Air Pollutants & Air Quality: Part 2

- Atmospheric Temperature Profile & Stability
- Vertical Mixing & Temperature Inversion
- Large Scale Circulation & Implications

Atmospheric Stability: Vertical Stability

- Vertical dispersion of pollutants greatly depends on the rate of change of air temperature with altitude

- Stable condition: buoyancy forces $\rightarrow \leftarrow$ vertical motion;

  $\Rightarrow$ air dispersion ______

- Unstable condition: buoyancy forces $\uparrow$ vertical motion;

  $\Rightarrow$ air quality ______

Atmospheric Stability: Adiabatic Lapse Rate

An air parcel with adiabatic condition: no heat exchange between the parcel and surrounding air:

(1) when the air parcel moves upward in the atmosphere,

the air parcel experiences $\downarrow$ pressure,

causing it to _________ (under isothermal condition);

(2) when the air parcel moves downward in the atmosphere,

the air parcel experiences $\uparrow$ pressure (adiabatic),

causing it to ____________ (under adiabatic condition)

Lapse Rate, Γ

- Dry adiabatic lapse rate, $\Gamma_{dry} = dT/dz = -\,g/\hat{c}_p$

  where $|g/\hat{c}_p|$ is a constant for dry air $\cong$ 0.967°C/100 m

  (or 1°C/102.39 m)

- Lapse rate in a saturated condition, Γ_{wet}

$$\Rightarrow \quad -dT/dz = g/\hat{c}_p + (\Delta H_v/\hat{c}_p)(dw_v/dz)$$

where

ΔH_v: latent heat of vaporization per gm of $H_2O_{(l)}$

dw_v/dz: change rate of mass of $H_2O_{(g)}$ per unit mass of air

Stability & Lapse Rate

Vertical stability depends on temperature profile of the atmosphere (Λ) and air parcel (Γ):

$\Lambda = \Gamma$ ………… neutral stability

$\Lambda > \Gamma$ ………… unstable (vertical motions $\uparrow$)

$\Lambda < \Gamma$ ………… stable (vertical motions $\downarrow$)

