1st Quali-Start-Up Science Lectures

September 11-15, 2017;
Forschungszentrum Jülich, IEK-8
Germany

JÜLICH
FORSCHUNGSZENTRUM

SHOTA RUSTAVELI NATIONAL SCIENCE FOUNDATION

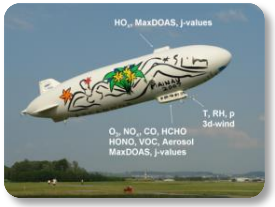
Atmospheric Chemistry and Climate

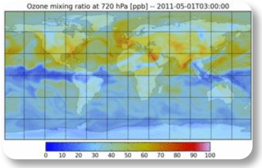
Prof. Andreas Wahner, Forschungszentrum Juelich, Germany

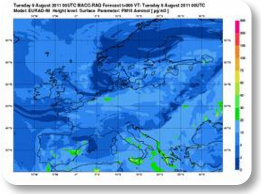
Atmospheric Research in Forschungszentrum Jülich; Germany Institut for Energy and Climate:Troposphere (IEK-8)

- Future energy supply:
  supply, resources, protection of nature and climate, economy
- Impact of energy production and usage on air quality and climate

Observation	Simulation / Prozess Understanding	Modell



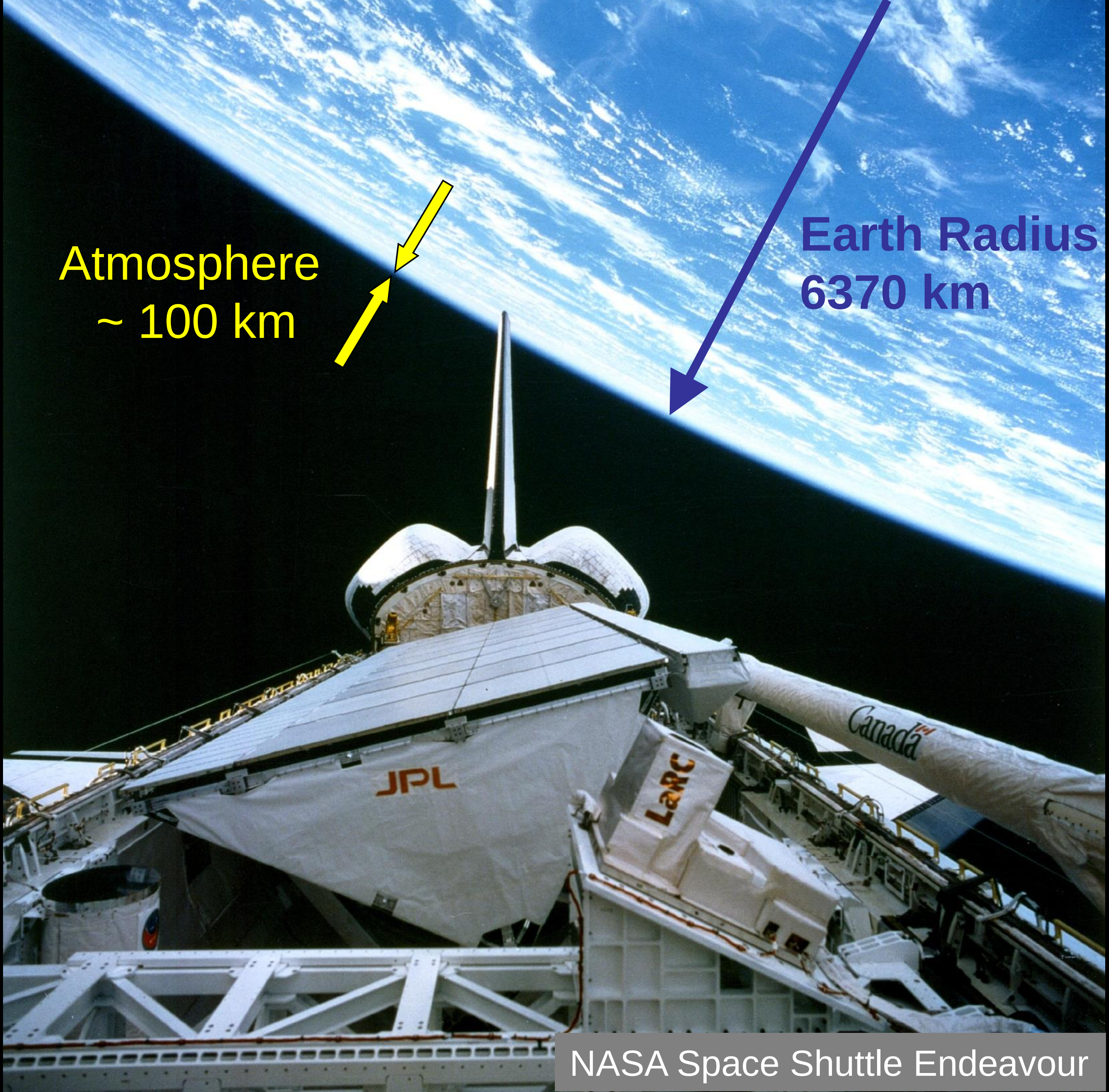




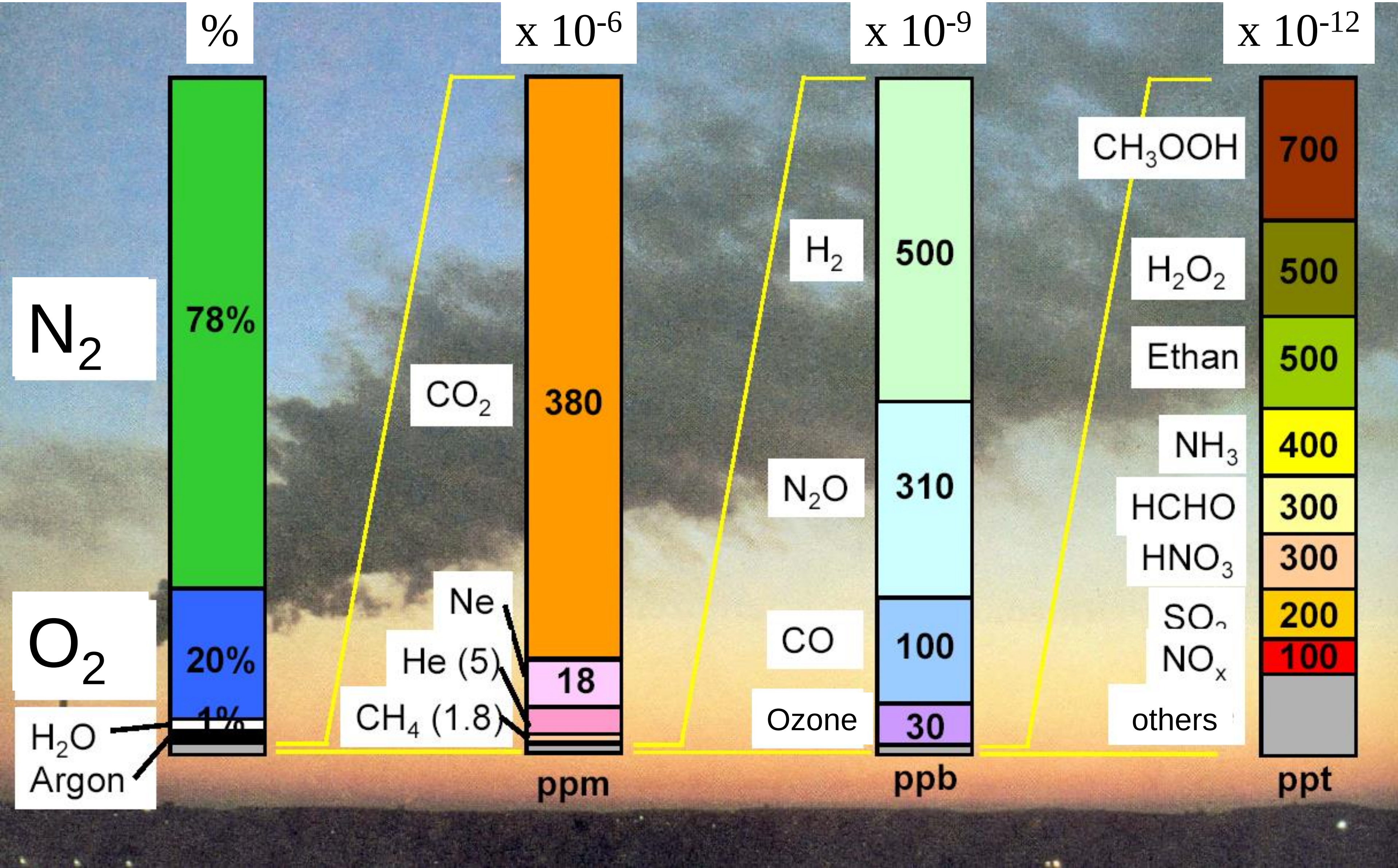
Scientific basis for societal and political decisions: Energy options, mitigation- and adaption strategies

The Atmosphere

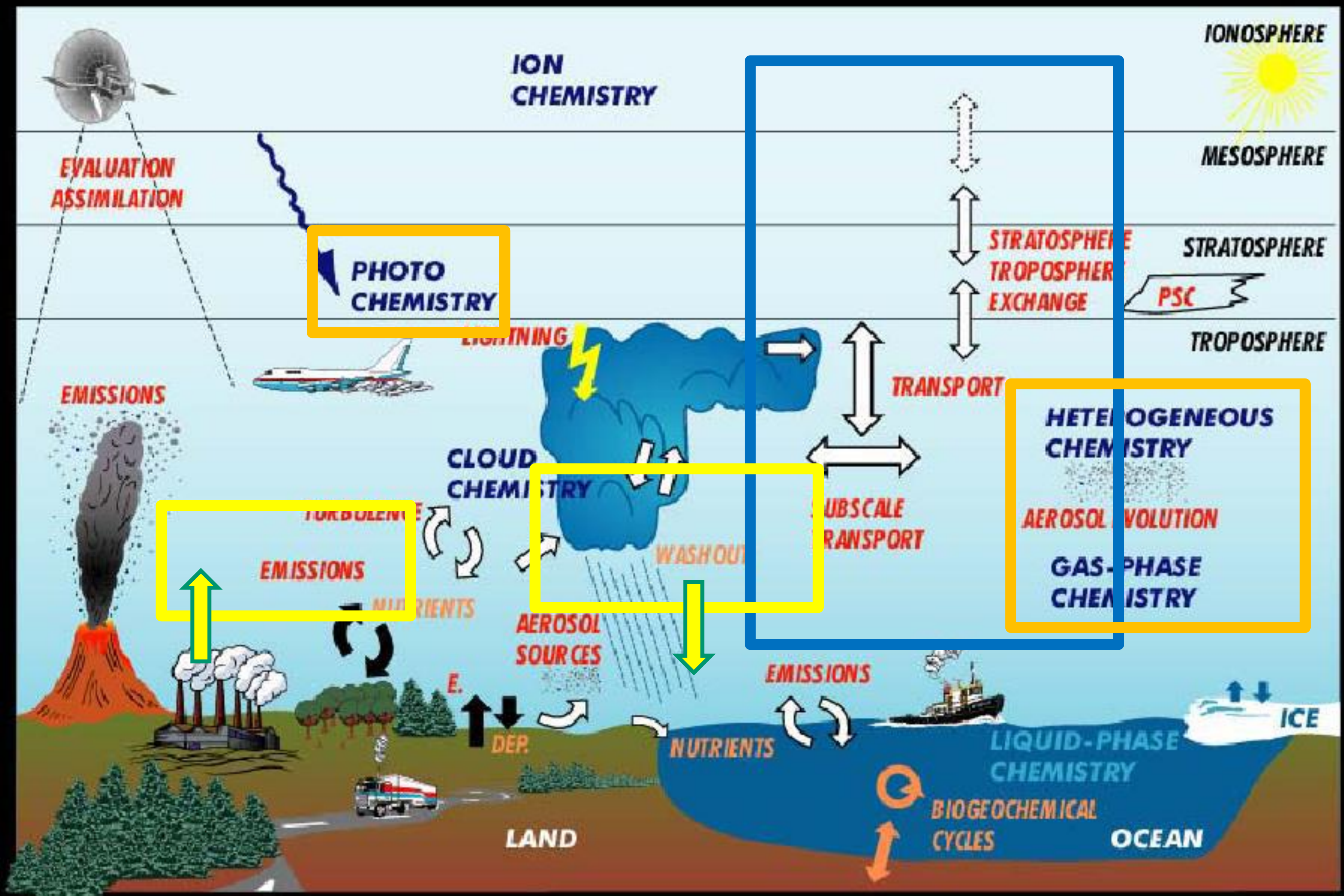
NASA


Atmosphere
~ 100 km
Earth Radius
6370 km
JPL
LaRC
Canada
NASA Space Shuttle Endeavour

