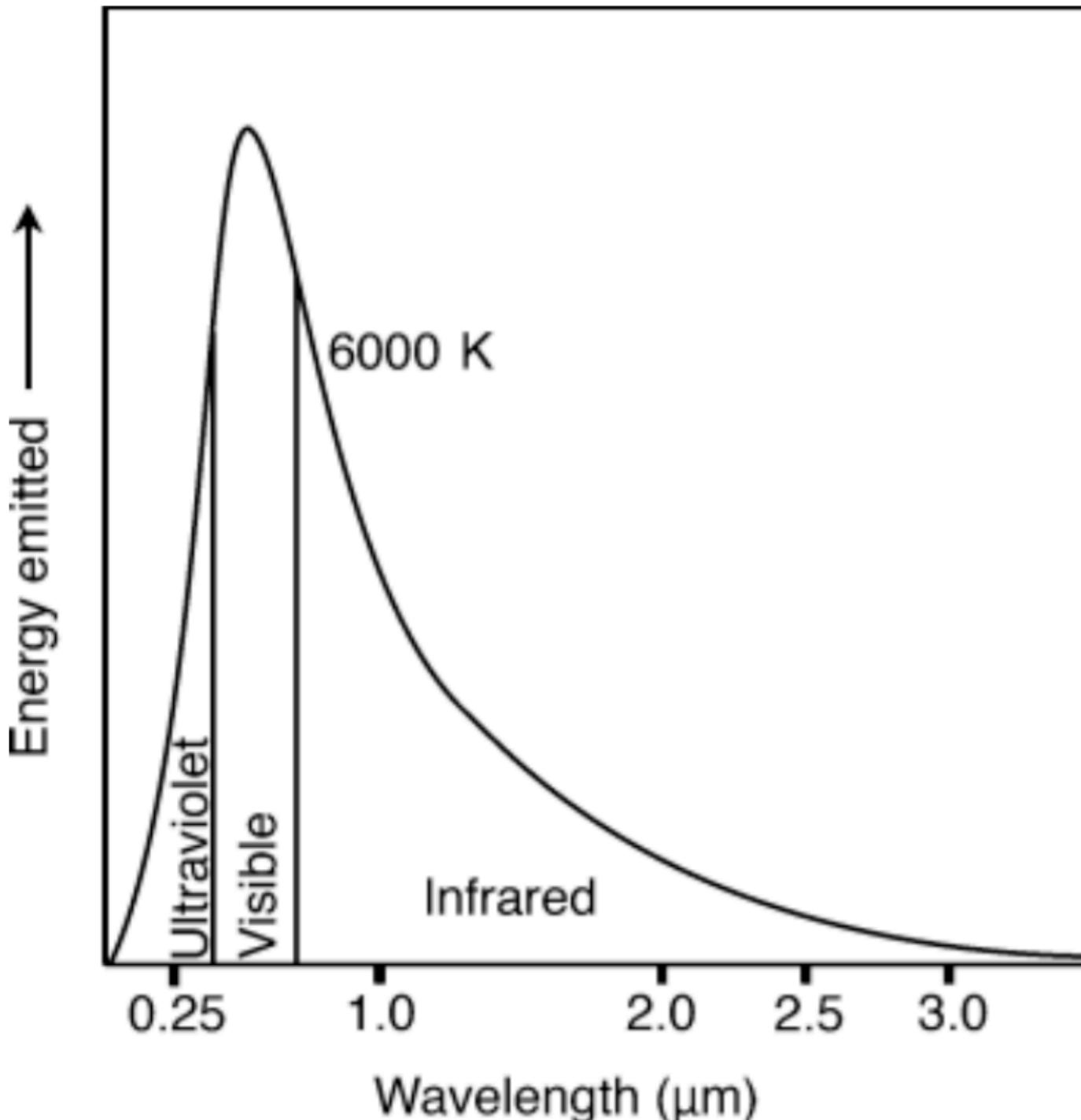
## Planetary emission temperature

- Black Body
- Plank's Law
- Stefan-Boltzman Law
- Wien's displacement Law
- The greenhouse effect

### Black Body

- BlackBody is an idealized physical body that absorbs all incident electromagnetic radiation
- $a = e = 1$