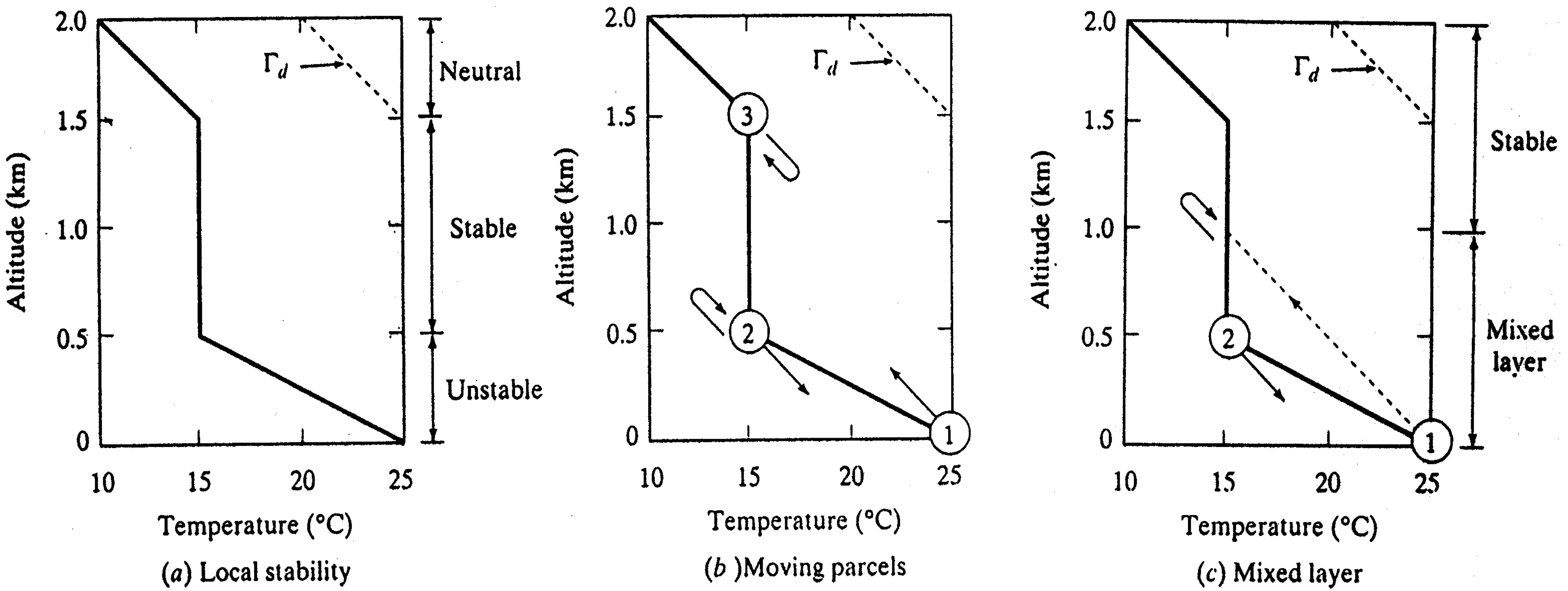
Adiabatic Lapse Rate: Example

Should the air coming into the cabin of a high-altitude aircraft be cooled or heated ?

An aircraft flying at an altitude of 9 km (30,000 ft) draws in fresh air at -40 ^{o}C for cabin ventilation. If that fresh air is compressed to the pressure at sea level, would the air need to be heated or cooled to keep the cabin temp. at 20 ^{o}C?

Source: Introduction to Environmental Engineering and Science by G.M. Masters, Prentice Hall, ‘97

Stability and Lapse Rate



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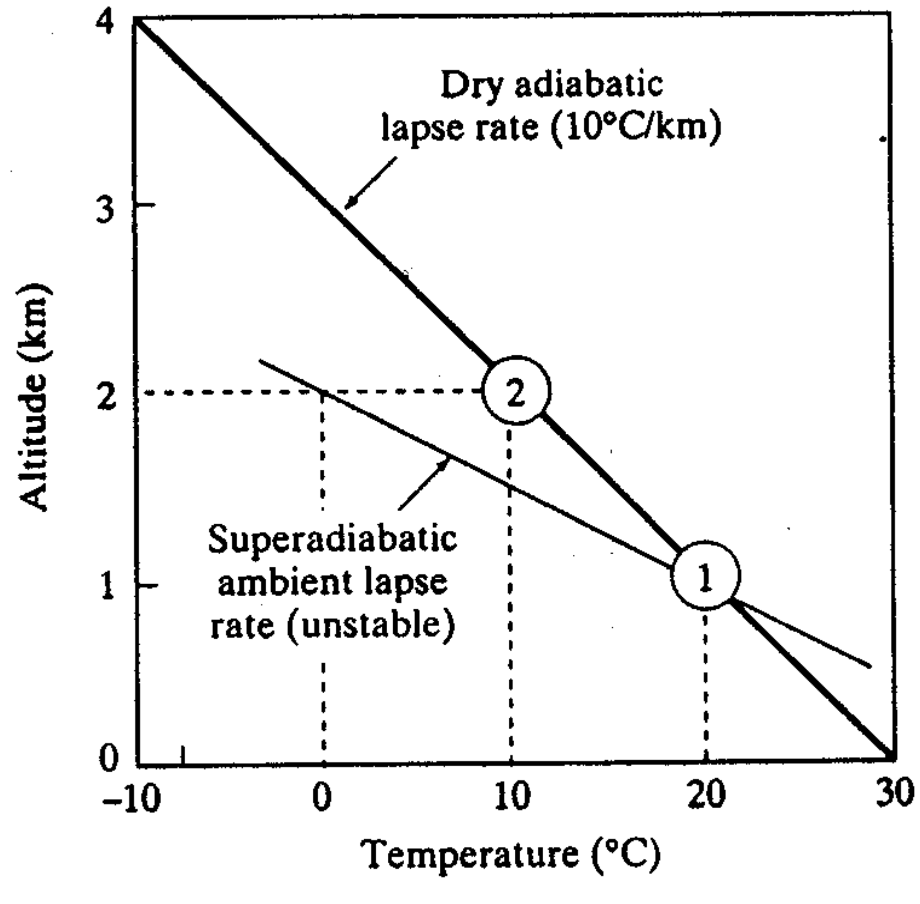
Stability and Lapse Rate