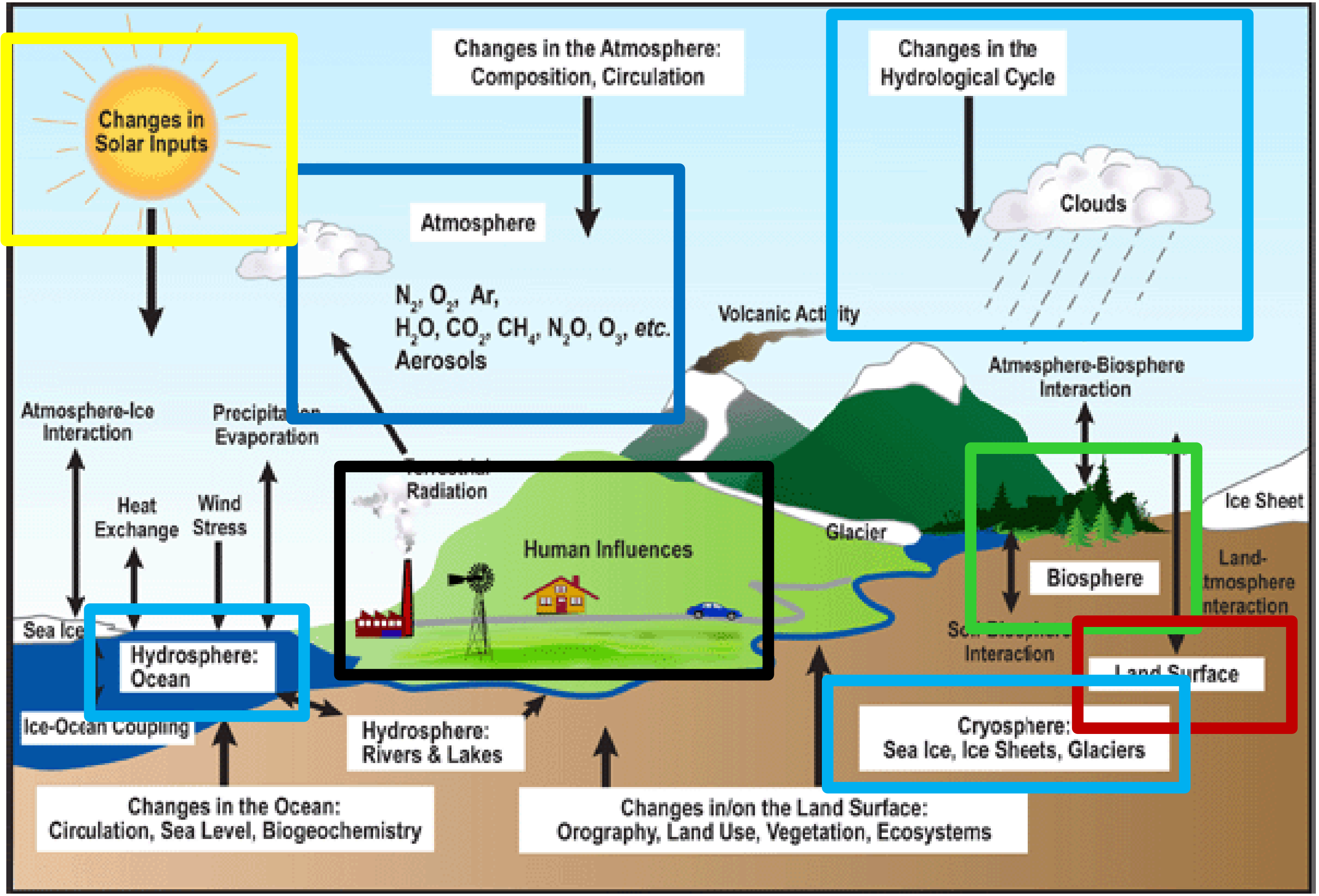
Gas Phase Composition of the Atmosphere



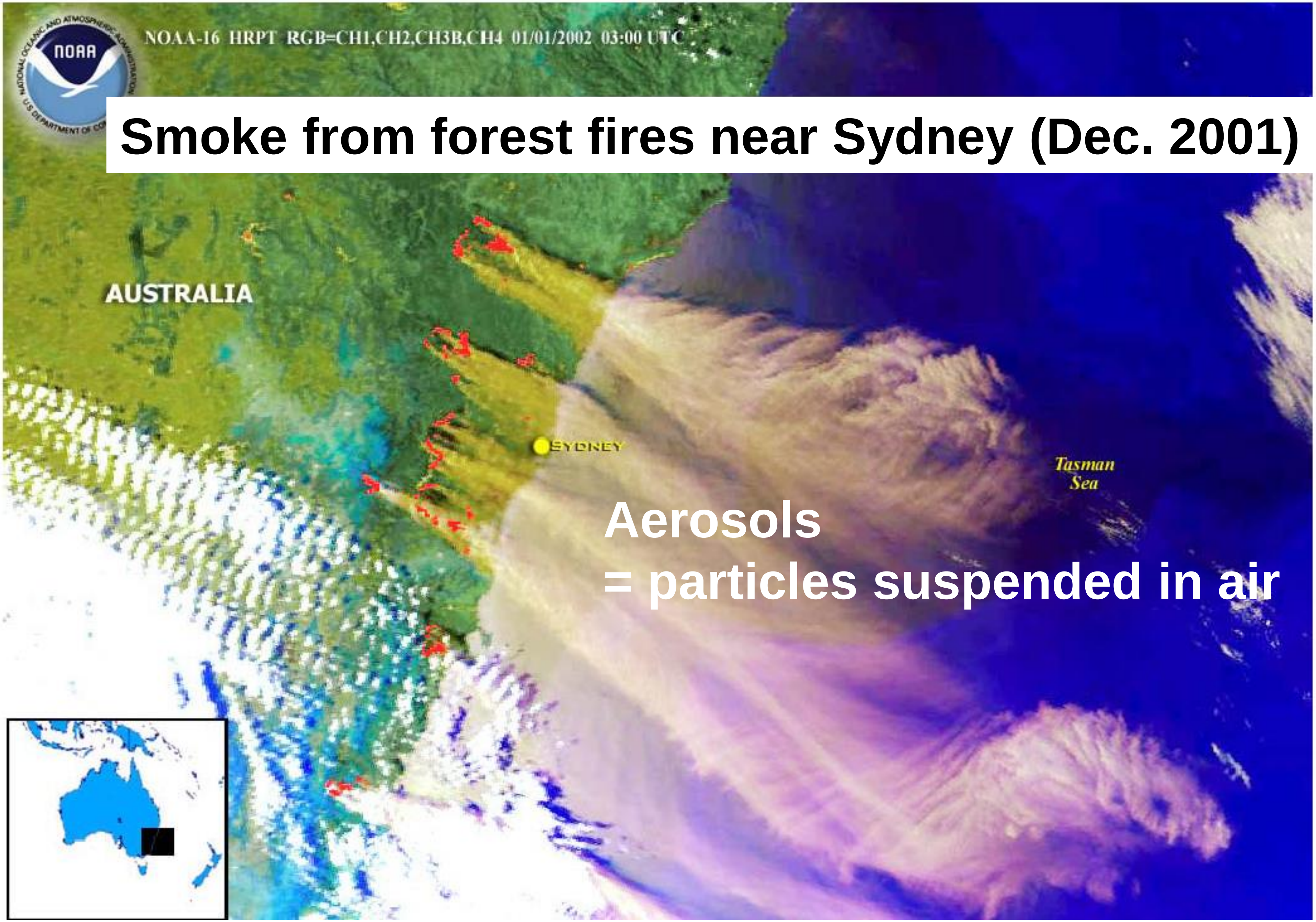
Atmospheric Chemistry and Dynamics



Schematic view of the components of the climate system, their processes and interactions.



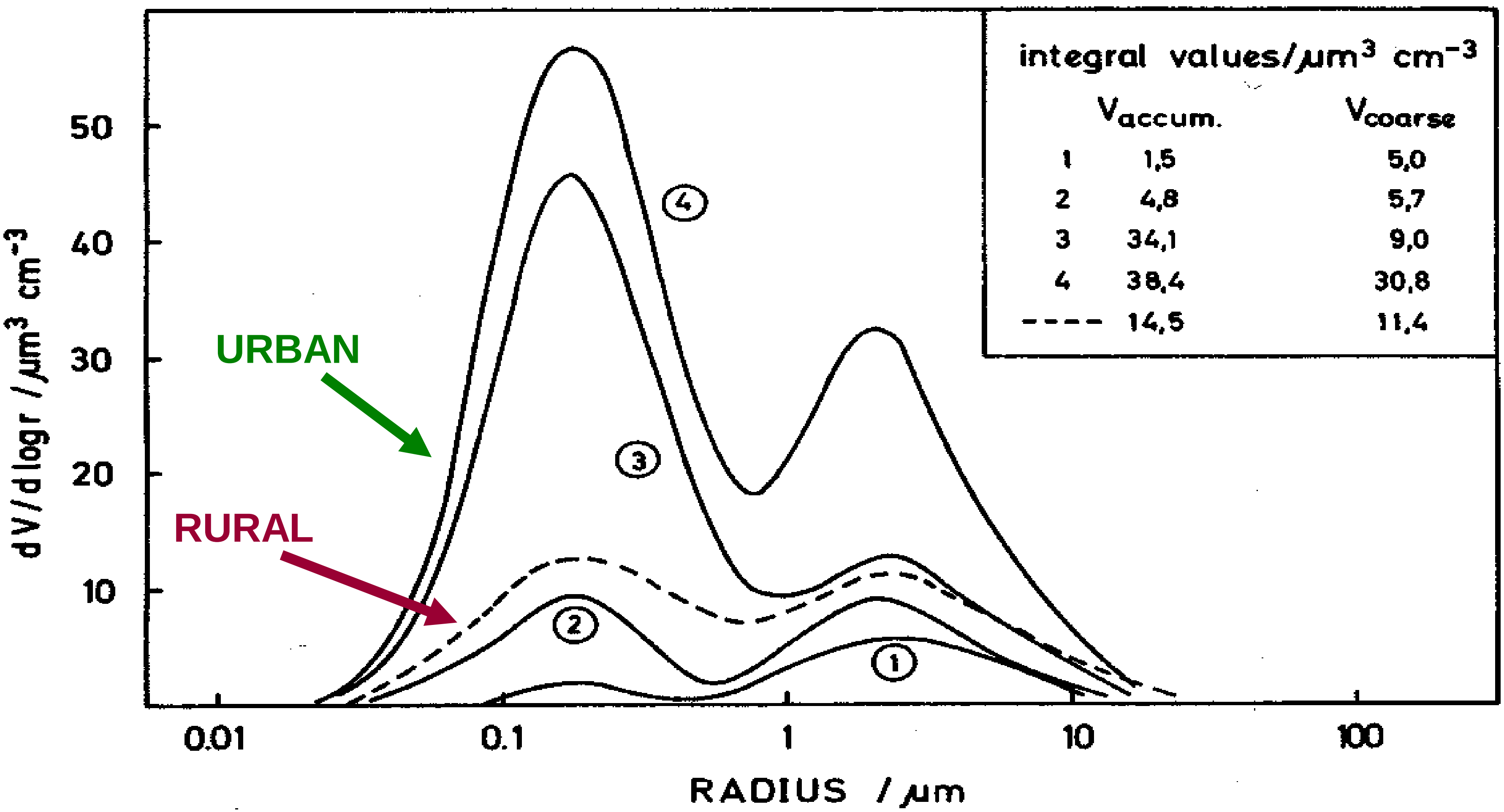
Smoke from forest fires near Sydney (Dec. 2001)



