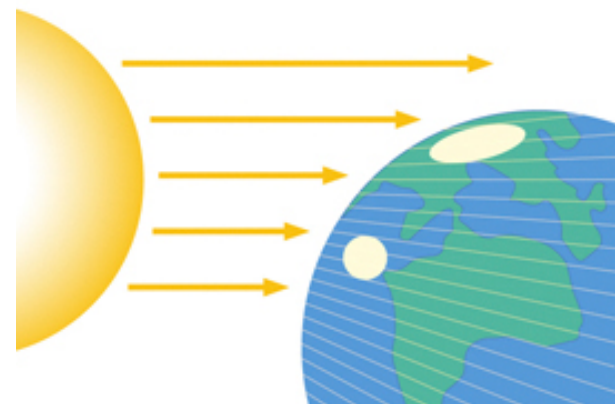




第二章:

大气环流的外部强迫



授课教师: 张洋

2022.9.22



第二章:

大气环流的外部强迫

Reference reading: PO Chapter 6.3

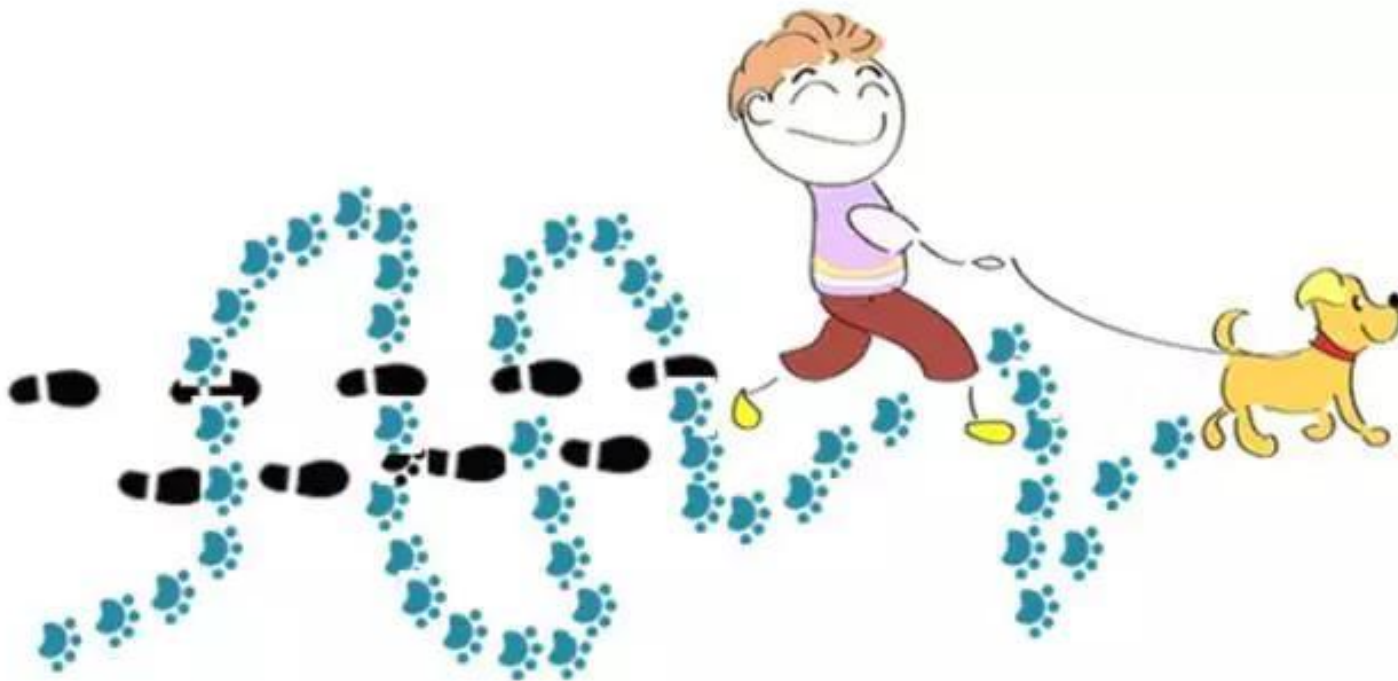
2022.9.22



大气环流的外部强迫



外部强迫与大气内部变率



选自谢尚平等

《揭开汛期降水变化的奥秘：厄尔尼诺回响曲》



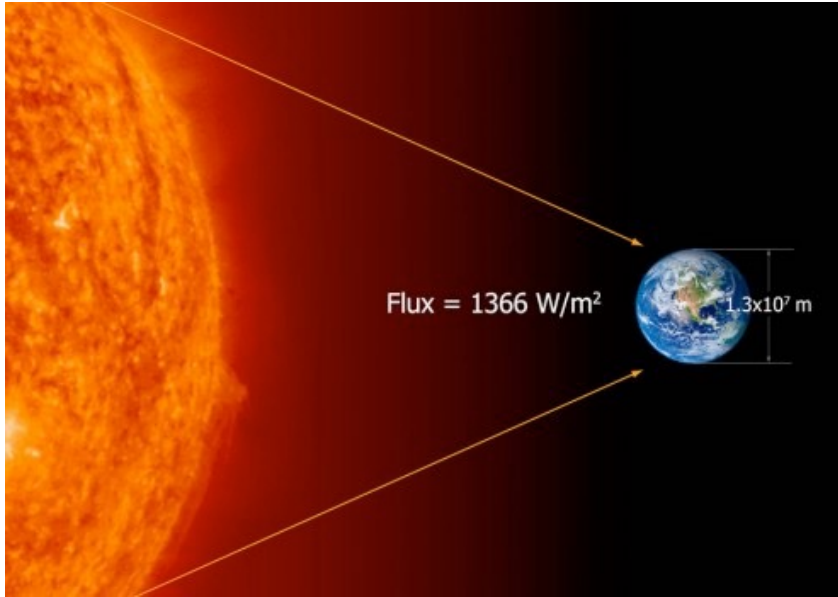