# 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  $x = \frac{hc}{k\lambda T}$

$$\left\{ \begin{array}{l} \lambda = \frac{hc}{xkT} \\ dx = \frac{-hckT}{(k\lambda T)^2} d\lambda \end{array} \right. \longrightarrow d\lambda = \frac{-(k\lambda T)^2}{hckT} dx = -\frac{-hc}{x^2 kT} dx$$

$$B(T) = 2 \frac{k^5 T^4}{h^4 c^3} \left( -\frac{hc}{kT} \right) \int_0^{\infty} \frac{x^3}{e^x - 1} dx$$

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

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

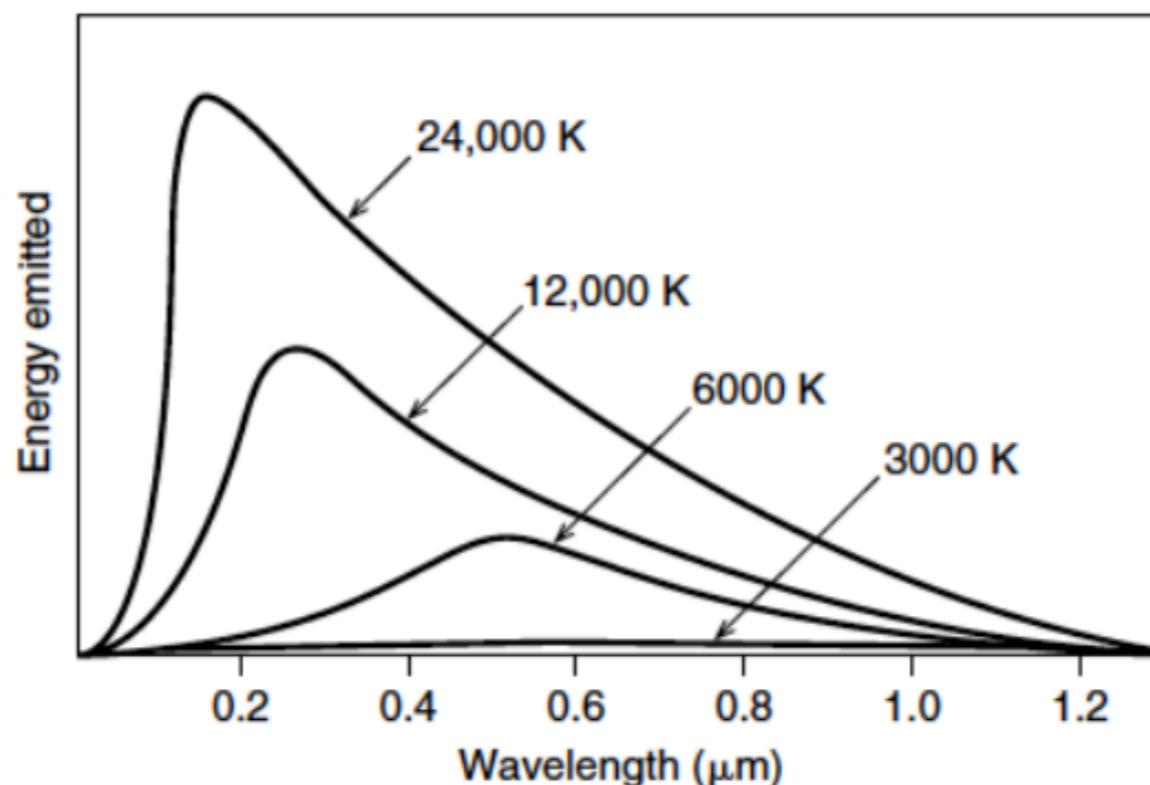
*b*

*π⁴/15*

## 03 The global energy balance

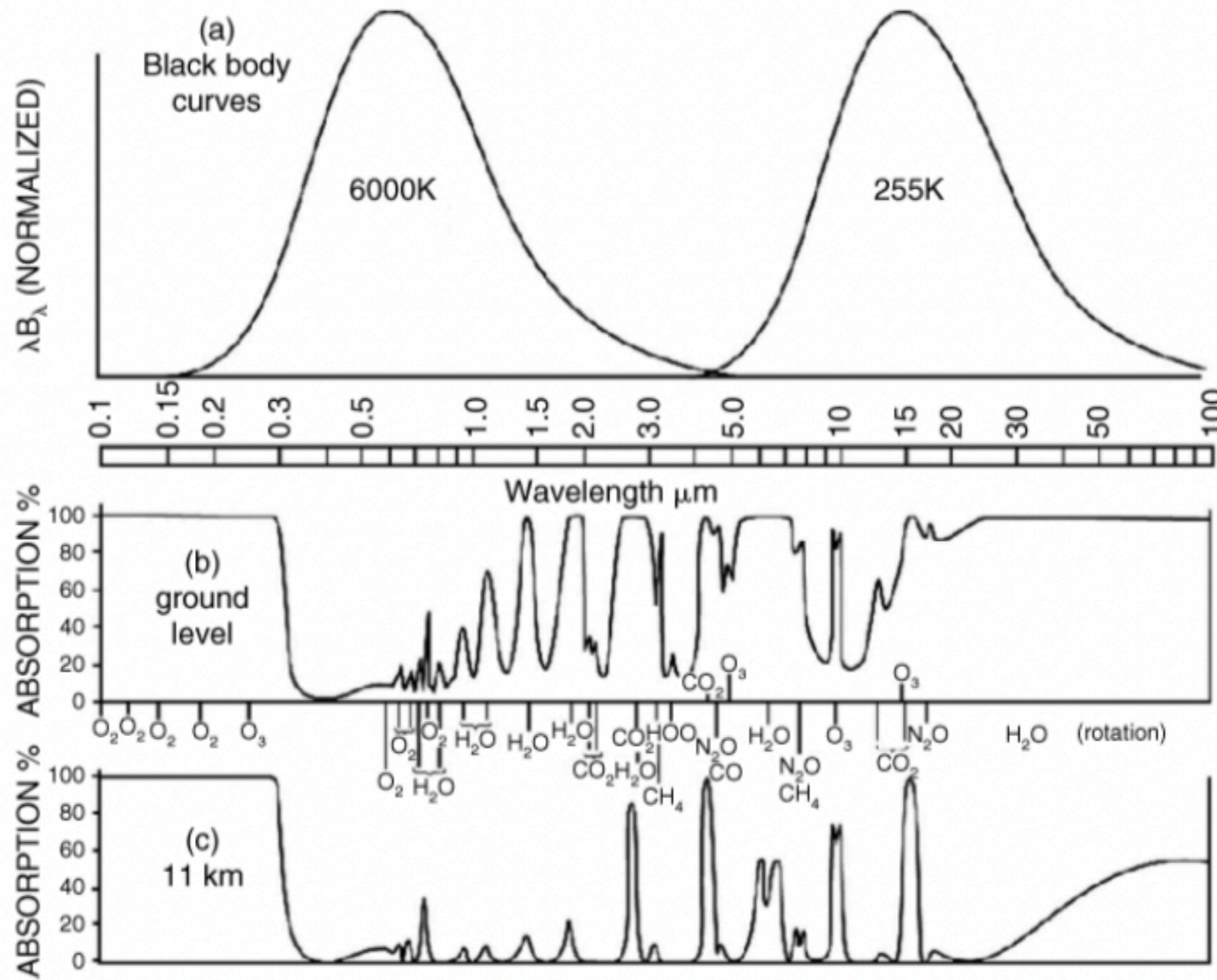
- Wien's displacement law

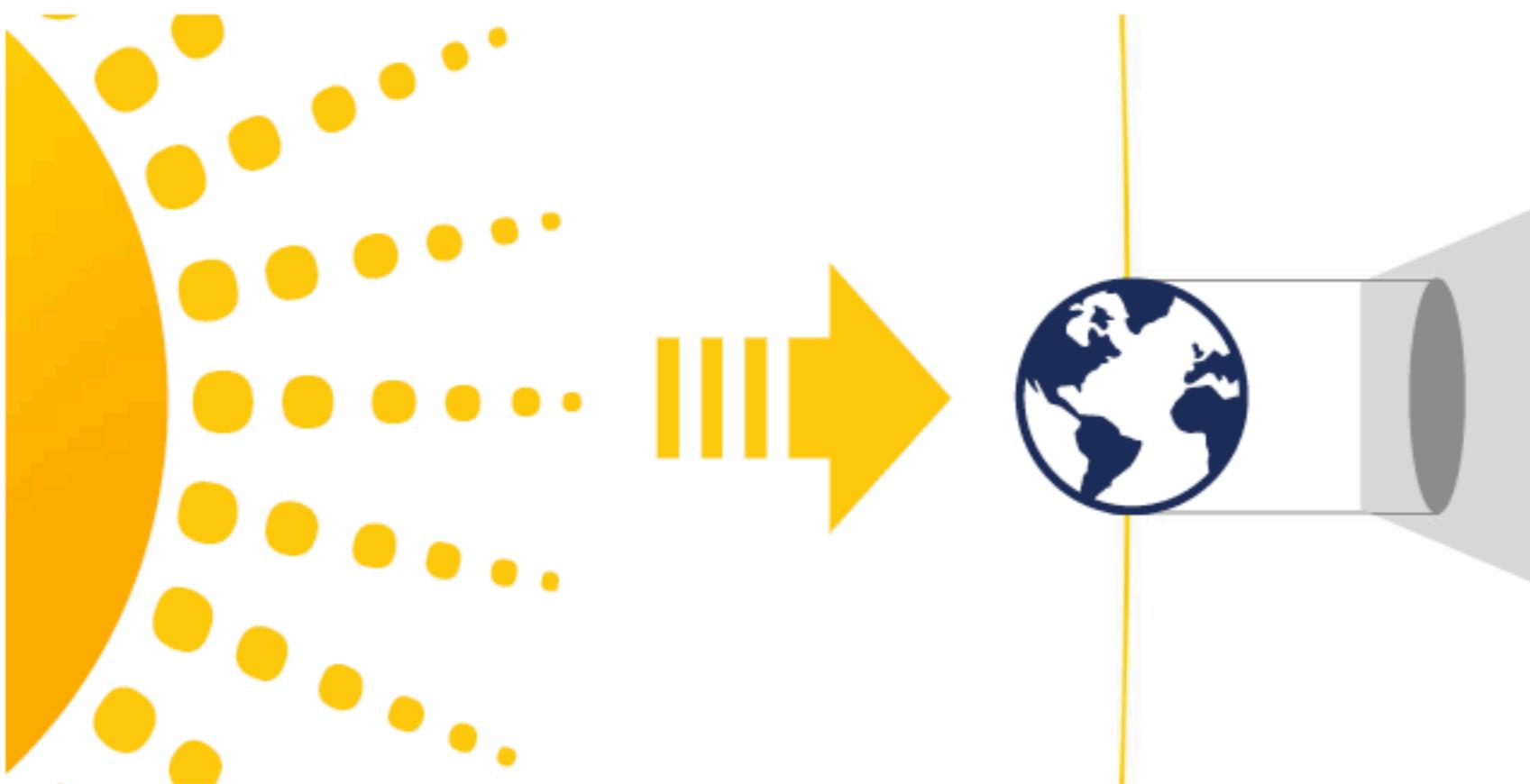
$$\lambda_m T = \text{constant}$$



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

## 03 The global energy balance



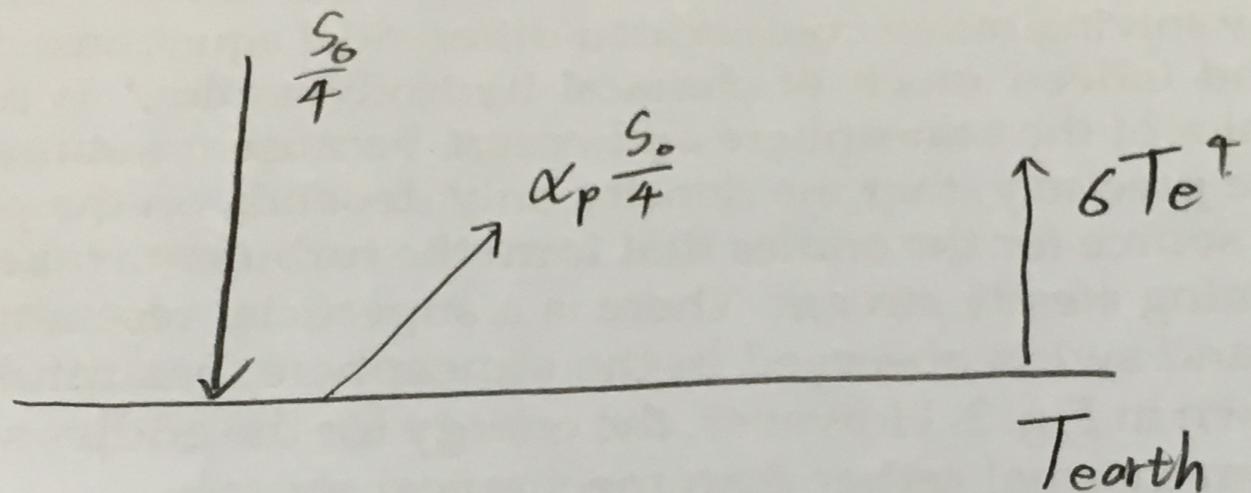