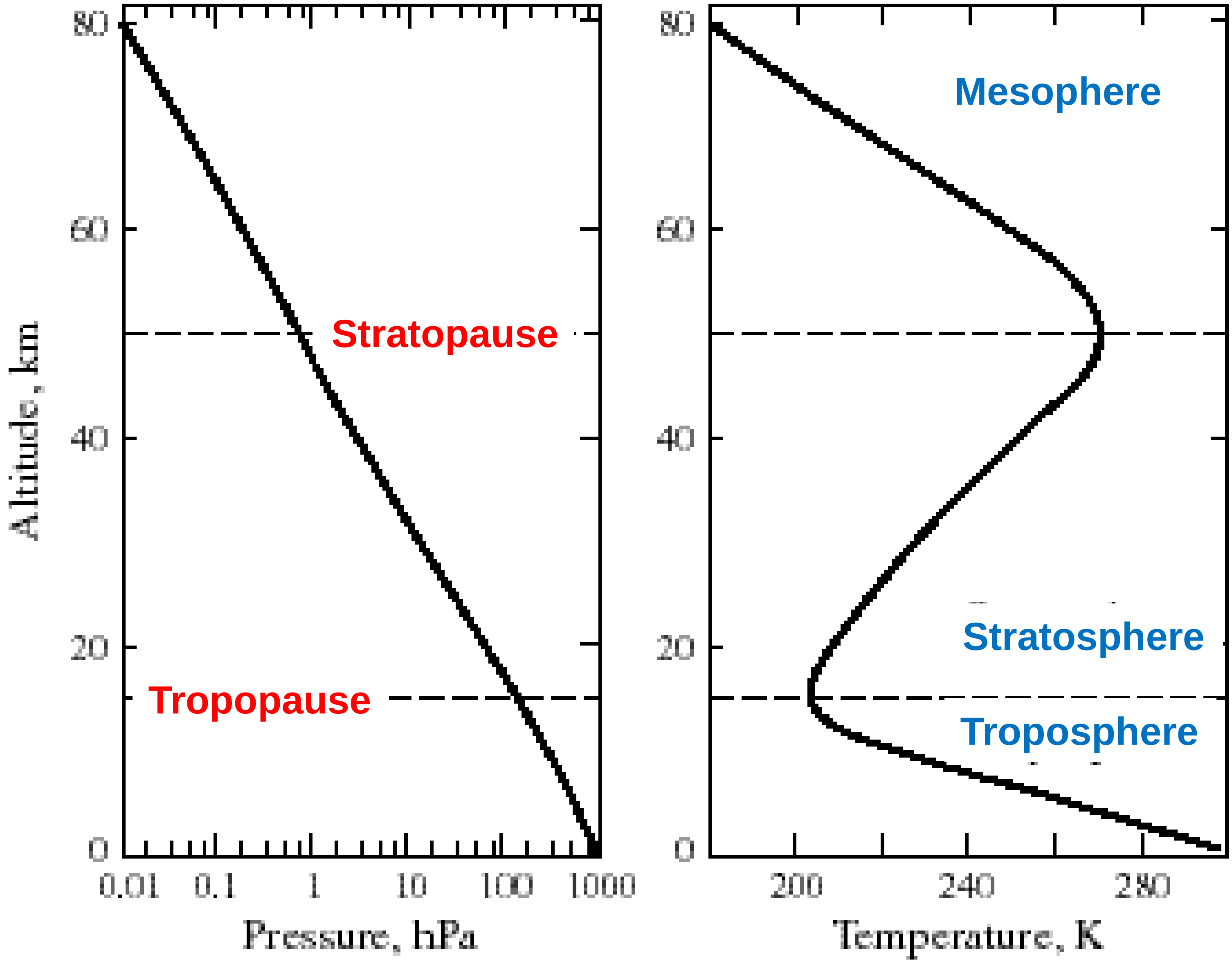
Aerosols
= particles suspended in air

Aerosol Concentrations

Typical U.S. aerosol size distributions by volume



Vertical Profiles of Pressure and Temperature



Ideal Gas Law
applicable to the atmosphere

- Assumption: gas is infinite compressible

$$pV = \nu RT$$

$$p = \rho RT$$

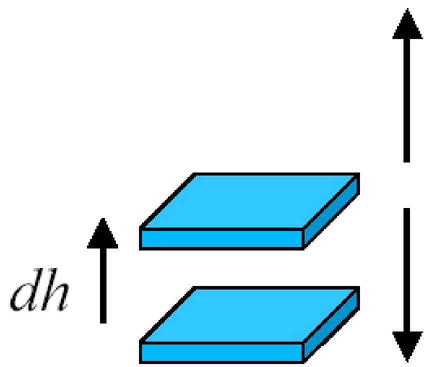
$R = 8.314$ J mol $^{-1}$ K^{-1}

R : universal gas constant
in dry air : 287.05 J kg^{-1} K^{-1}

Example:

Pressure at ground : 1000 hPa, T = 280 K → ρ = 1.244 kg m^{-3}
stratosphere: 0.10 hPa, T = 230 K → ρ = 0.015 kg m^{-3}

Hydrostatic Equilibrium -- Barometric Height Equation



$$F_{\uparrow} = p \cdot A$$

$$F_{\downarrow} = m \cdot g$$

Air Pressure
←→ Gravity

Pressure change at infinitesimal change of height :

$$\frac{dp}{dh} = -g \cdot \rho$$

Considering the ideal gas law:

$$\frac{dp}{dh} = -\frac{g}{R \cdot T} p$$

Integration yields the <u>barometric height equation</u>:

$$p = p_0 \exp(-h/H)$$

$H = RT/g$ scale height

Scale Height

$$H = \frac{RT}{g} \approx 7.4 \text{ km} \; (T = 250 \text{ K})$$

Scale height is not constant ! Real application must include the temperature gradient (lapse rate) :

$\Gamma \approx -6.5$ K km^{-1}	in the troposphere
$\Gamma \approx 0$	in the tropospause region
$\Gamma \approx +4$ K km^{-1}	in the stratosphere

Atmospheric Mass (m_a)

$$p_b = \frac{m_a\, g}{A}$$

Radius of Earth:
6378 km

Average Pressure at Ground:
984 hPa

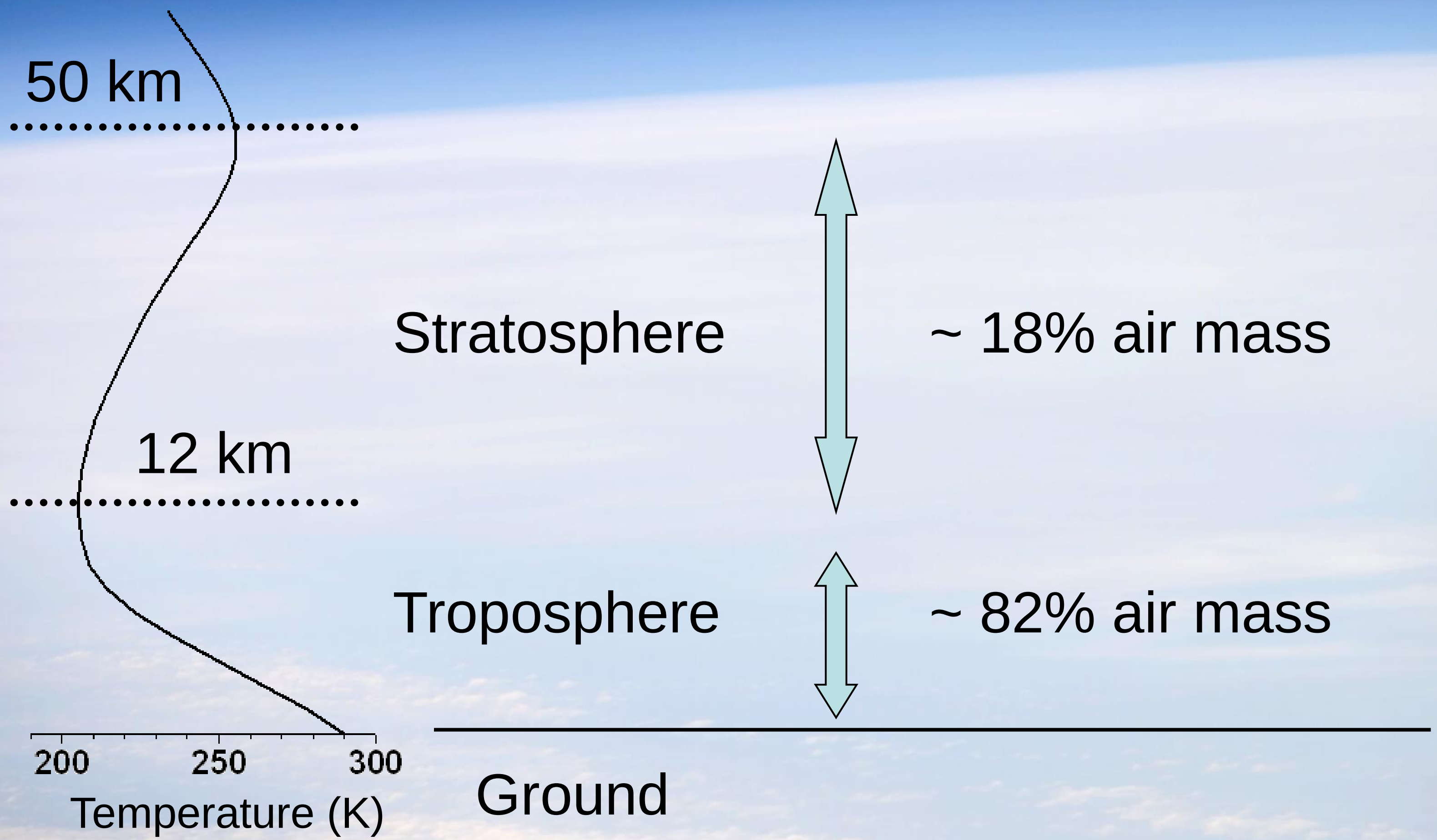
$$m_a = \frac{4\pi R^2\, p_b}{g} = 5.2\times 10^{18}\ \text{kg}$$

Total mole number of air in the atmosphere

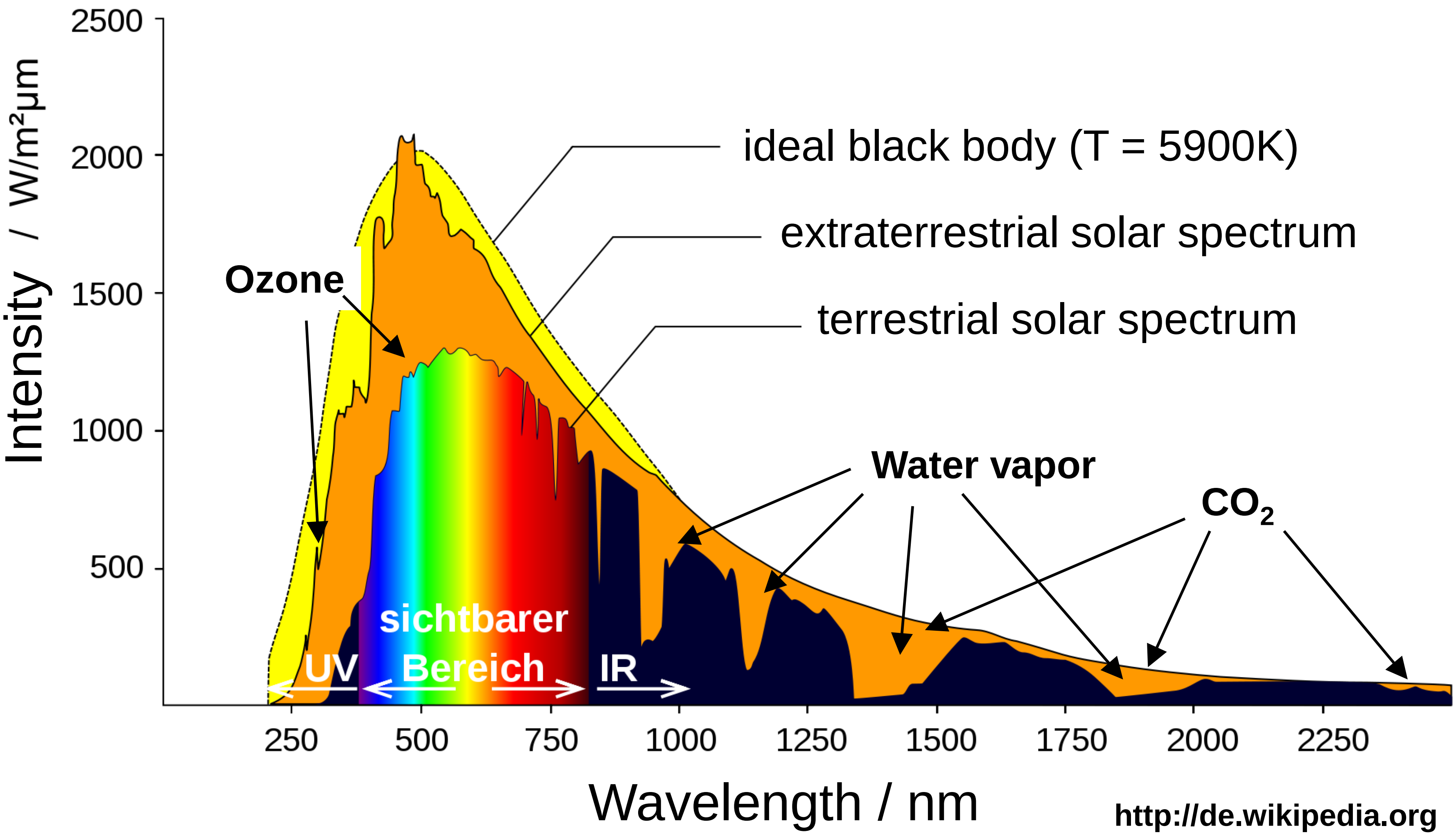
$$N_a = \frac{m_a}{M_a} = 1.8\times 10^{20}\ \text{moles}$$