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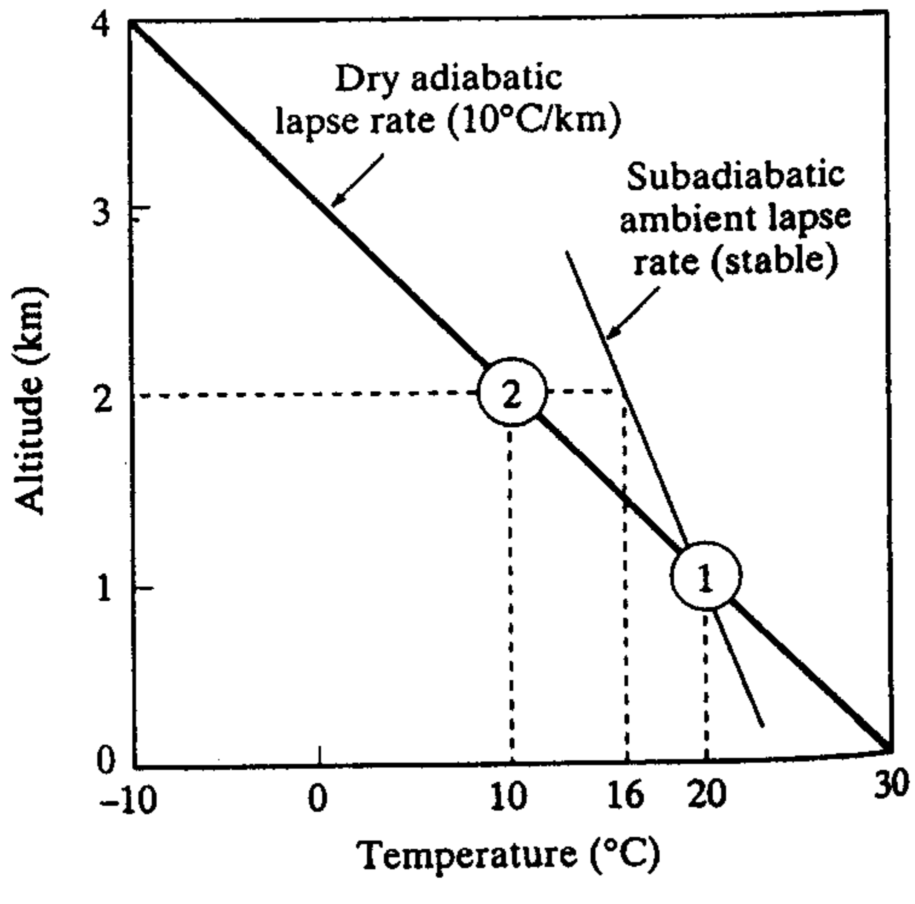
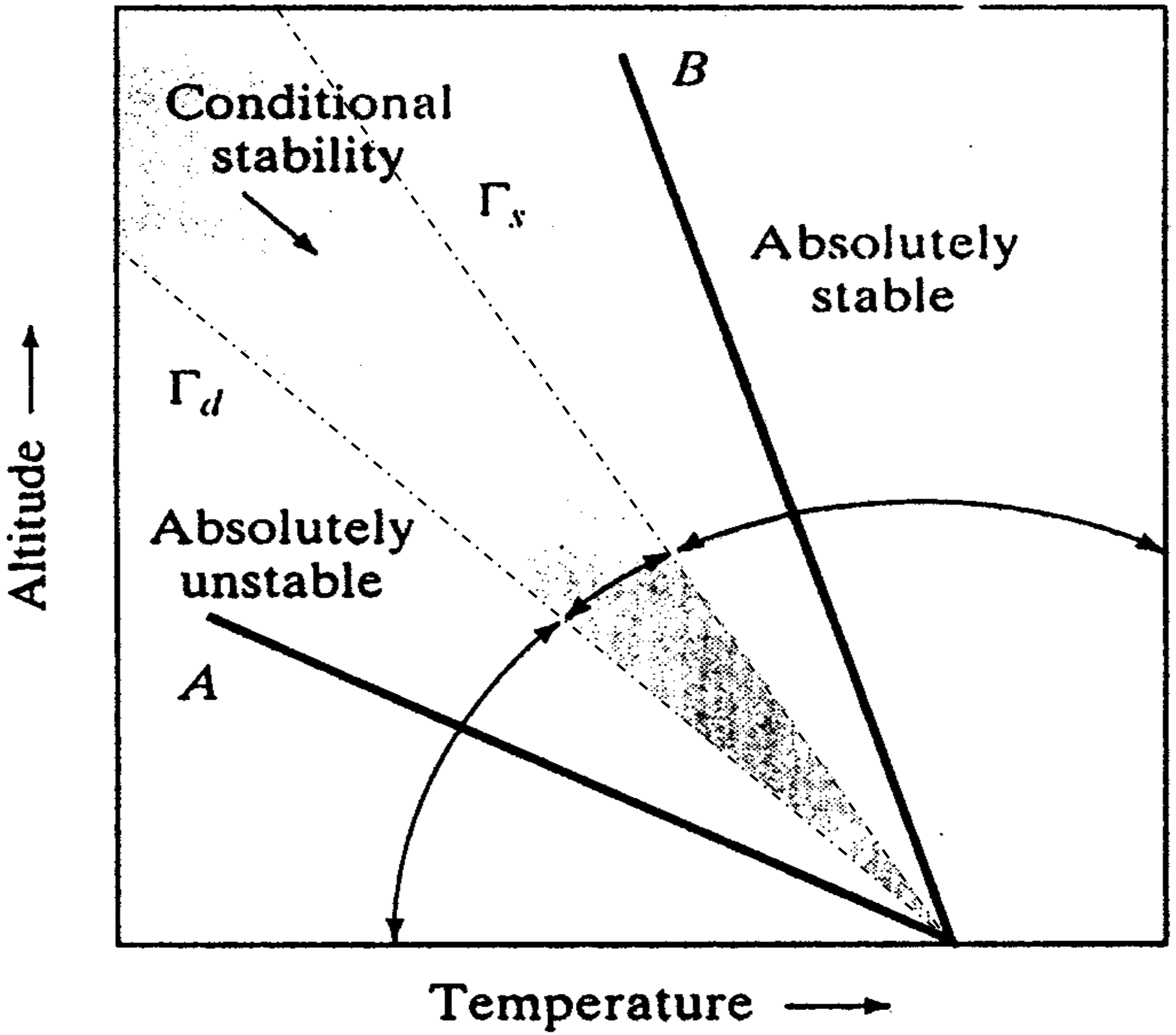