Outline



- Global averaged feature
 - TOA (Top of the atmosphere)
 - Surface
- Latitudinal distribution (zonal averaged feature)
 - TOA
 - Surface
- Zonal distribution
 - TOA
 - Surface



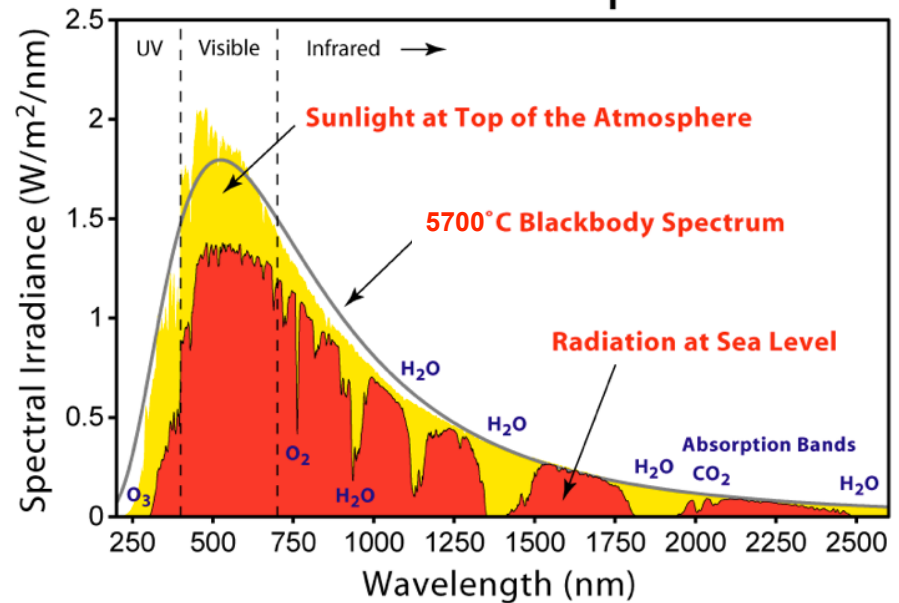
From the solar radiation...



