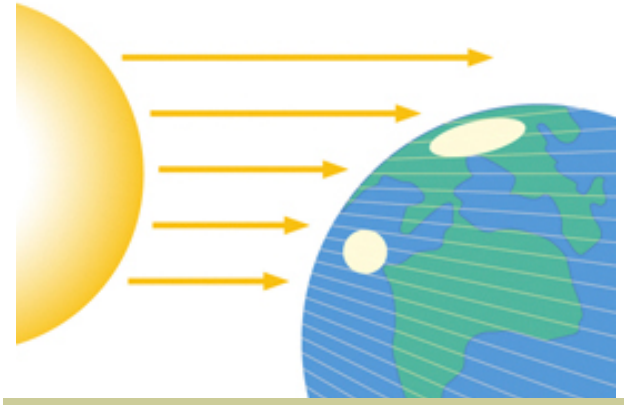
第二章:

大气环流的外部强迫



授课教师：张洋

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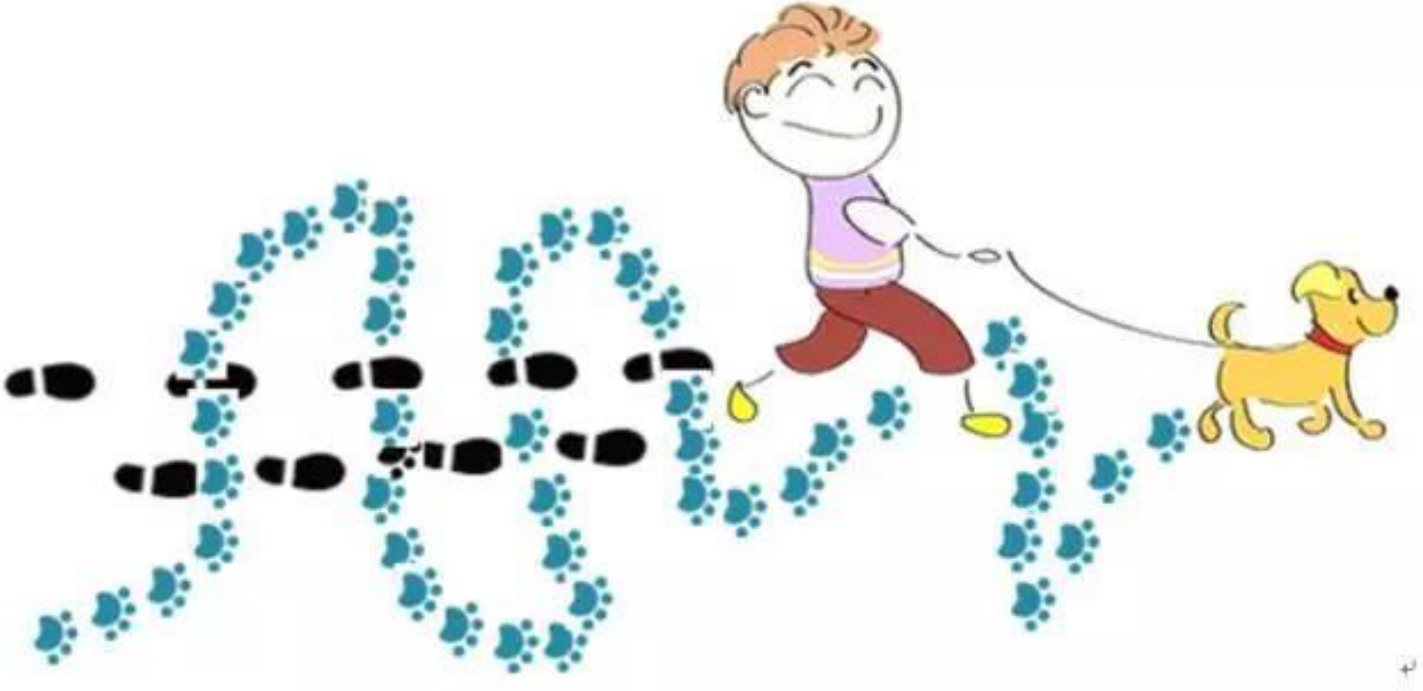
大气环流的外部强迫