(b)

Source: Introduction to Environmental Engineering and Science by G.M. Masters, Prentice Hall, ‘97

Stability and Lapse Rate

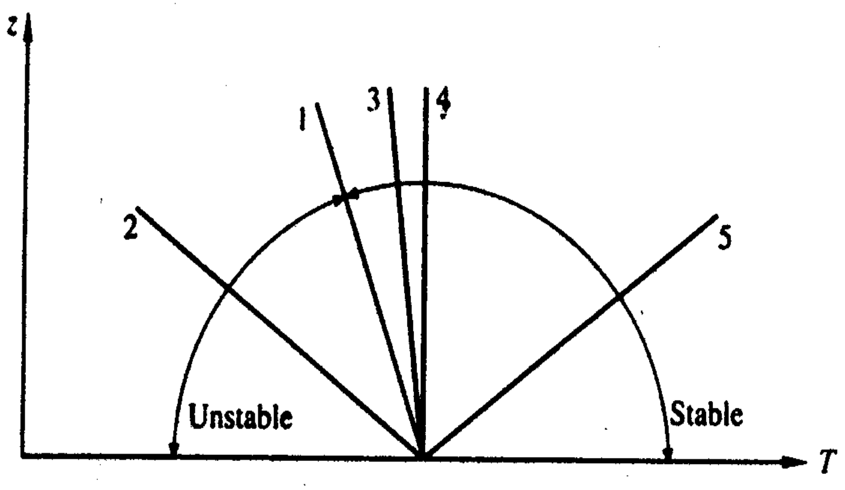


Source: Masters, G.M., Introduction to Environmental Engineering and Science, by, Prentice Hall, New Jersey (1997)