S_0 -- solar constant (1360~1370 W/m^2),
太阳辐射通量

$$S = S_0 \left(\frac{\pi a^2}{4\pi a^2} \right) \approx 340 \text{ } Wm^{-2}, \text{ 辐射率}$$

Solar Radiation Spectrum



Effective emission temperature:

$$\sigma T_e^4 \equiv \frac{S_0}{4} (1 - a_p)$$

Earth: $T_e = 255K = -18^\circ C$ 实际大气: 288K

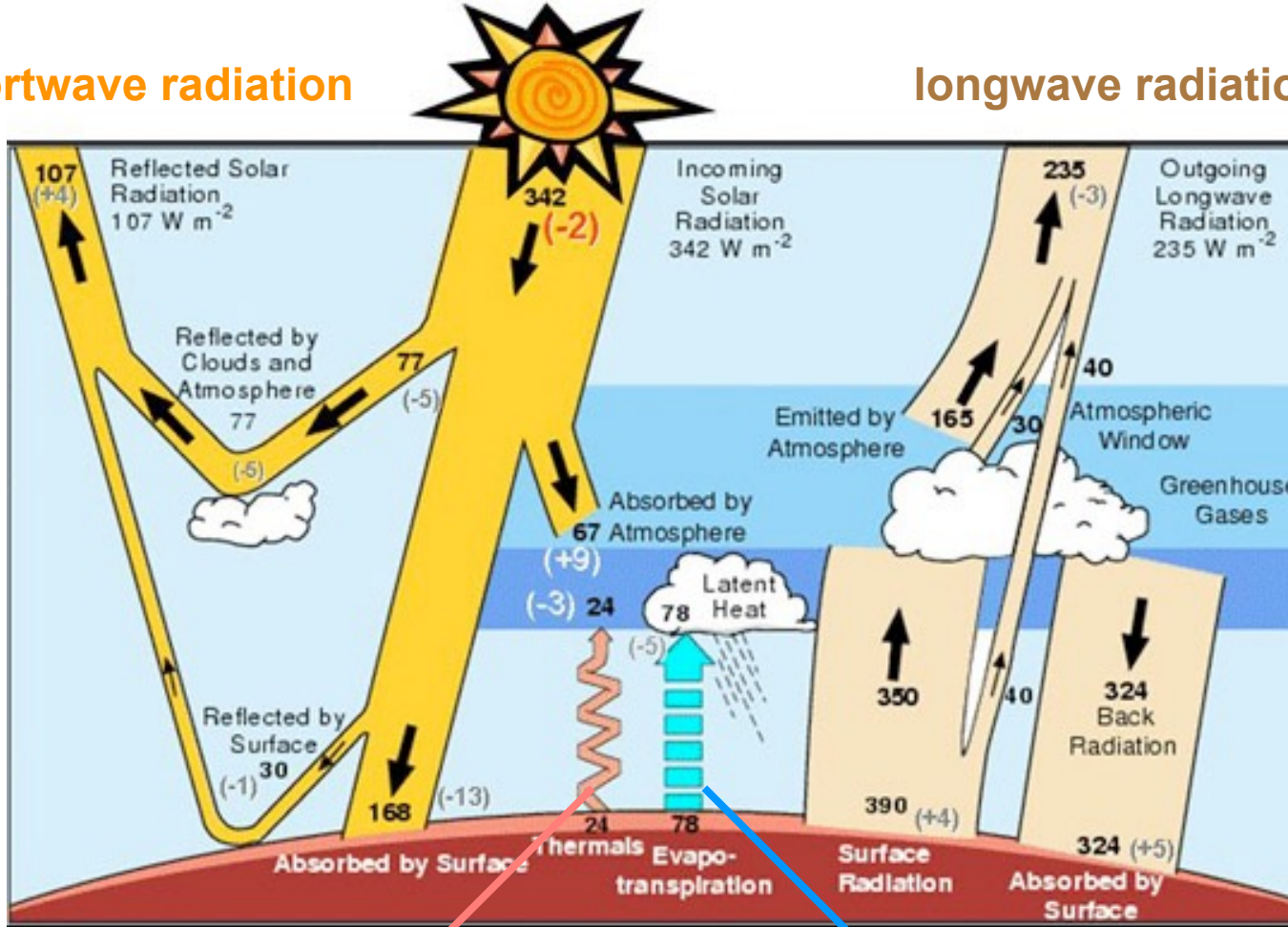


From the solar radiation...