Molar Mass of Air
M_a = 28.6 g/mol

Mass Distribution of the Atmosphere

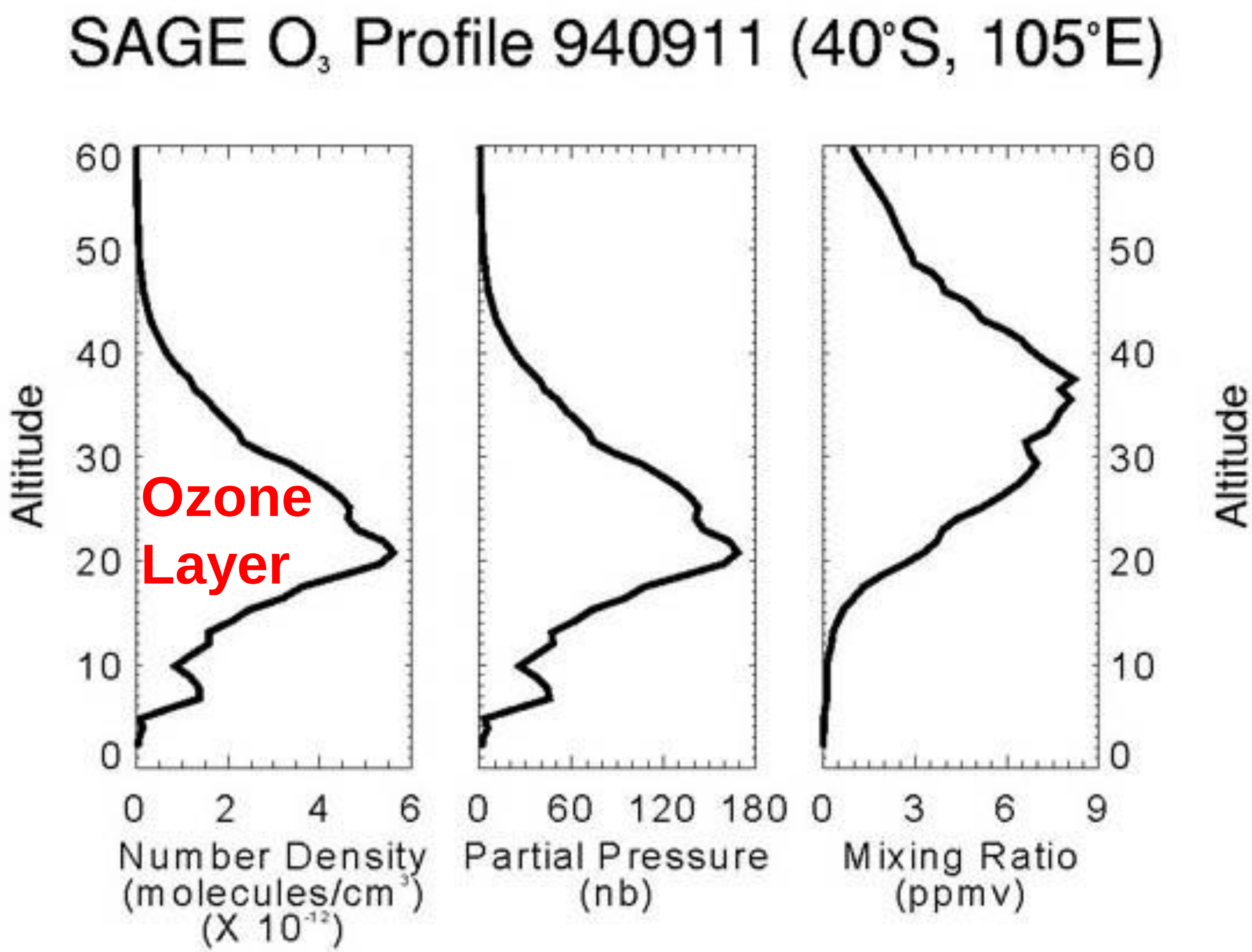


Solar Flux at the Top of the Atmosphere and at Ground



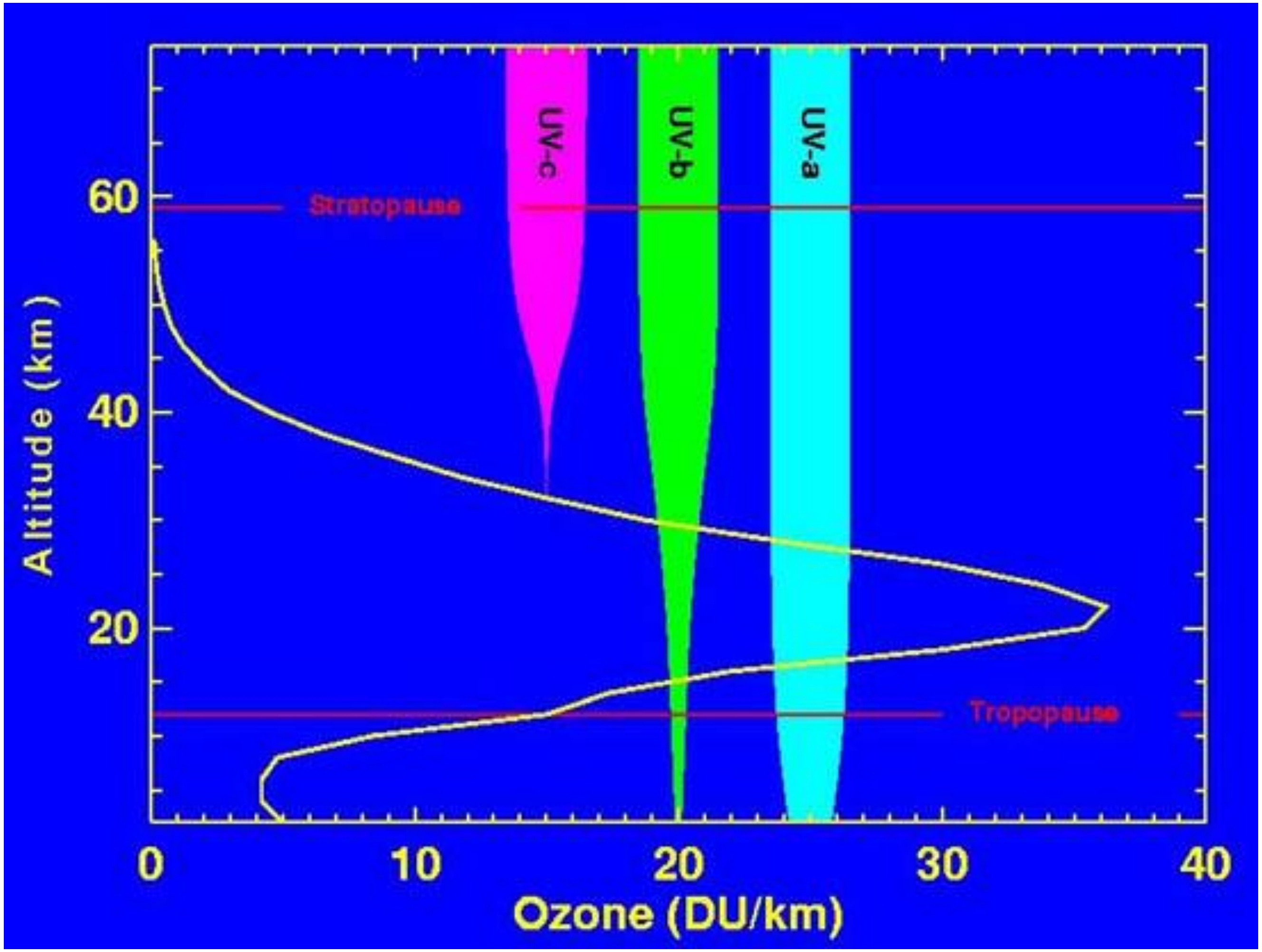
http://de.wikipedia.org

Vertical Distribution of Ozone in the Atmosphere

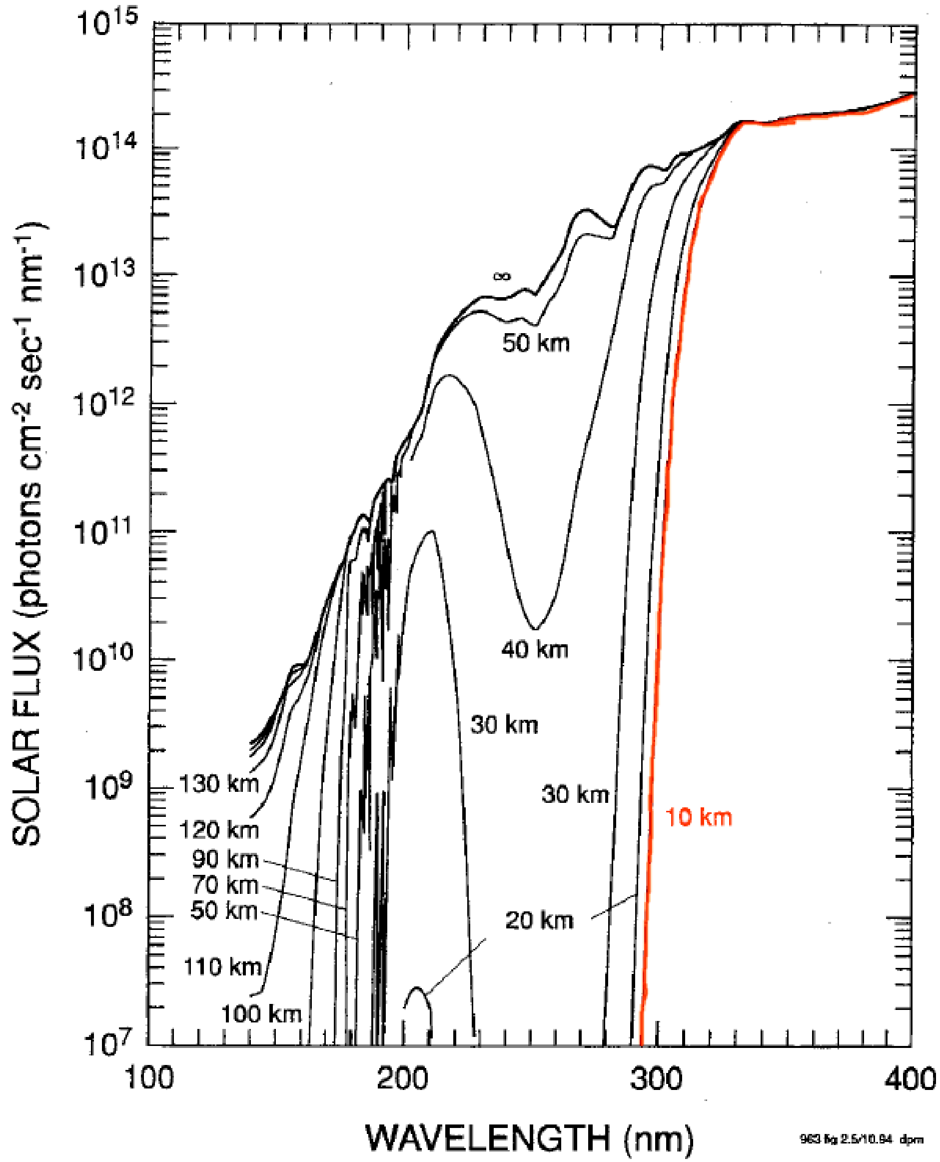


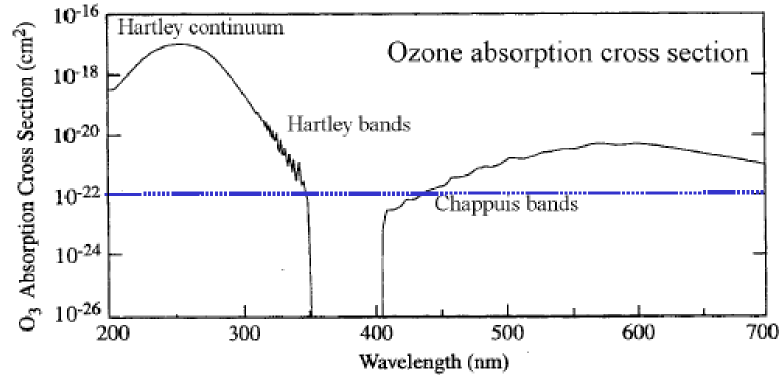
UV Absorption by Ozone

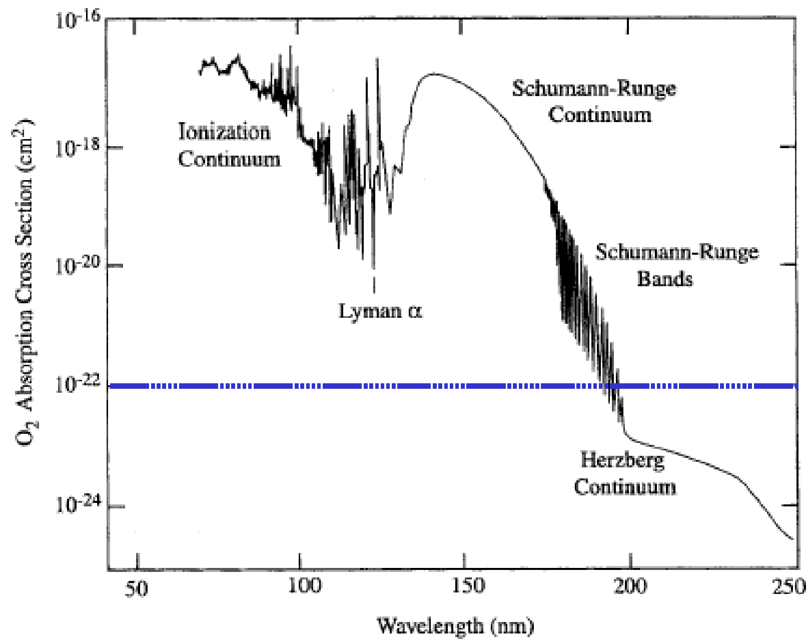
UV-C 100-280 nm | UV-B 280-320 nm | UV-A 320-380 nm