Stability and Lapse Rate

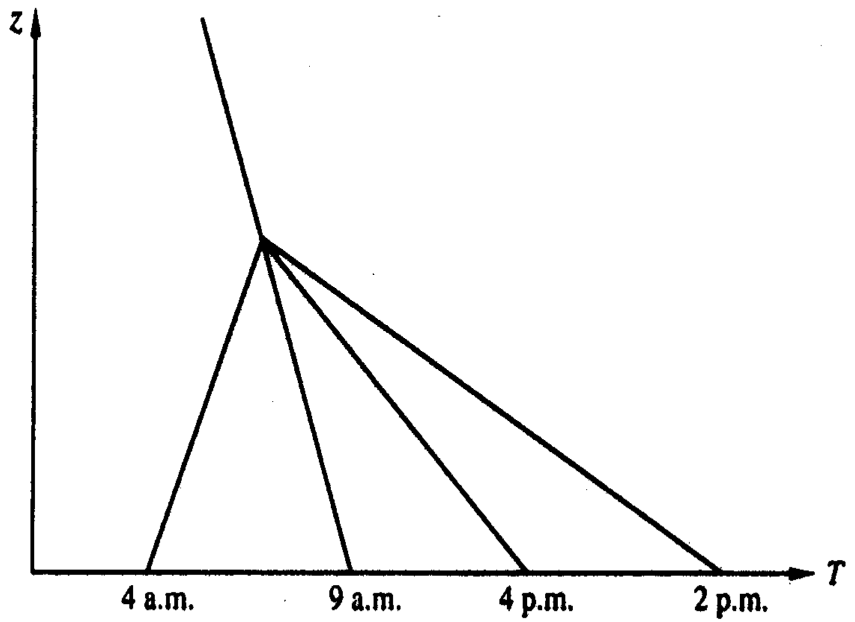
Atmospheric temp. profiles

1. Neutral; adiabatic lapse rate
2. Unstable; ________________
3. Stable; ________________
4. Stable; ________________
5. Extremely stable; ___________



Diurnal temp. variation

- 4 am: ____________________
- 9 am: _____________________
- 2 pm: ____________________
- 4 pm: ____________________

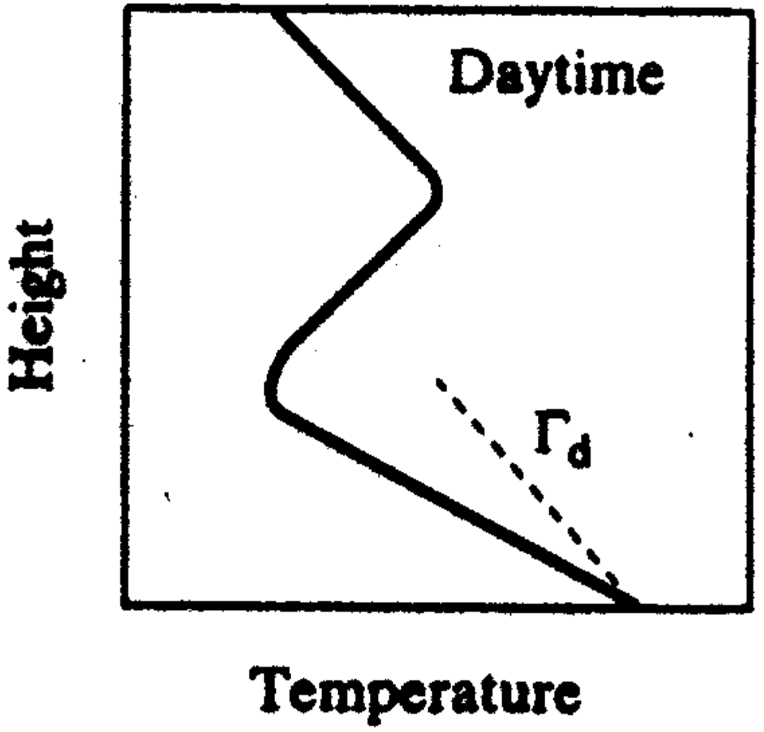


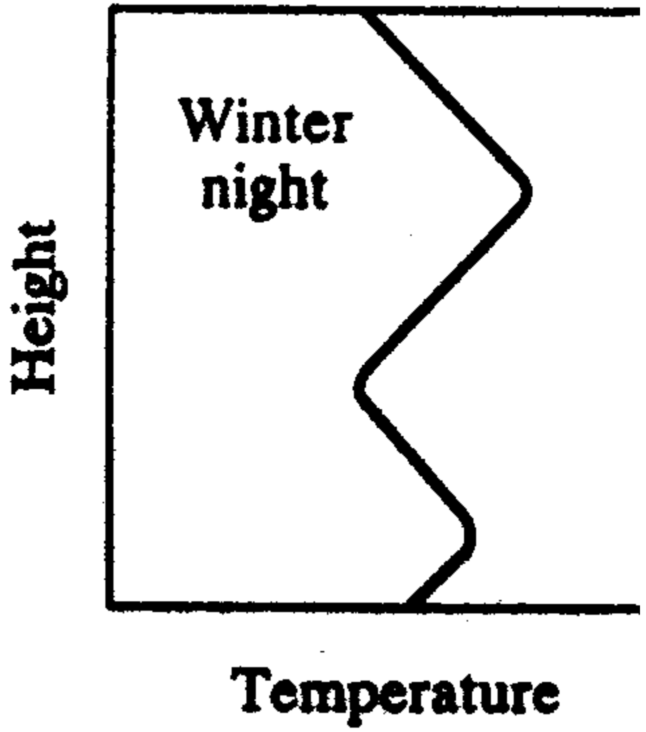
From Atmospheric Chemistry and Physics of Air Pollution by Seinfeld, J.H., John Wiley & Sons, New York, 1986.