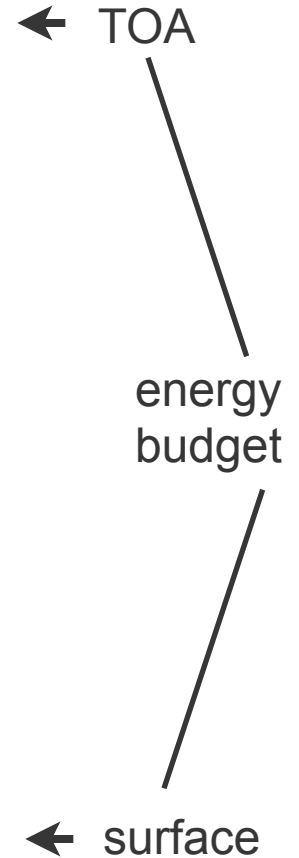


shortwave radiation

longwave radiation



sensible heat latent heat





From the solar radiation...

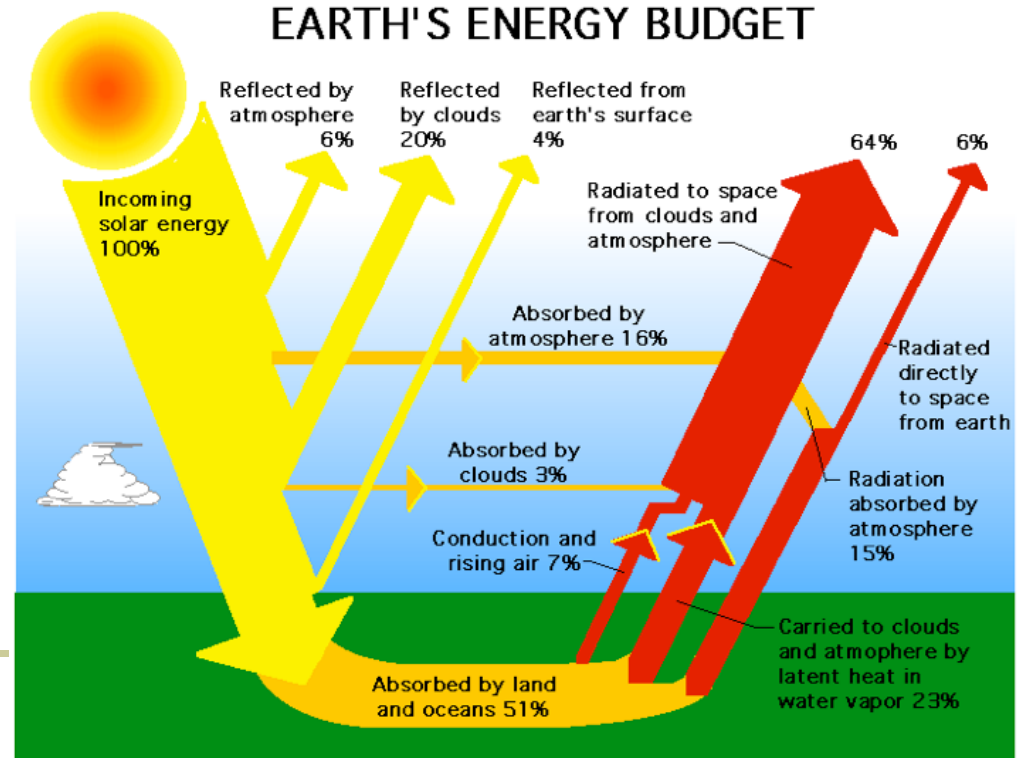
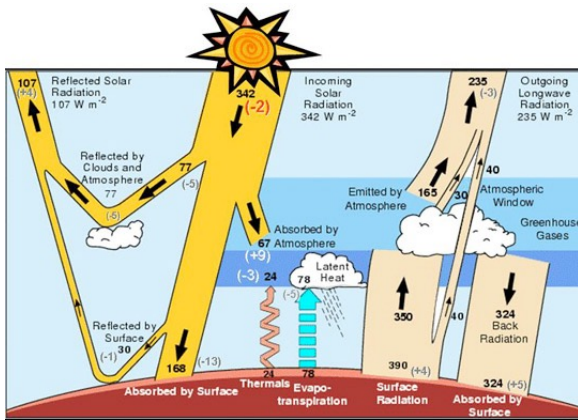


Incident solar radiation	340 W/m ²
Planetary albedo	0.3
Absorbed solar radiation	240 W/m ²
Outgoing longwave radiation (OLR)	240 W/m ²

SW ~ LW

$S(1 - \alpha)$ ← TOA

Table: globally and annually averaged TOA radiation budget





From the solar radiation...

