PHY353S
Electromagnetic Waves
Lecture 1

- **Electromagnetic interaction caused by fundamental property of matter: matter contains charges**

- **Compared to other forces in nature electromagnetic forces dominate our daily existence**

<u>Forces</u>:
Gravitational
Weak
Electromagnetic
Strong

Increasing strength

- **Strong force limited to short spatial scales**
- **Gravitational and weak forces occur over large and small spatial scales, respectively, but are weaker than electromagnetic forces**

Electromagnetic forces represent the dominant interactions in areas ranging from chemistry to electronics to optics and to the way we visually perceive the world

Electrodynamics

- **Stationary and moving charges generate electric fields**
- **Electric currents produce magnetic fields**
- **Electromagnetic fields exert force on charges:** $\vec{F} = q(\vec{E} + v \times \vec{B})$
- **Time varying (E,B) fields induce (B,E) fields**
- **Electromagnetic fields interact with matter by accelerating charges, which in turn emit electromagnetic radiation**

Focus of this course

Implications for Interaction of Electromagnetic Radiation with Matter

1. **The blue colour of sky light - Rayleigh scattering:**
   EM radiation induces oscillating dipoles in atmospheric molecules (Ch 11)

Intensity of scattered radiation, $I \propto \frac{1}{\lambda^4}$

⇒ Shorter wavelength (UV and blue) more efficiently scattered

- **Dipole radiation results in polarization of skylight: no radiation along axis of dipole ⇒ radiation along line of sight is polarized**

Implications for Interaction of Electromagnetic Radiation with Matter

2. Polarization of star light due to interstellar dust (first observed in 1940s):

- **Elongated dust grains are aligned with major axis perpendicular to ambient interstellar magnetic field lines**
- **EM waves with polarization parallel to major axis of elongated dust grains are more readily absorbed**
- **Transmitted light consists of EM radiation with polarization perpendicular to the major axis of the dust grains, and parallel to the interstellar magnetic field**

Implications for Interaction of Electromagnetic Radiation with Matter

3. Remote sensing of the atmosphere:
We use measurements of EM radiation to learn about the composition and dynamics of the atmosphere (we measure the absorption and emission spectra of atmospheric gases)

EM radiation induces:

- **Electronic transitions**
  (mainly in the ultraviolet (UV) and visible)

- **Vibrational transitions**
  (mainly in the infrared (IR))

- **Rotational transitions**
  (mainly in the infrared (IR))

Vibrational Modes Of H_2O and CO_2

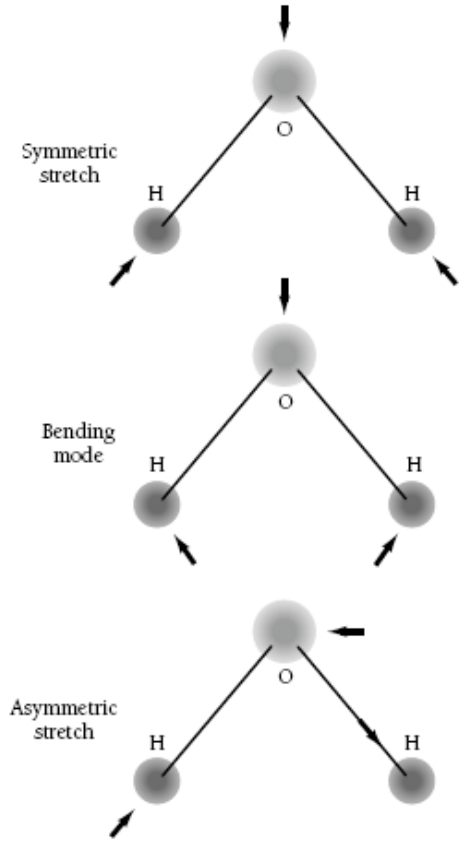


Figure 3.6 Vibrational modes of H_2O.