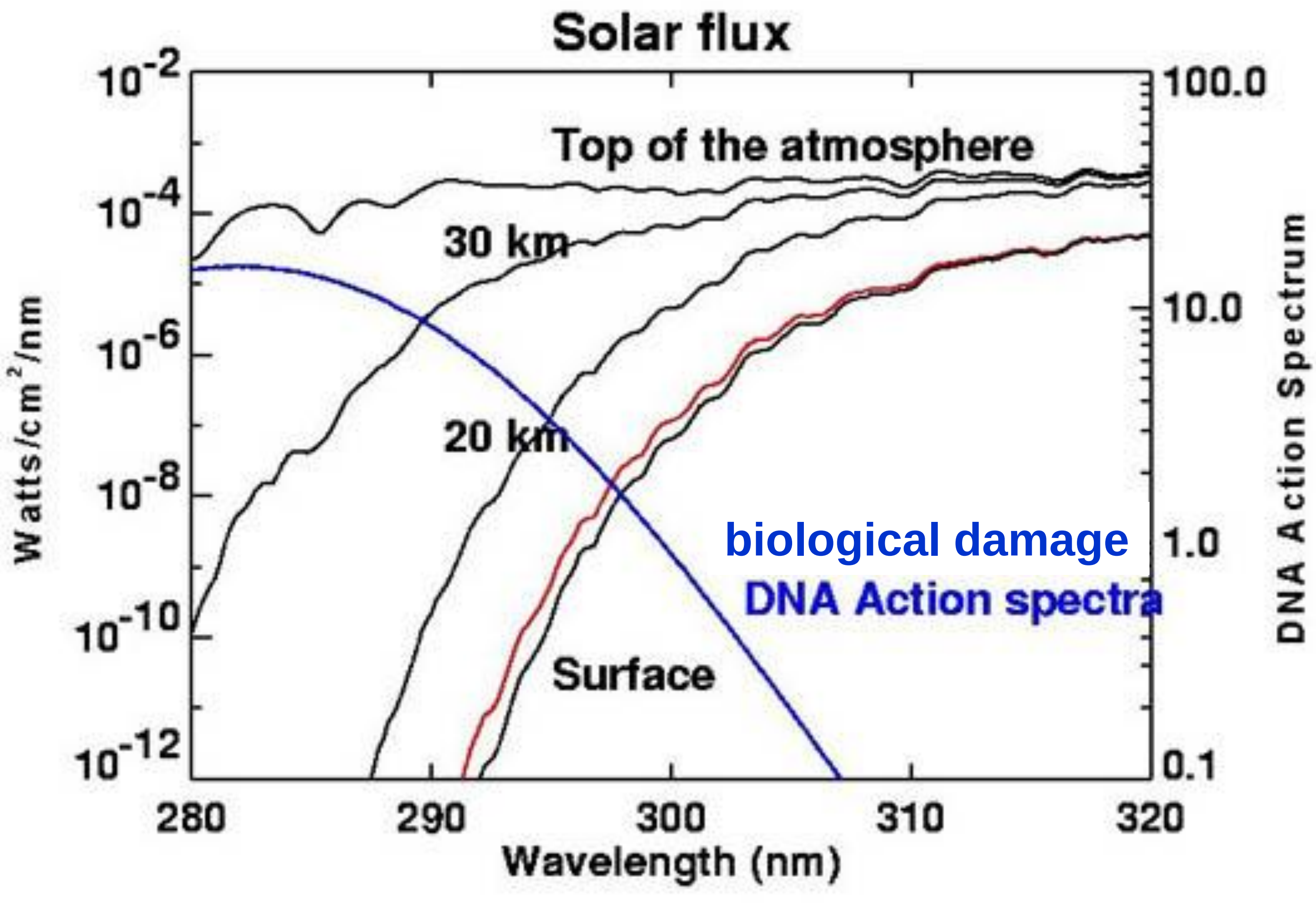
Penetration of UV radiation



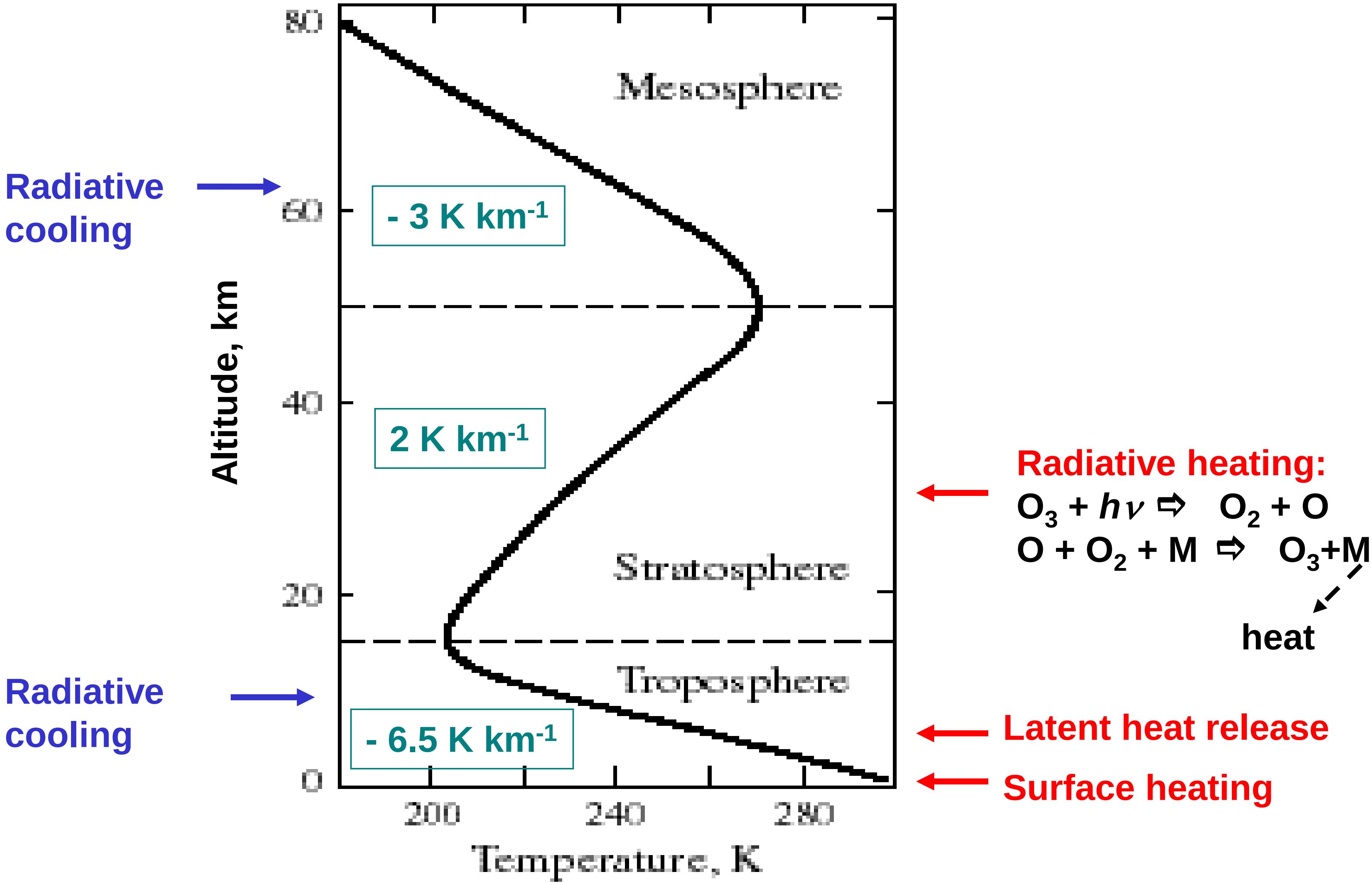




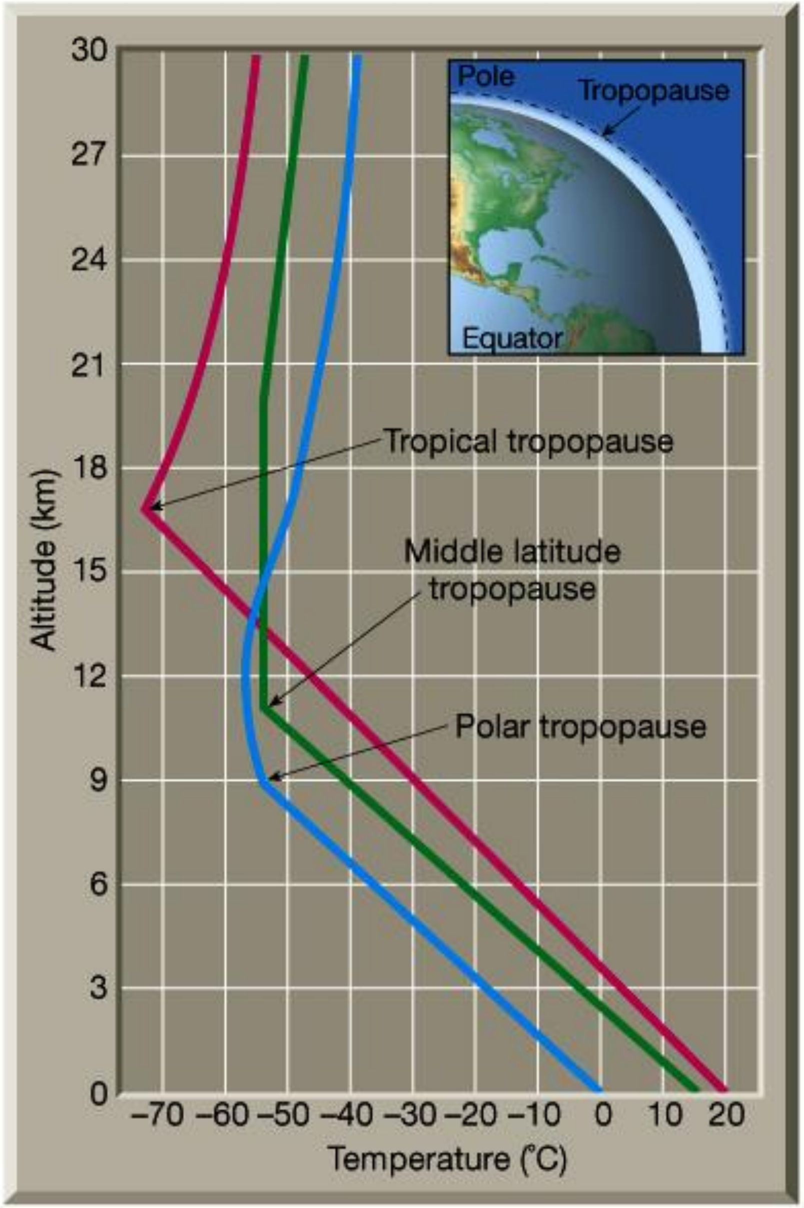
Solar Irradiance with Altitude



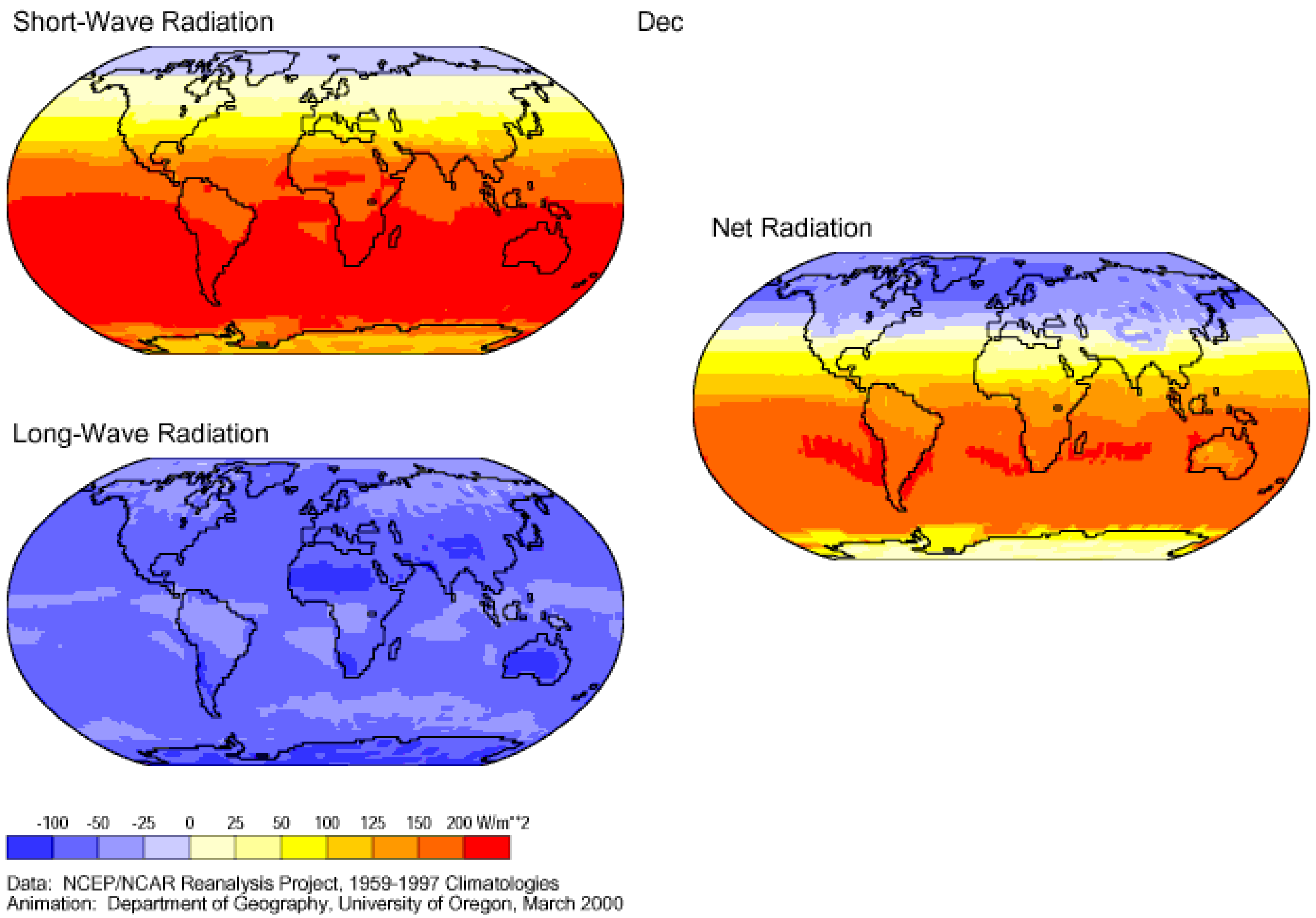
VERTICAL PROFILE OF TEMPERATURE
Mean values for 30ºN, March