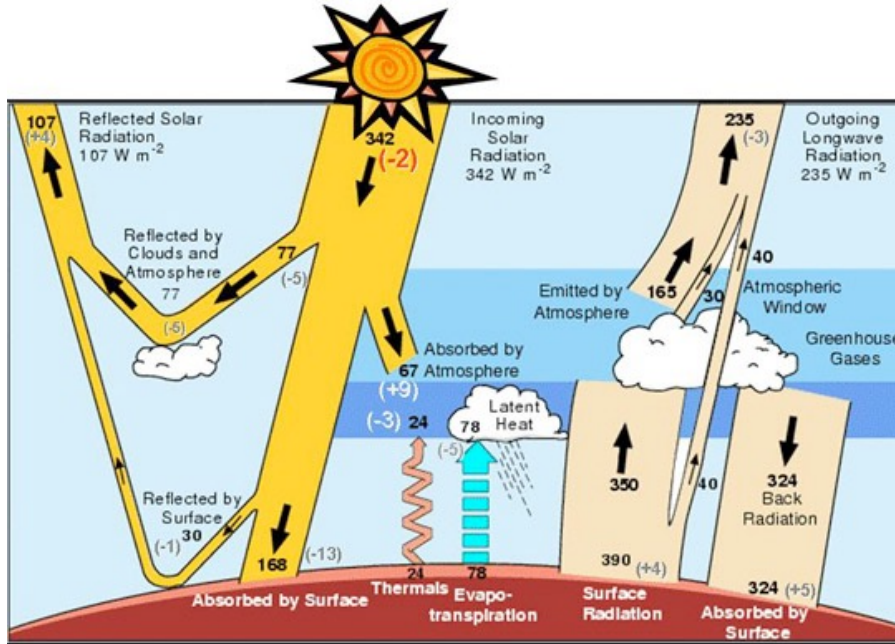


- Planetary albedo (TOA总反射辐射与总入射辐射的比值)
 - penetrate into the atmosphere, absorbed and scattered by:
 - atmospheric gases: H₂O, O₃, CO₂...
 - aerosols: direct injection, chemical reactions
 - clouds: albedo 30% thin stratus, 60-70% thick stratus
 - at the earth's surface -- surface albedo, strongly depends on the nature of the surface, vegetation cover, snow cover...

Sand	Grassland	Green crops	Forest	Dense Forest	Fresh snow	Old snow	Cities
18-28	16-20	15-25	14-20	5-10	75-95	40-60	14-18



From the solar radiation...



$$SW \sim LW$$

$$S(1 - \alpha)$$

← TOA

Absorbed solar (SW)	176 W m ⁻²
Downward infrared (LW↓)	312 W m ⁻²
Upward infrared (LW↑)	-385 W m ⁻²
Net longwave (LW)	-73 W m ⁻²
Net radiation (SW + LW)	103 W m ⁻²
Latent heat (LH)	-79 W m ⁻²
Sensible heat (SH)	-24 W m ⁻²

energy budget

Table: globally and annually averaged **surface** energy budget

Long term, global average: $SW(\text{net}) + LW(\text{net}) + LH + SH \sim 0$ ← surface



From the solar radiation...



Incident solar radiation	340 W/m ²
Planetary albedo	0.3
Absorbed solar radiation	240 W/m ²
Outgoing longwave radiation	240 W/m ²

SW ~ LW
 $S(1 - \alpha)$

← TOA

Table: globally and annually averaged TOA radiation budget

Absorbed solar (SW)	176 W m ⁻²
Downward infrared (LW↓)	312 W m ⁻²
Upward infrared (LW↑)	-385 W m ⁻²
Net longwave (LW)	-73 W m ⁻²
Net radiation (SW + LW)	103 W m ⁻²
Latent heat (LH)	-79 W m ⁻²
Sensible heat (SH)	-24 W m ⁻²

Absorbed solar radiation (240 - 176)	64 W m ⁻²
Net emitted terrestrial radiation (-240 + 73)	-167 W m ⁻²
Net radiative heating	-103 W m ⁻²
Latent heat input	79 W m ⁻²
Sensible heat input	24 W m ⁻²

energy budget

Table: globally and annually averaged atmosphere energy budget

∴ $SW(\text{net}) + LW(\text{net}) + LH + SH \sim 0$ ← surface

Table: globally and annually averaged surface energy budget