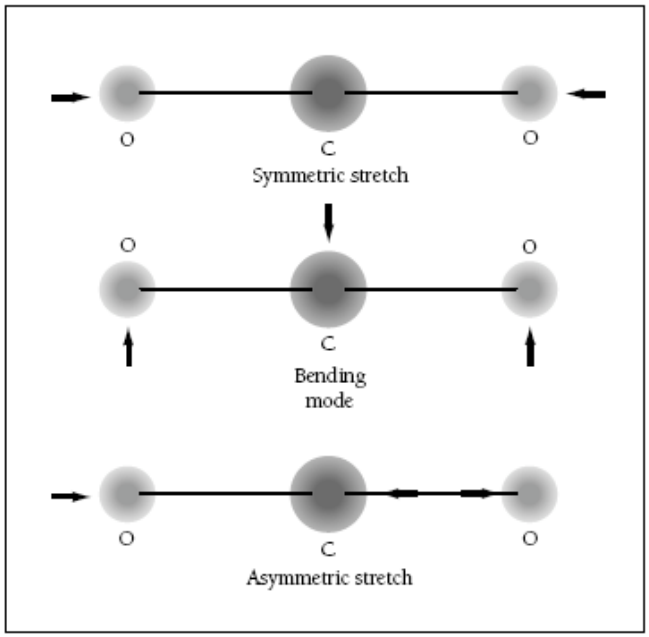
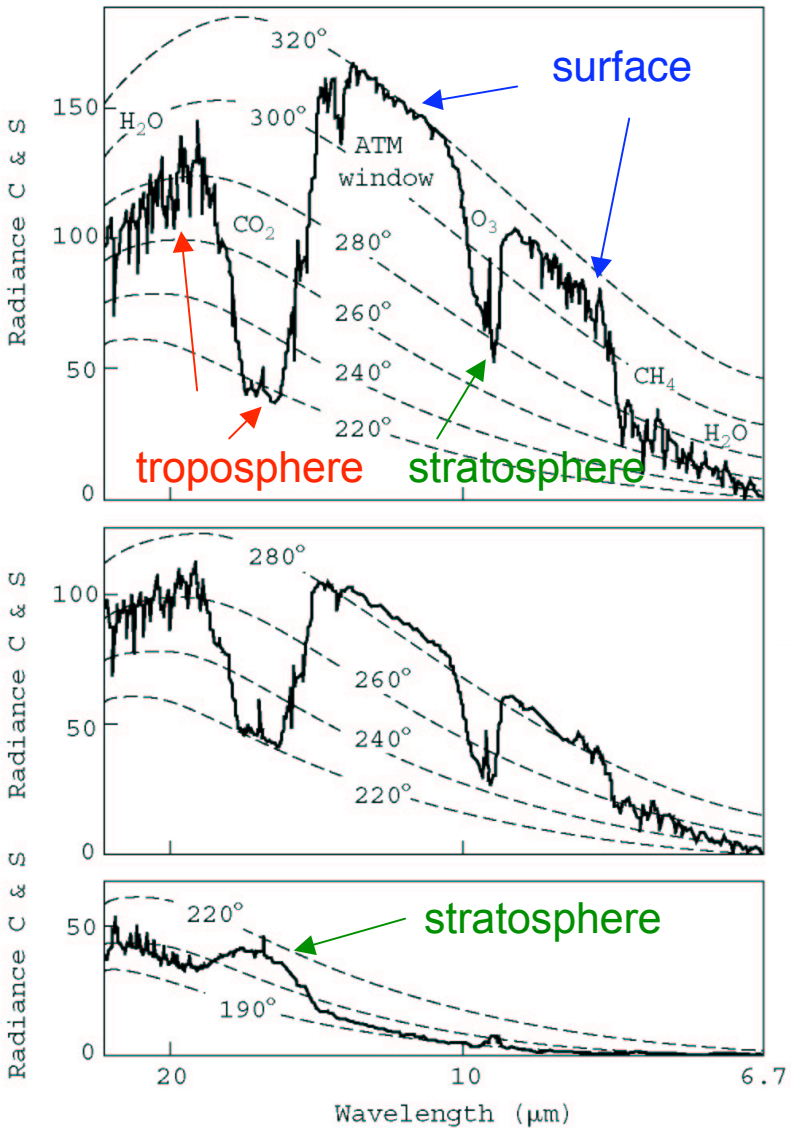


Figure 3.5 Vibrational modes of CO_2. Source: UPL 1994.