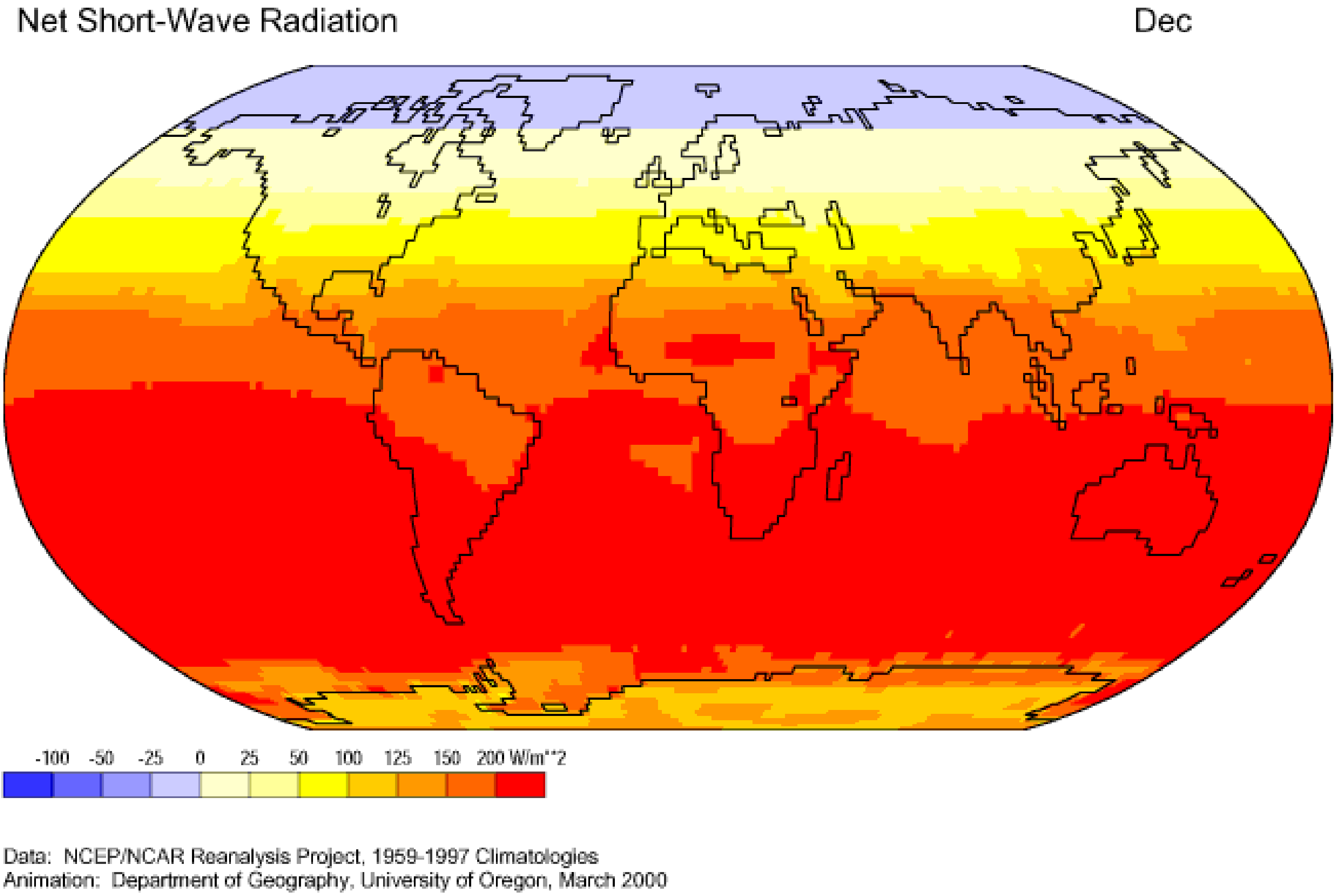
Variations in Tropopause with Latitude



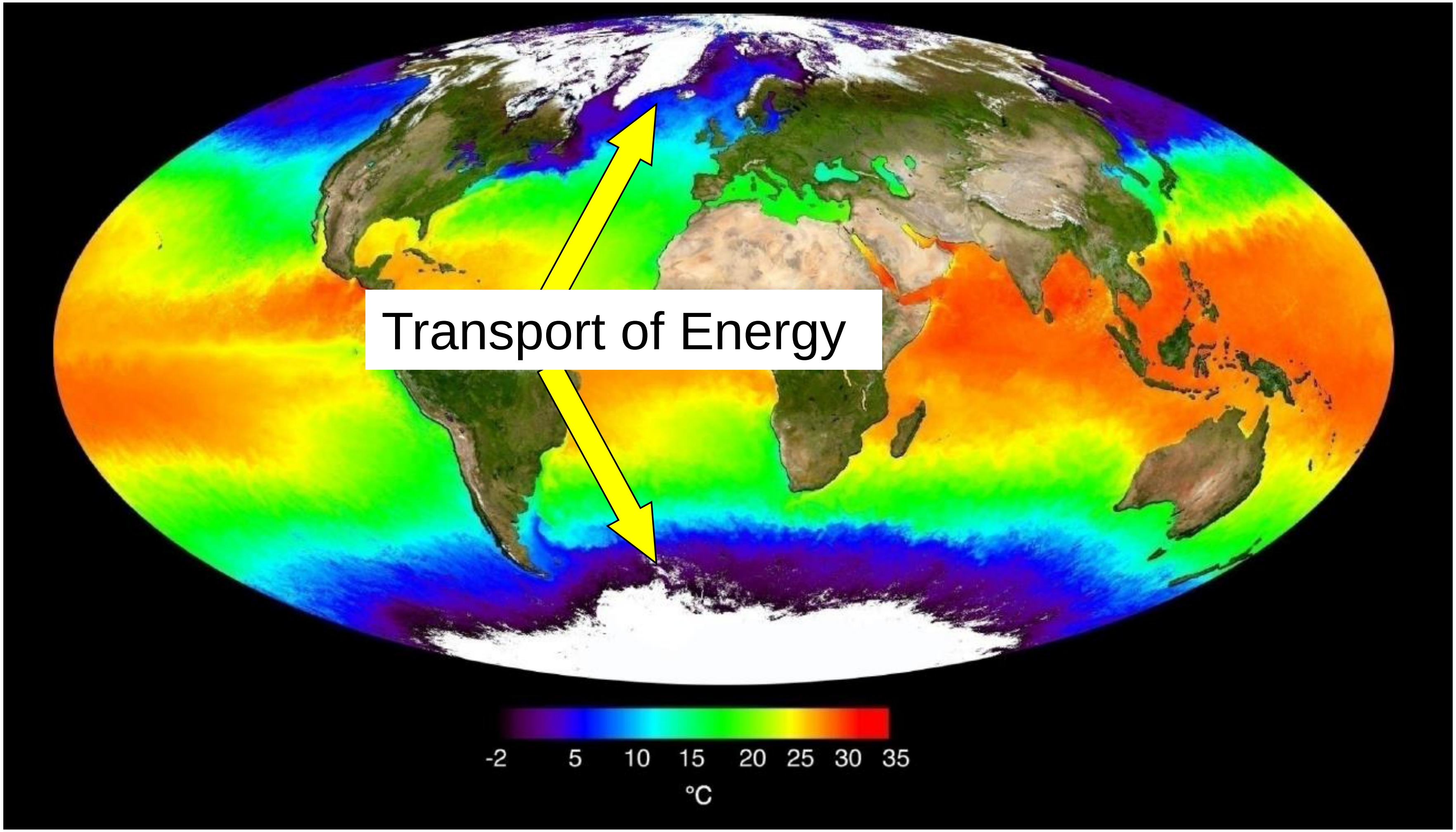
Net Radiation



Solar Radiation

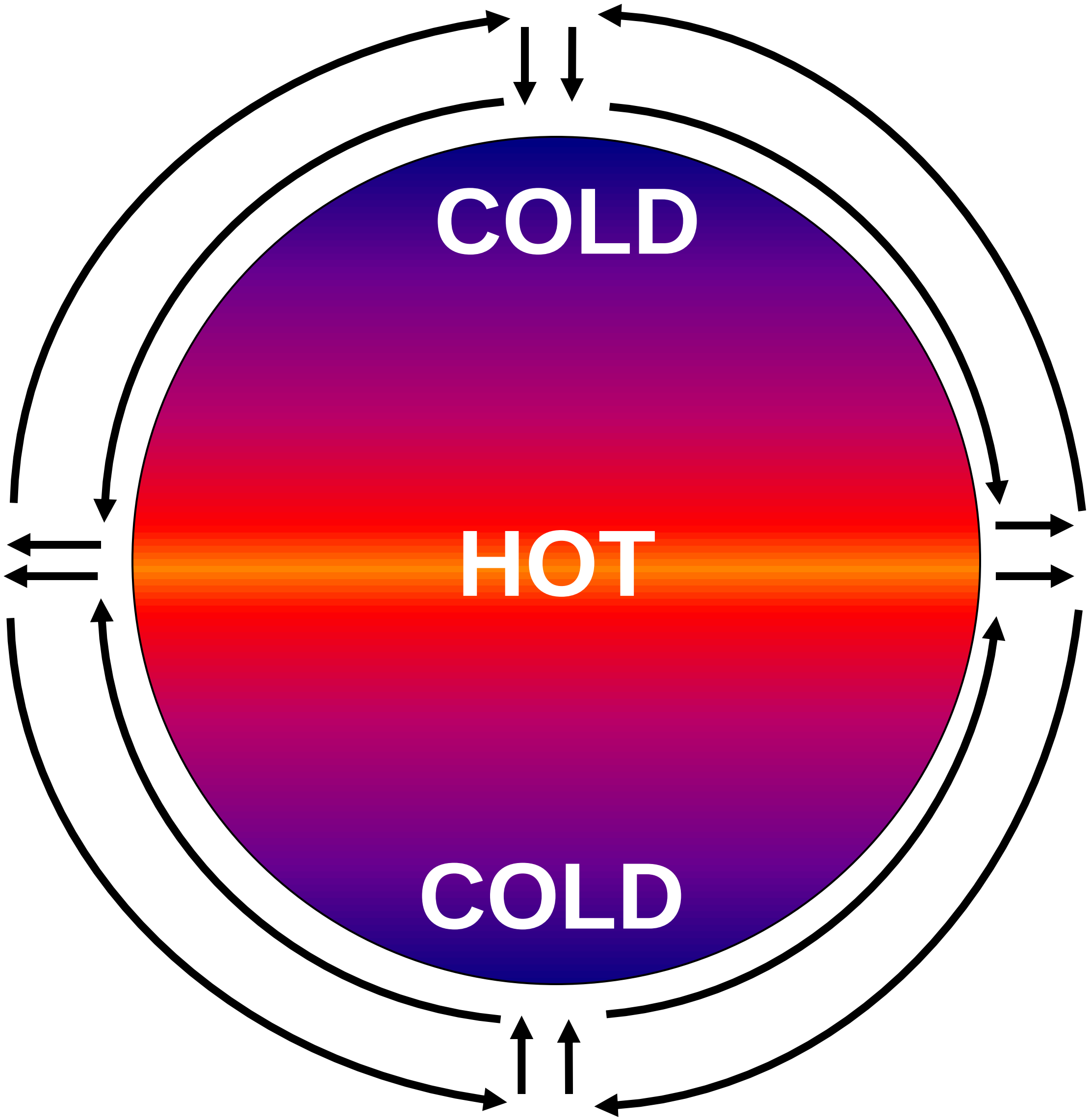


Modis Satellite Data: Surface Temperature



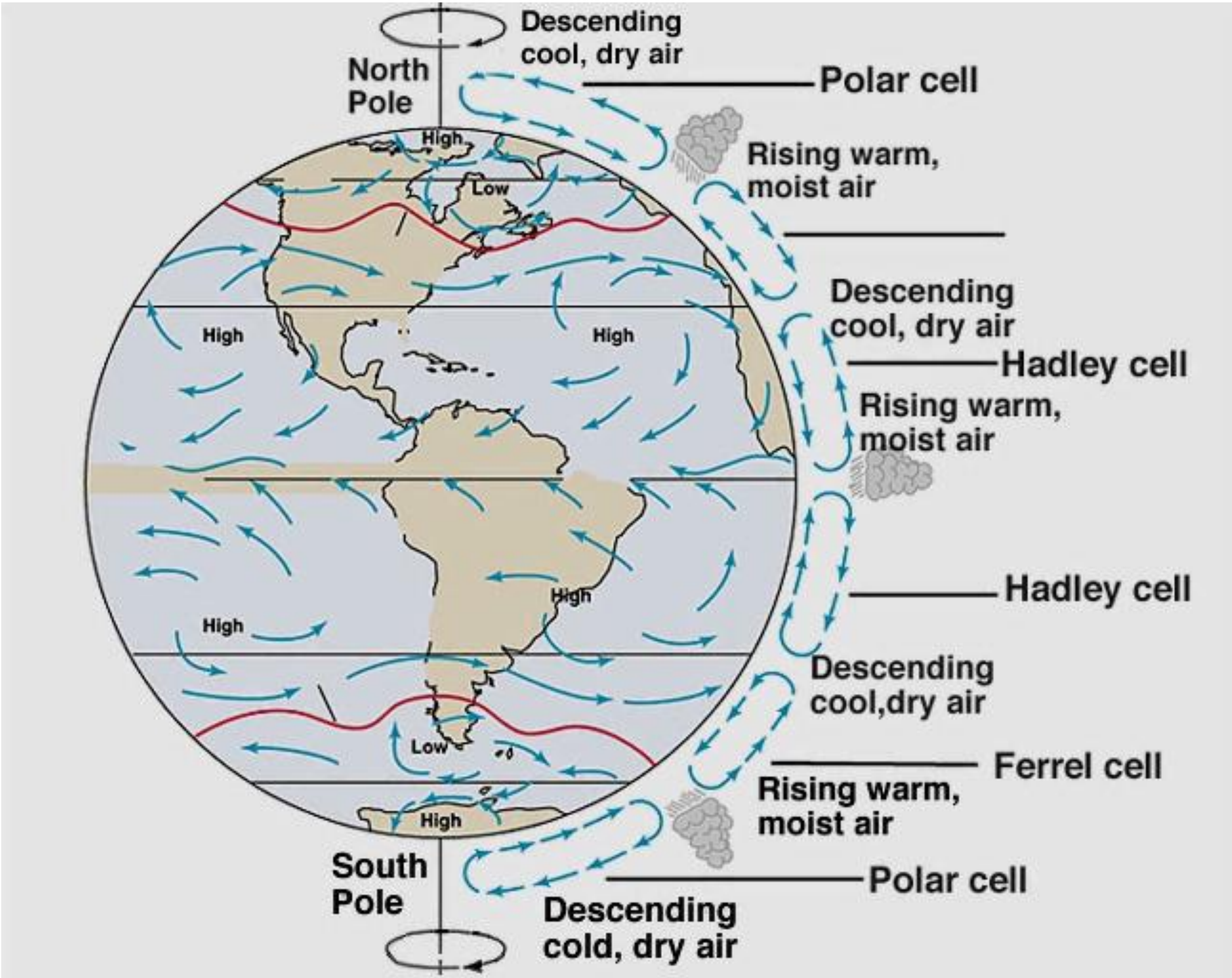
http://modis-atmos.gsfc.nasa.gov/

THE HADLEY CIRCULATION (1735):

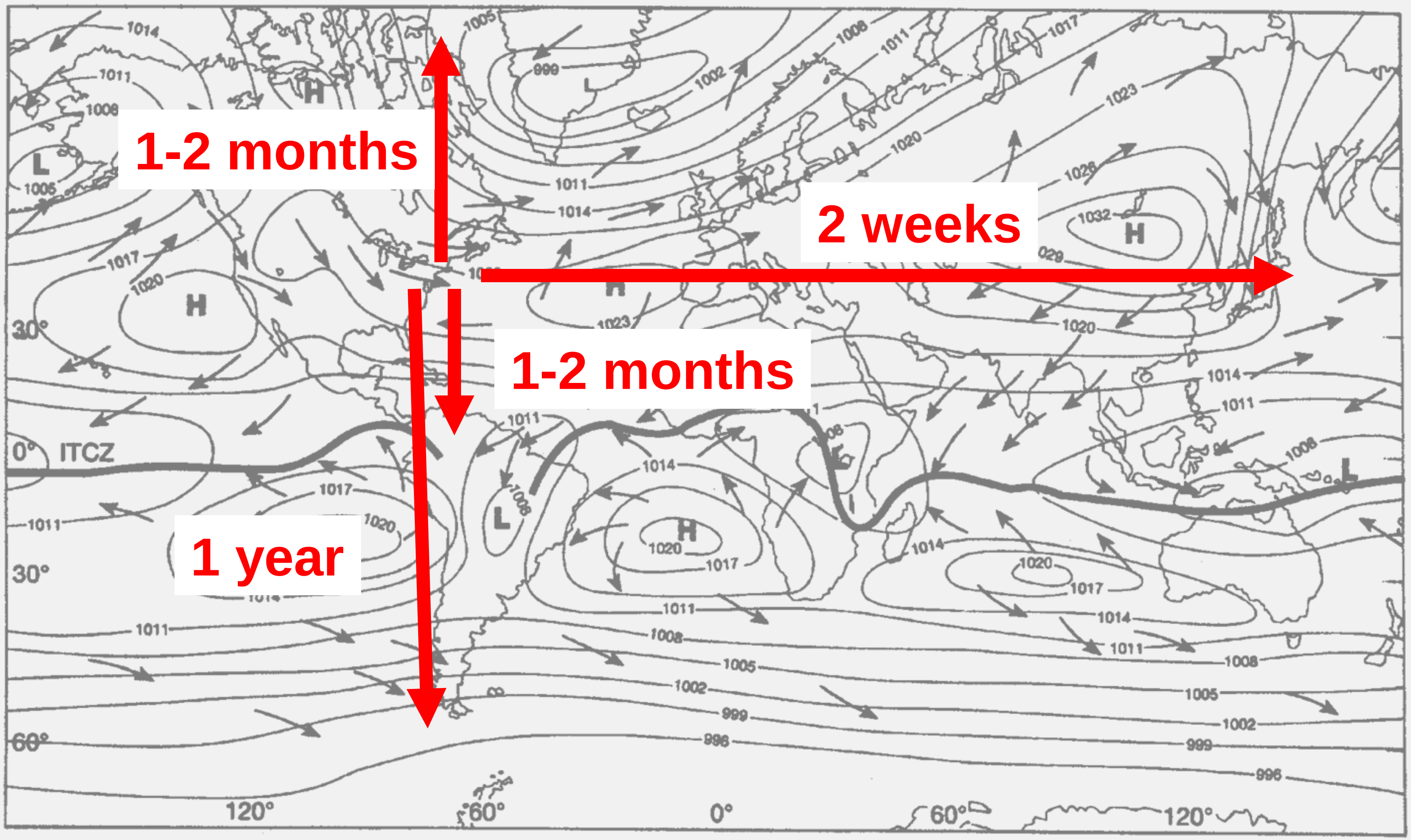


Explains:
- **Intertropical Convergence Zone (ITCZ)**
- **Wet tropics, dry poles**

Problem: does not account for Coriolis force. Meridional transport of air between Equator and poles would result in unstable longitudinal motion.


Descending