average solar energy flux

$$= \frac{\text{intercepted incoming radiation}}{\text{Earth's surface area}}$$

$$= \frac{S_0 \pi a^2}{4\pi a^2} = \frac{S_0}{4}.$$

## 03 The global energy balance



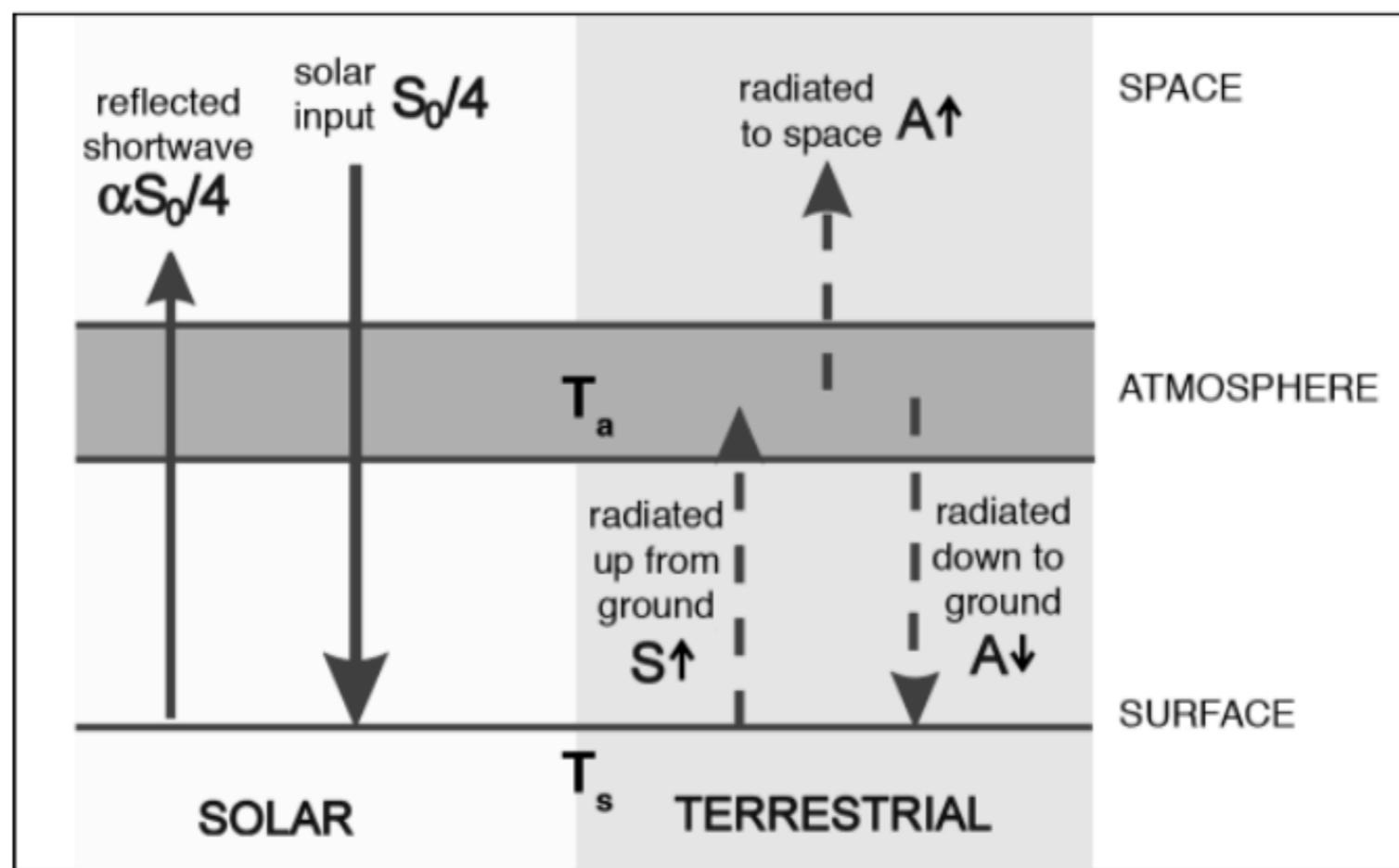
$$E_{\text{in}} = E_{\text{out}}$$

$$(1 - \alpha_p) \frac{S_0}{4} = 6T_e^4$$

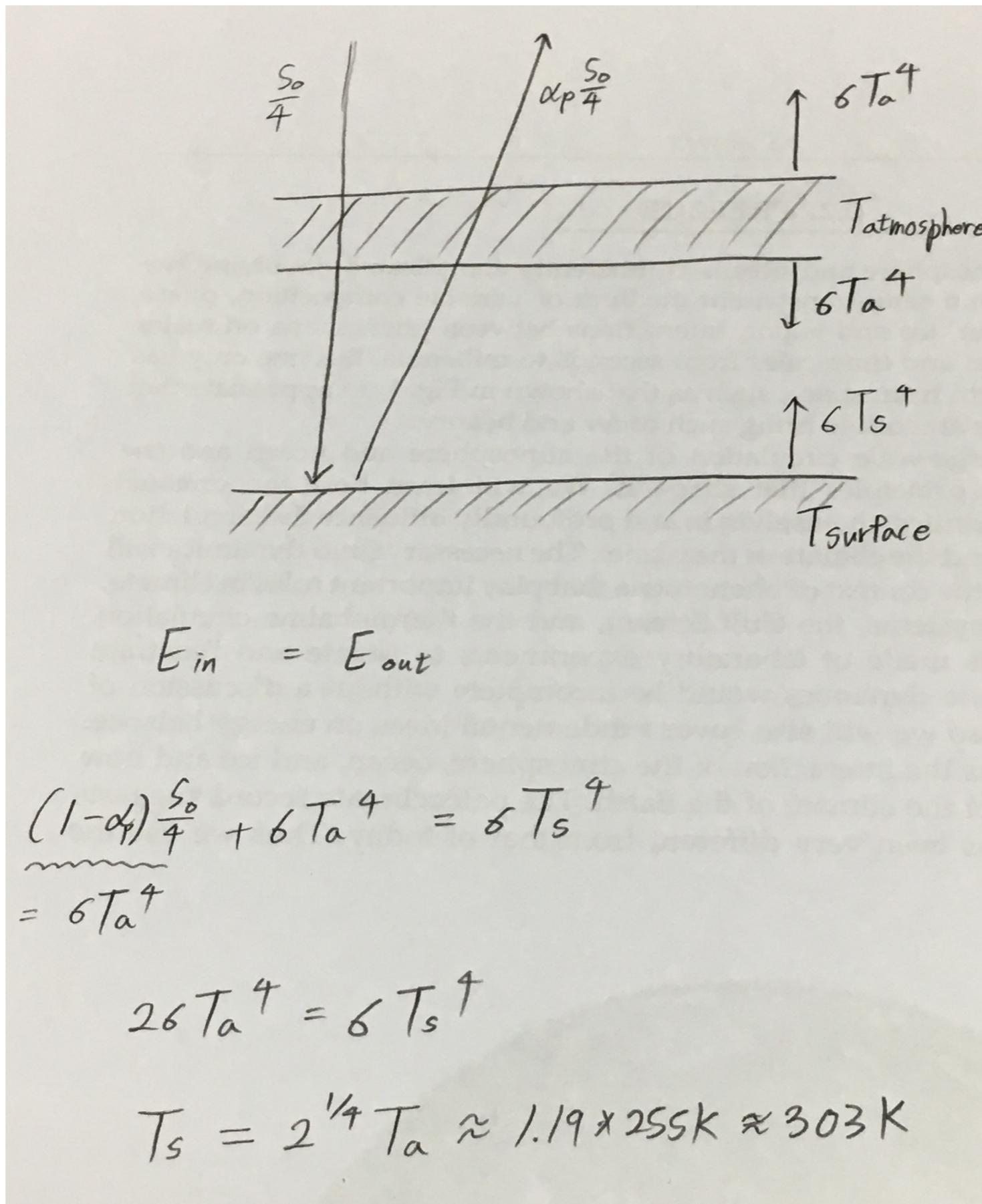
$$T_e = \left[ \frac{(1 - \alpha_p)S_0}{46} \right]^{1/4} \approx 255 \text{K}$$

### 3. The greenhouse effect: a. An opaque model

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



## 03 The global energy balance



## 03 The global energy balance

**TABLE 2.1.** Properties of some of the planets.  $S_0$  is the solar constant at a distance  $r$  from the Sun,  $\alpha_p$  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,  $\tau$ , is given in Earth days.

	$r$ $10^9$ m	$S_0$ $\text{W m}^{-2}$	$\alpha_p$	$T_e$ K	$T_m$ K	$T_s$ K	$\tau$ 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( $\text{Wm}^{-2}$ )	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-볼쓰만 상수는  $5.67 \times 10^{-8} \text{ W m}^{-2}\text{K}^{-4}$ 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)

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# Thank You

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