Terrestrial Radiation Spectrum From Space



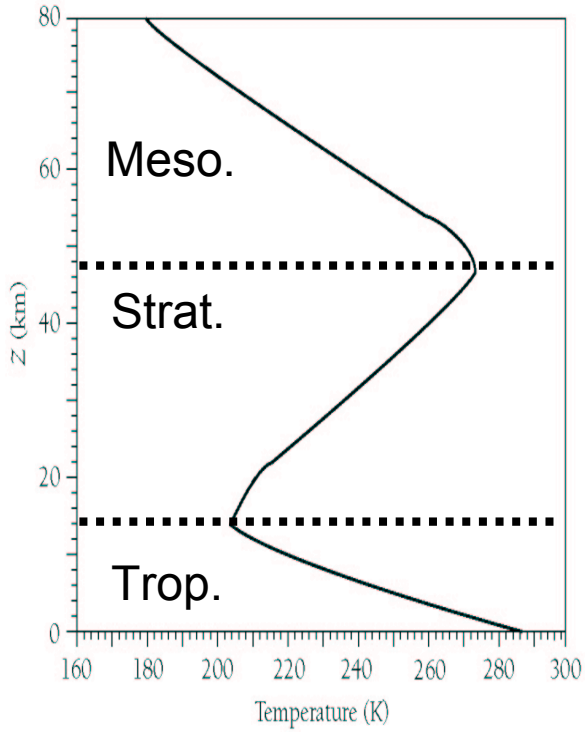
Composite of blackbody radiation spectra for different *T*