cool, dry air
North
Pole
Polar cell
High
Low
Rising warm,
moist air
Descending
cool, dry air
High
High
Hadley cell
Rising warm,
moist air
High
High
Hadley cell
Descending
cool,dry air
Low
Ferrel cell
Rising warm,
moist air
High
South
Pole
Polar cell
Descending
cold, dry air

Time Scales for Transport in the Troposphere

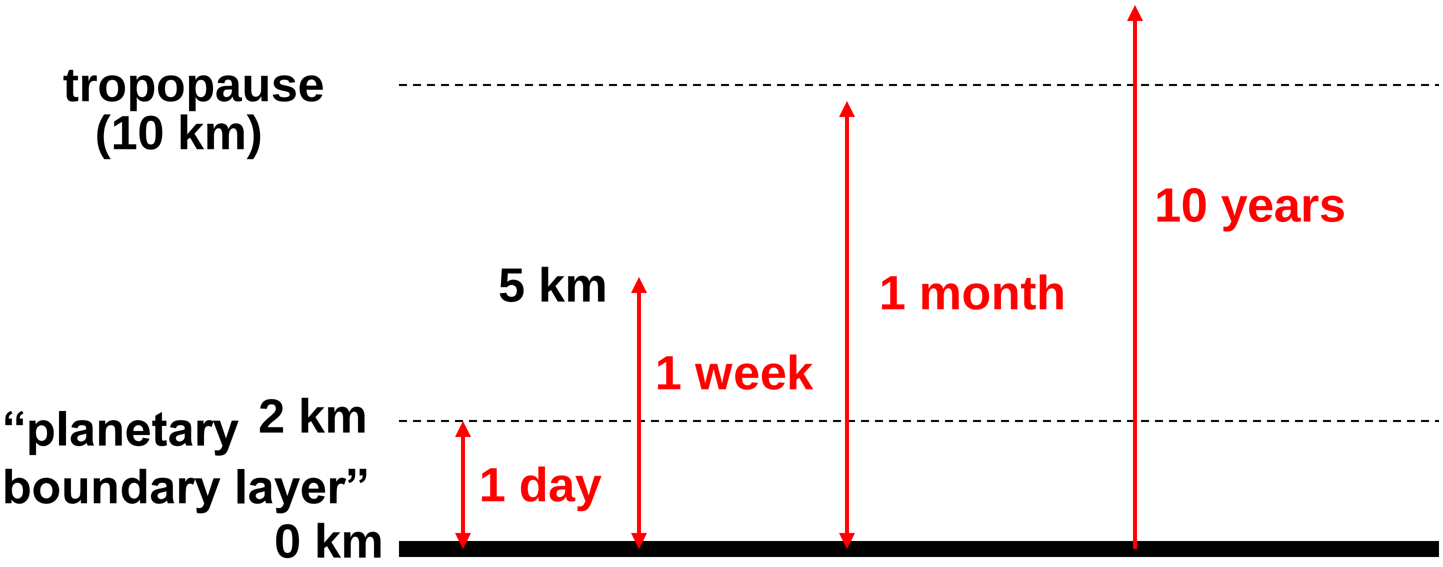


(a) January

TYPICAL TIME SCALES FOR VERTICAL MIXING in the troposphere

- Estimate time Δt to travel Δz by analogy with molecular diffusion:

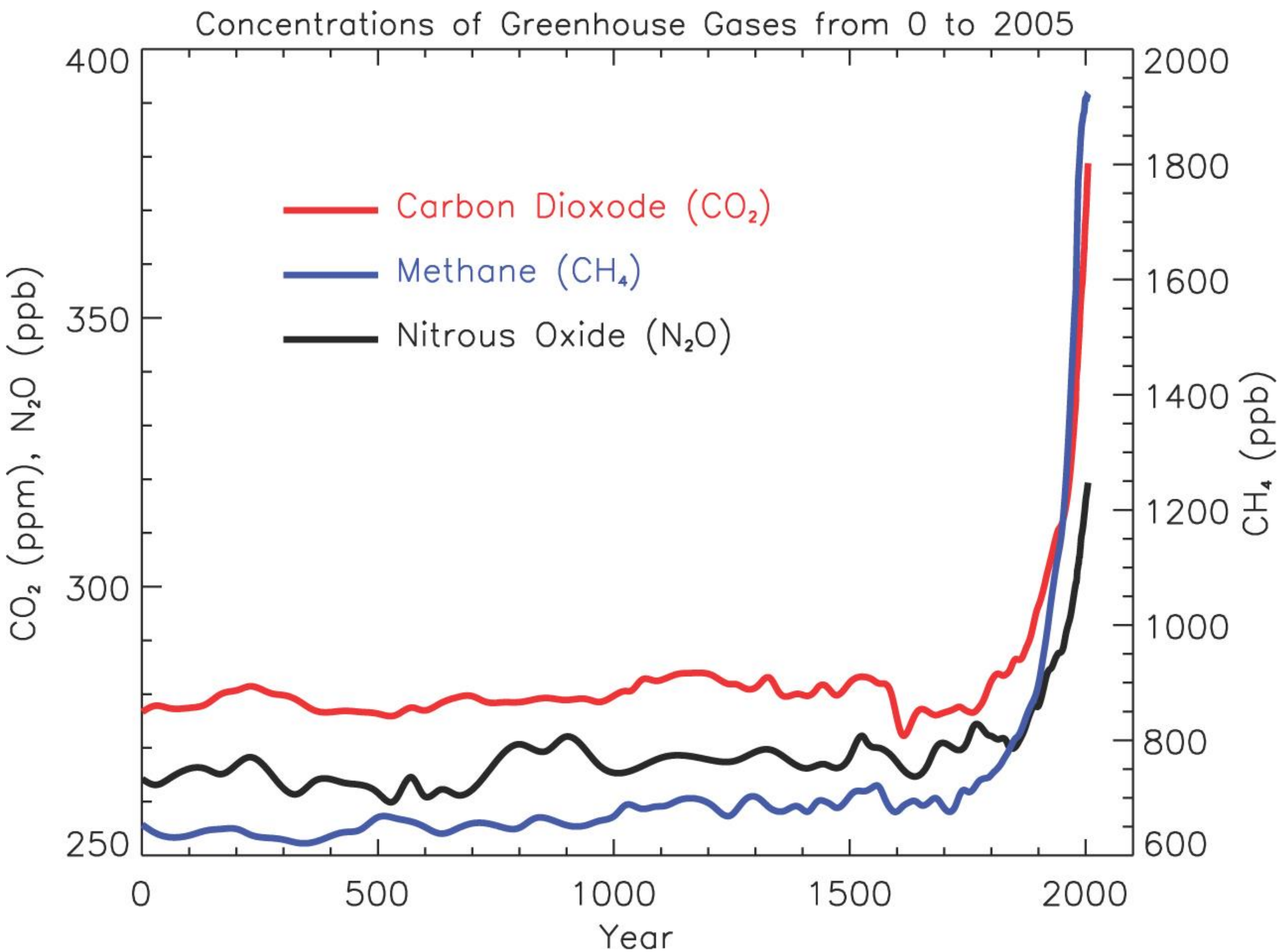
$$\Delta t = \frac{(\Delta z)^2}{2K_z} \quad \text{with } K_z = 10^5 \text{cm}^2\text{s}^{-1}$$