外部强迫与大气内部变率

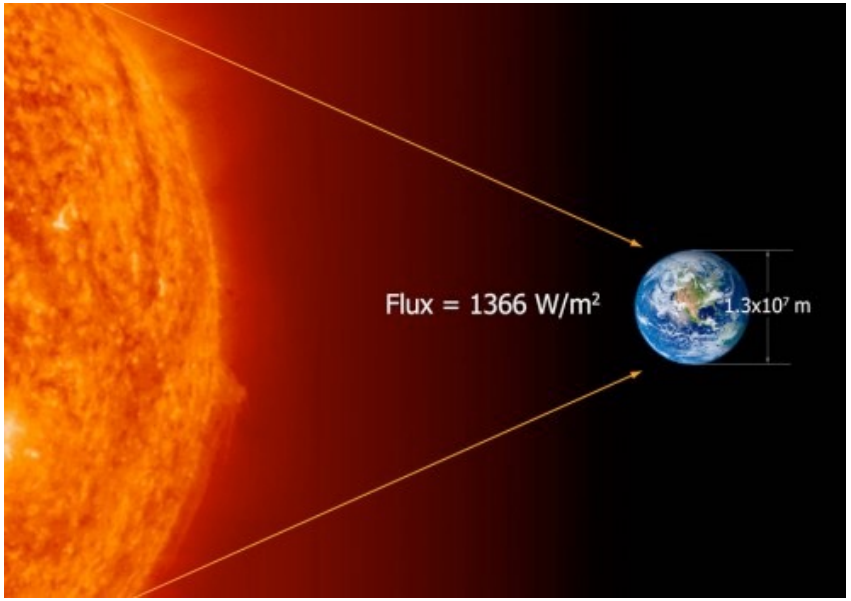


选自谢尚平等
《揭开汛期降水变化的奥秘：厄尔尼诺回响曲》

Outline

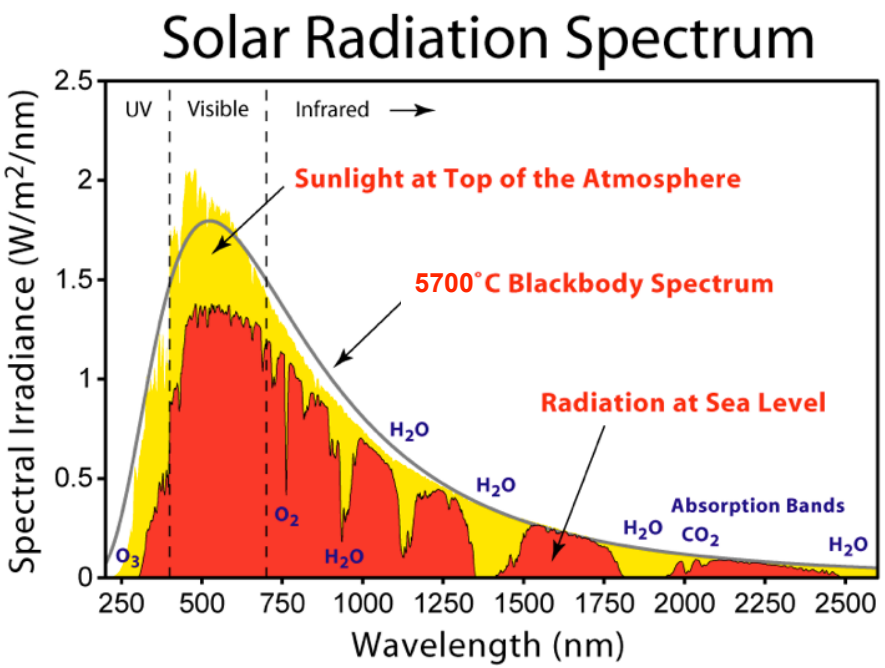
- Global averaged feature
  - TOA (Top of the atmosphere)
  - Surface
- Latitudinal distribution (zonal averaged feature)
  - TOA
  - Surface
- Zonal distribution
  - TOA
  - Surface

From the solar radiation...



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

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



Effective emission temperature:

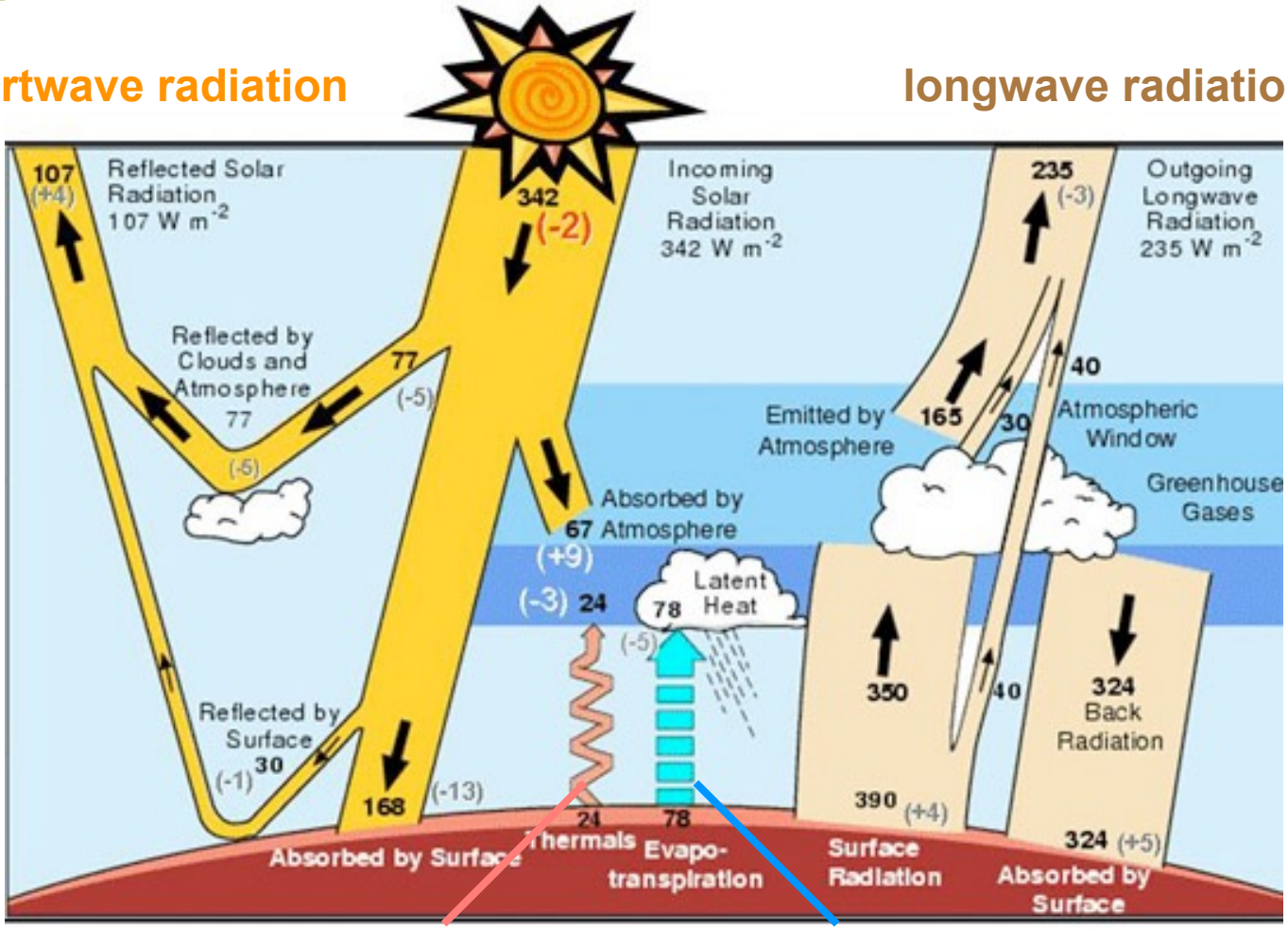
$$\sigma T_e^{\ 4} \equiv \frac{S_0}{4}\left(1 - a_p\right)$$

Earth: $T_e = 255K = -18°C$ 实际大气：288K

From the solar radiation…

shortwave radiation

longwave radiation



TOA

energy budget

surface

sensible heat

latent heat

From the solar radiation…

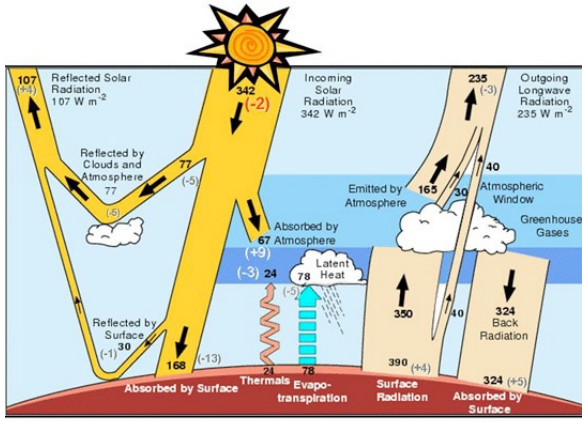
Incident solar radiation	340 W/m^2
Planetary albedo	0.3
Absorbed solar radiation	240 W/m^2
Outgoing longwave radiation (OLR)	240 W/m^2