Sahara

Mediterranean

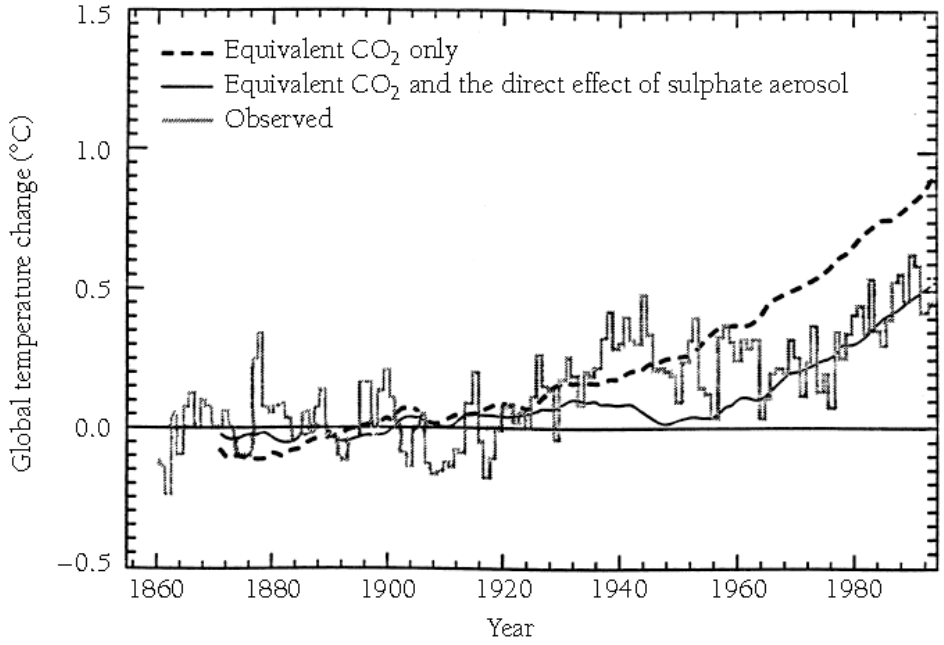
Antarctica

Atmospheric T profile



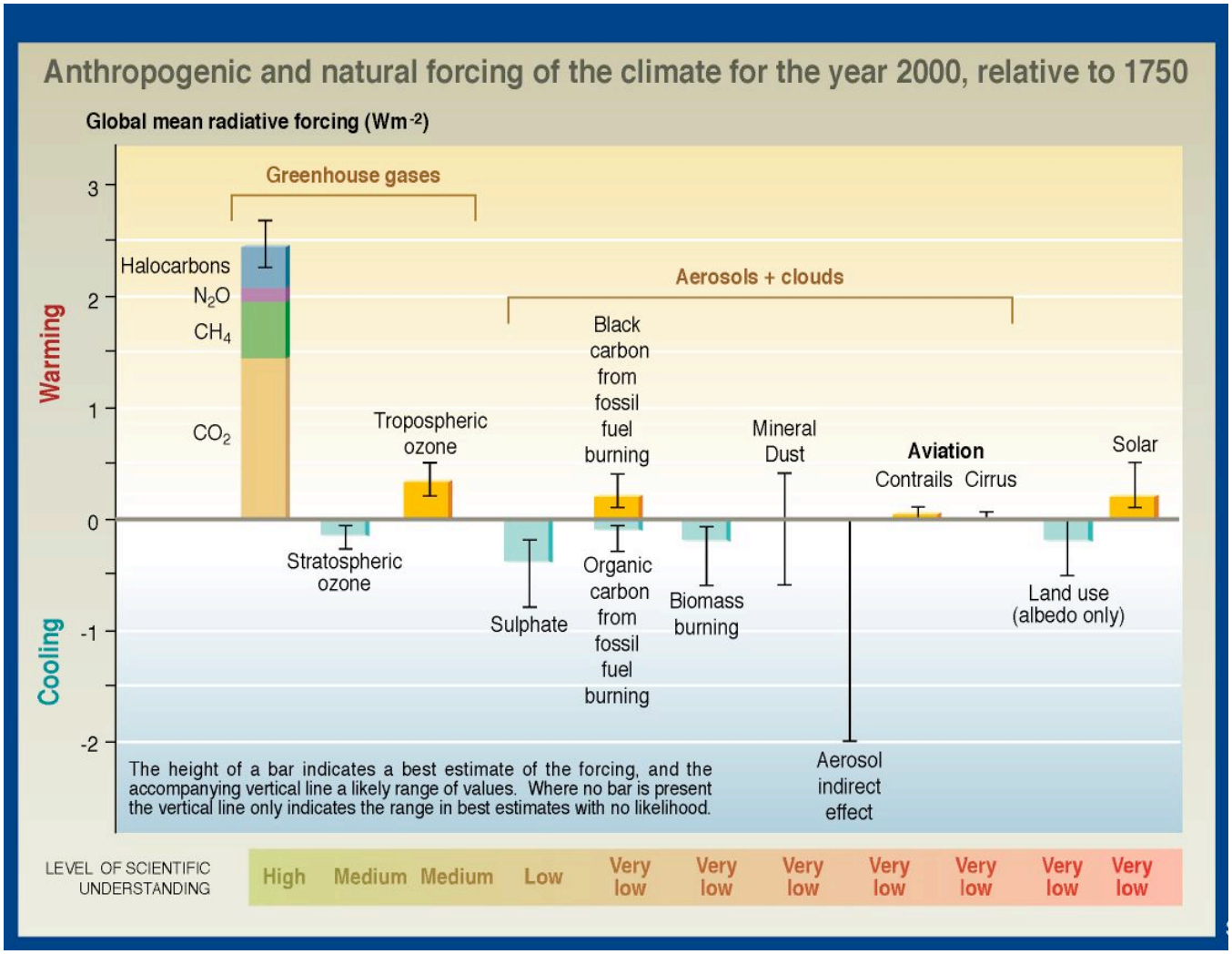
Implications for Interaction of Electromagnetic Radiation with Matter

4. Atmospheric aerosols (small solid particles and liquid droplets) absorb and scatter incoming sunlight



Cooling associated with aerosols from industrial emissions of SO_2 may contribute a significant offset to CO_2-induced warming

Implications for Interaction of Electromagnetic Radiation with Matter: radiative effects of atmospheric aerosols



The effects of aerosol are a large source of uncertainty in climate change