Thank you
by Glynn Gorick

Gobal Change of the Atmospheric Composition

Development of Greenhouse Gases

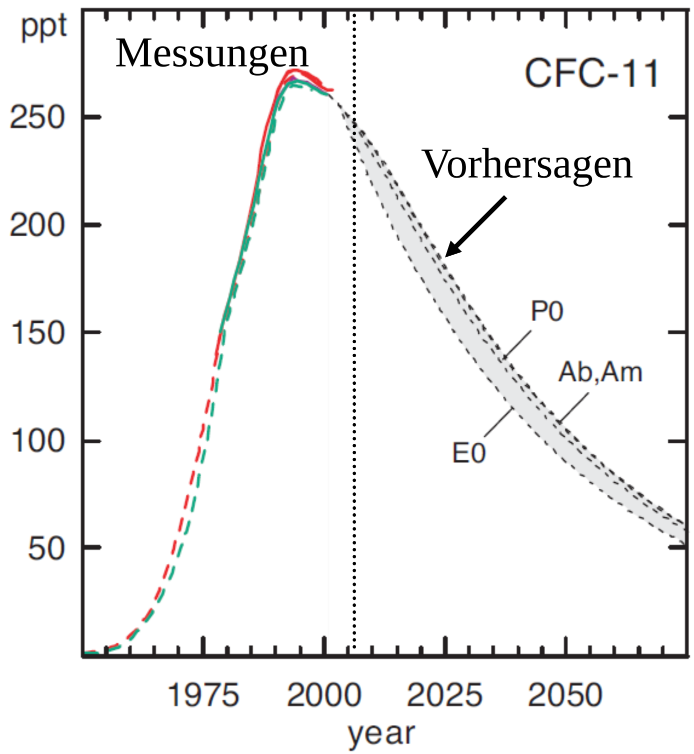


from IPCC 2007

Expected global temperature increase
+1°C to +6°C   until 2100

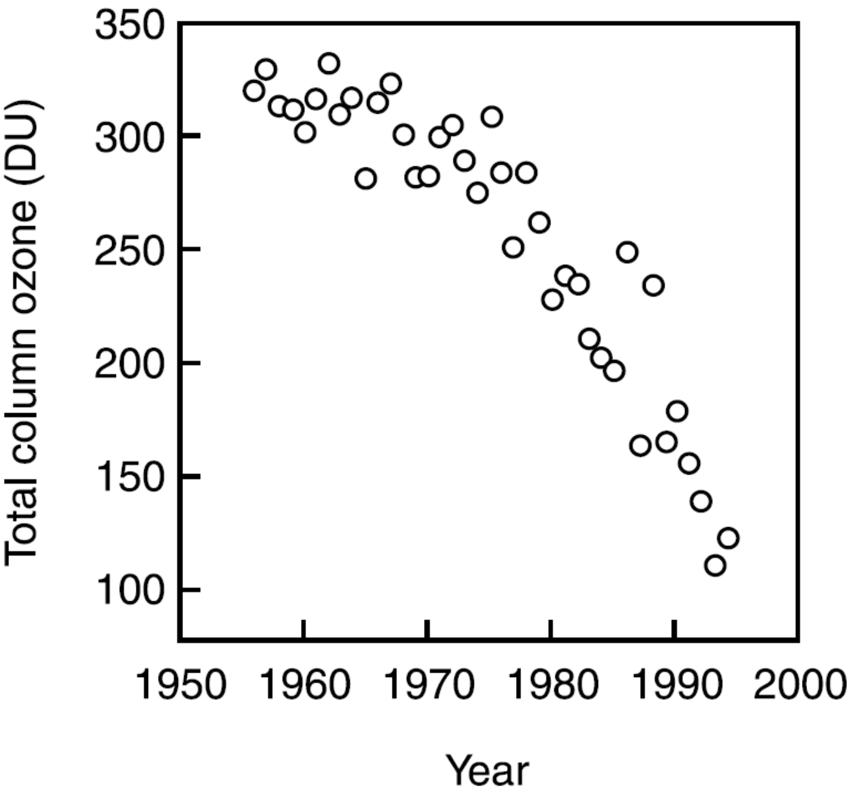
Stratospheric Ozone Depletion

Atmospheric CFC Load



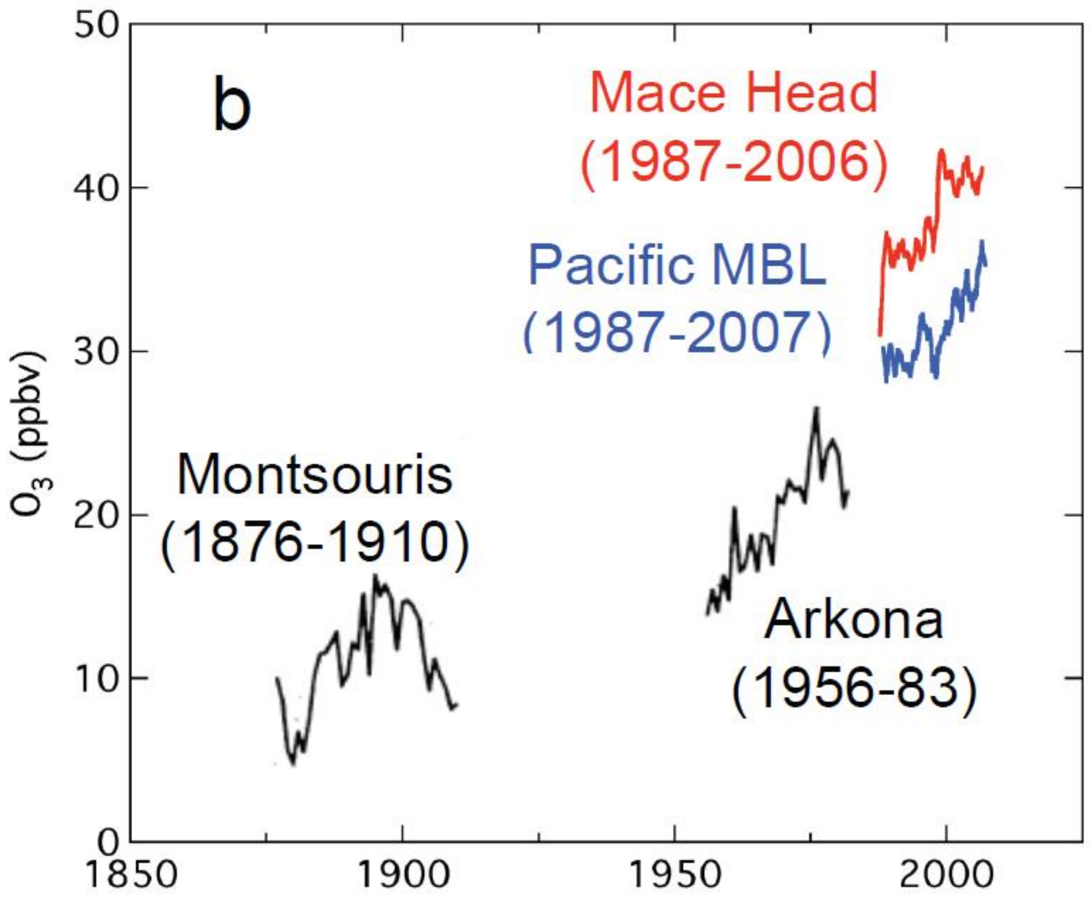
from WMO Report 2003

Antarctic Ozone Hole



Total ozone column in October
above Halley Bay
after Jones & Shanklin, 1995

Increase of Tropospheric Ozone

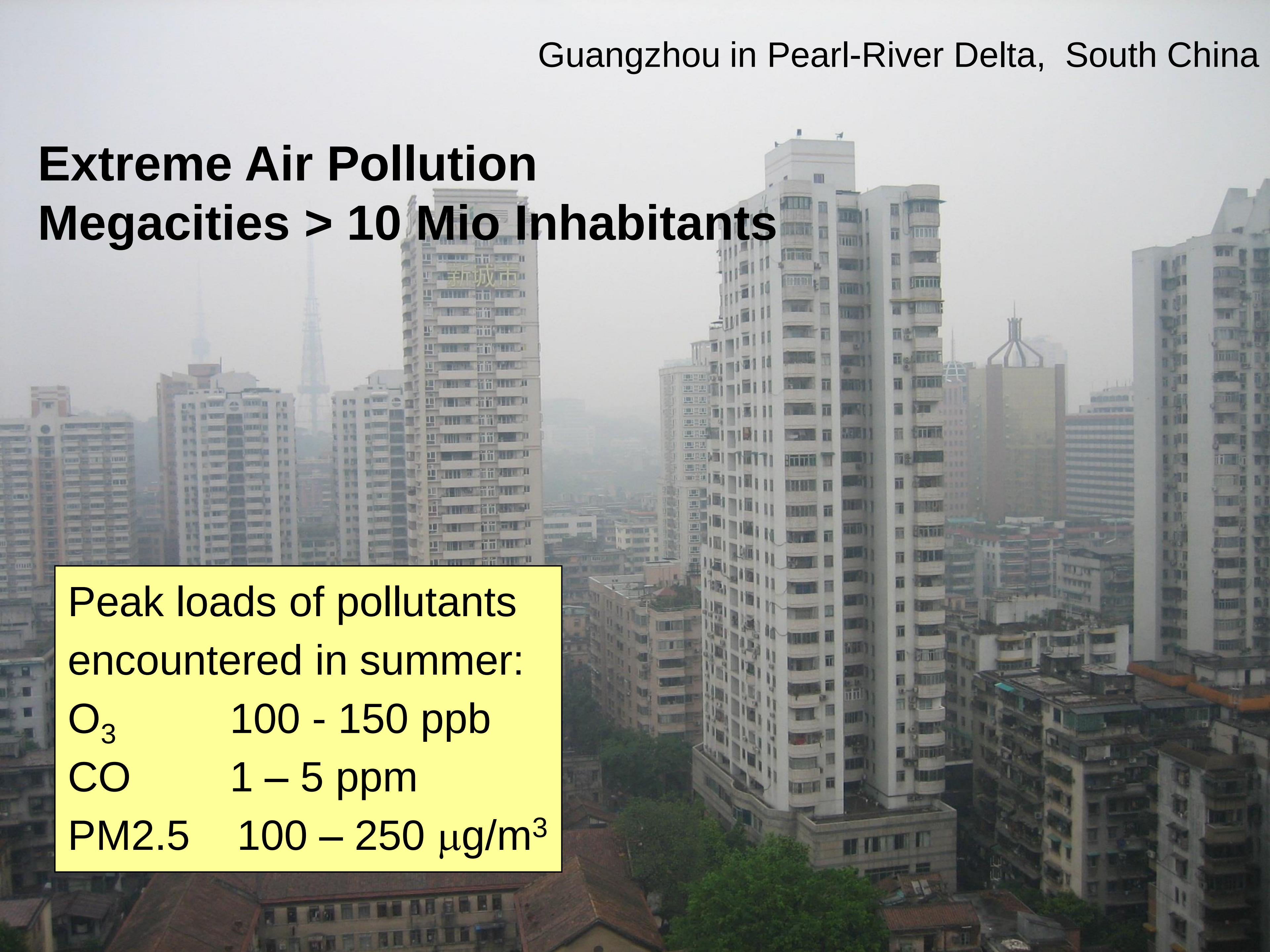


Tropospheric ozone is part of photochemical smog (toxic air pollutants)

Parrish et al., 2008; Volz & Kley, 1988

Guangzhou in Pearl-River Delta, South China

Extreme Air Pollution
Megacities > 10 Mio Inhabitants



Peak loads of pollutants encountered in summer:

O_3	100 - 150 ppb
CO	1 – 5 ppm
PM2.5	100 – 250 $\mu g/m^3$