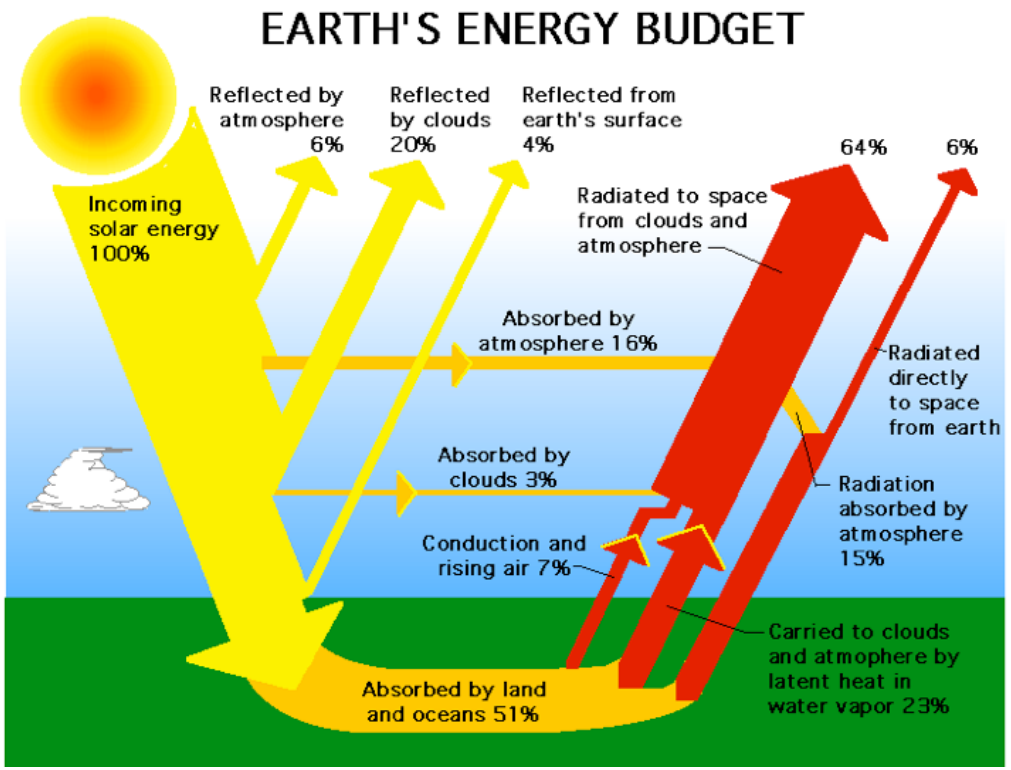
$$\mathrm{SW} \sim \mathrm{LW}$$

$$S(1-\alpha)$$

← TOA

Table: globally and annually averaged TOA radiation budget



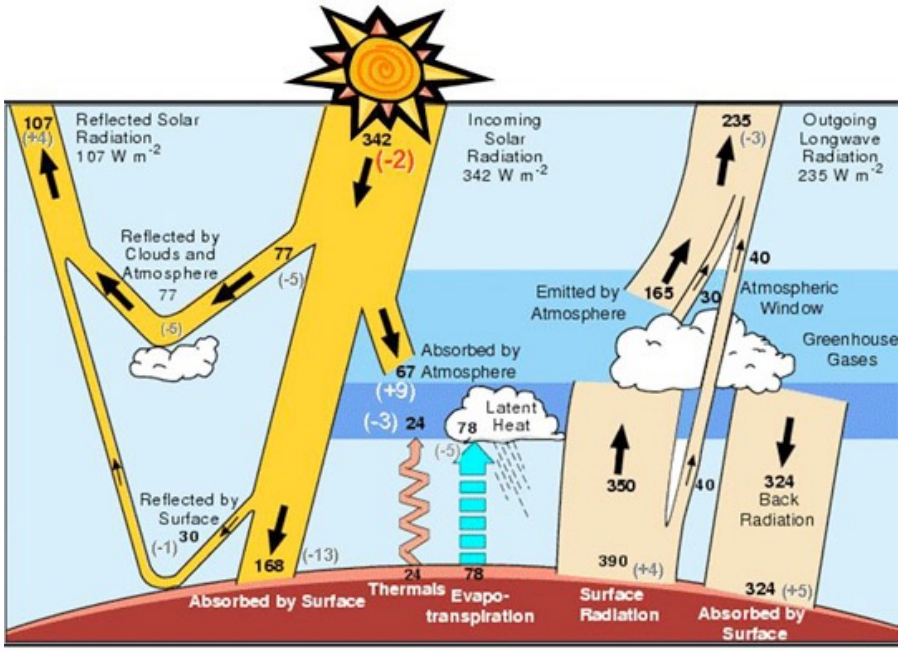


From the solar radiation...

- 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: H20, 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}

Table: globally and annually averaged surface energy budget

energy budget

Long term, global average: SW(net) + LW(net) + LH +SH ~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

Table: globally and annually averaged TOA radiation budget

$$SW \sim LW$$

$$S(1-\alpha)$$

← TOA

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}

Table: globally and annually averaged atmosphere energy budget

energy 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}

Table: globally and annually averaged surface energy budget

$$SW(net) + LW(net) + LH + SH \sim 0$$ ← surface