Temperature Inversions: Radiation Inversion

Ground-based/surface inversions:

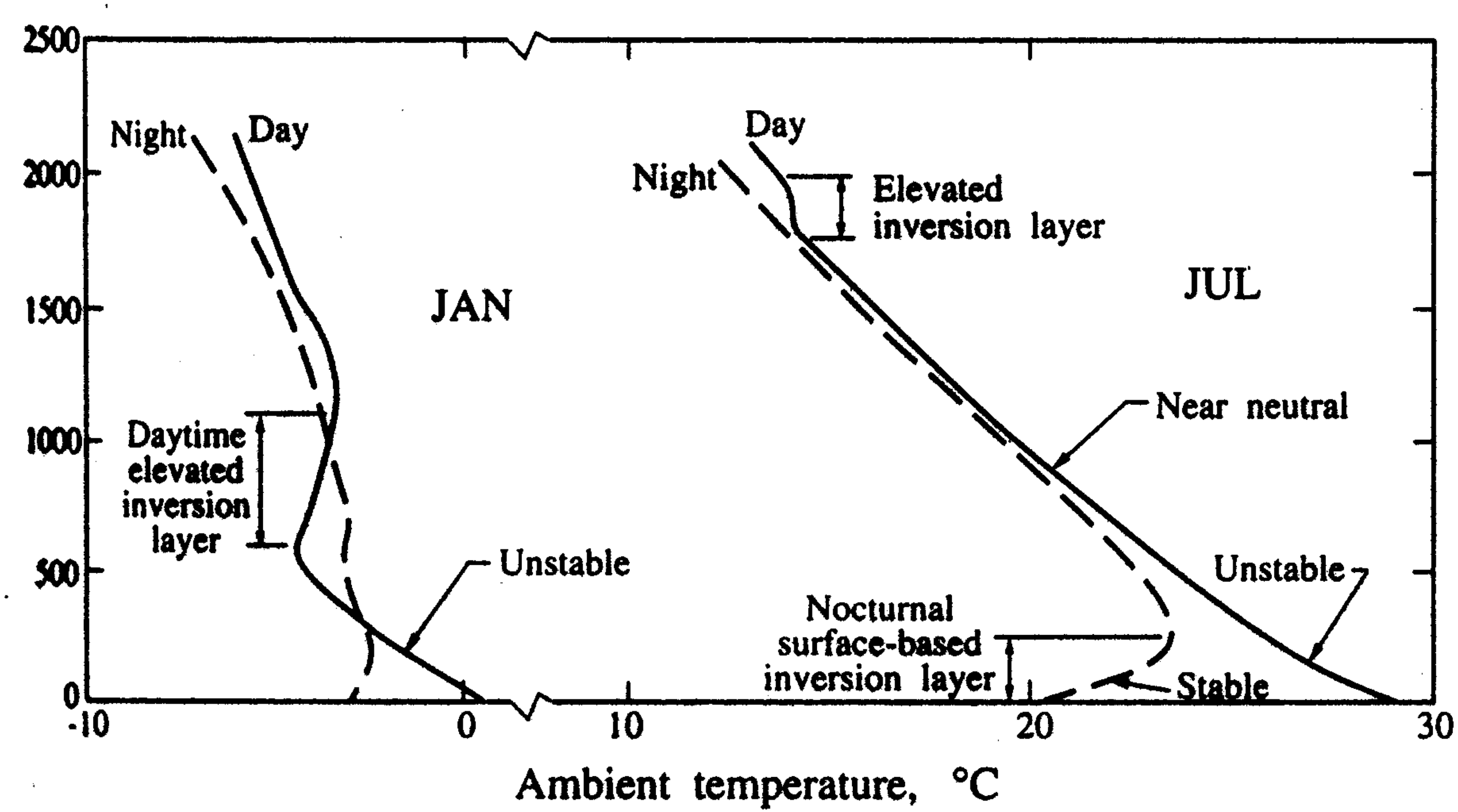
- nocturnal cooling of the earth's surface
- cloudy nights vs. clear nights
- close to the ground, lasting for only a few hours
- fumigation: pollutants are brought back to earth





Source: Introduction to Environmental Engineering and Science by G.M. Masters, Prentice Hall, New Jersey, 1997

Temperature Inversion



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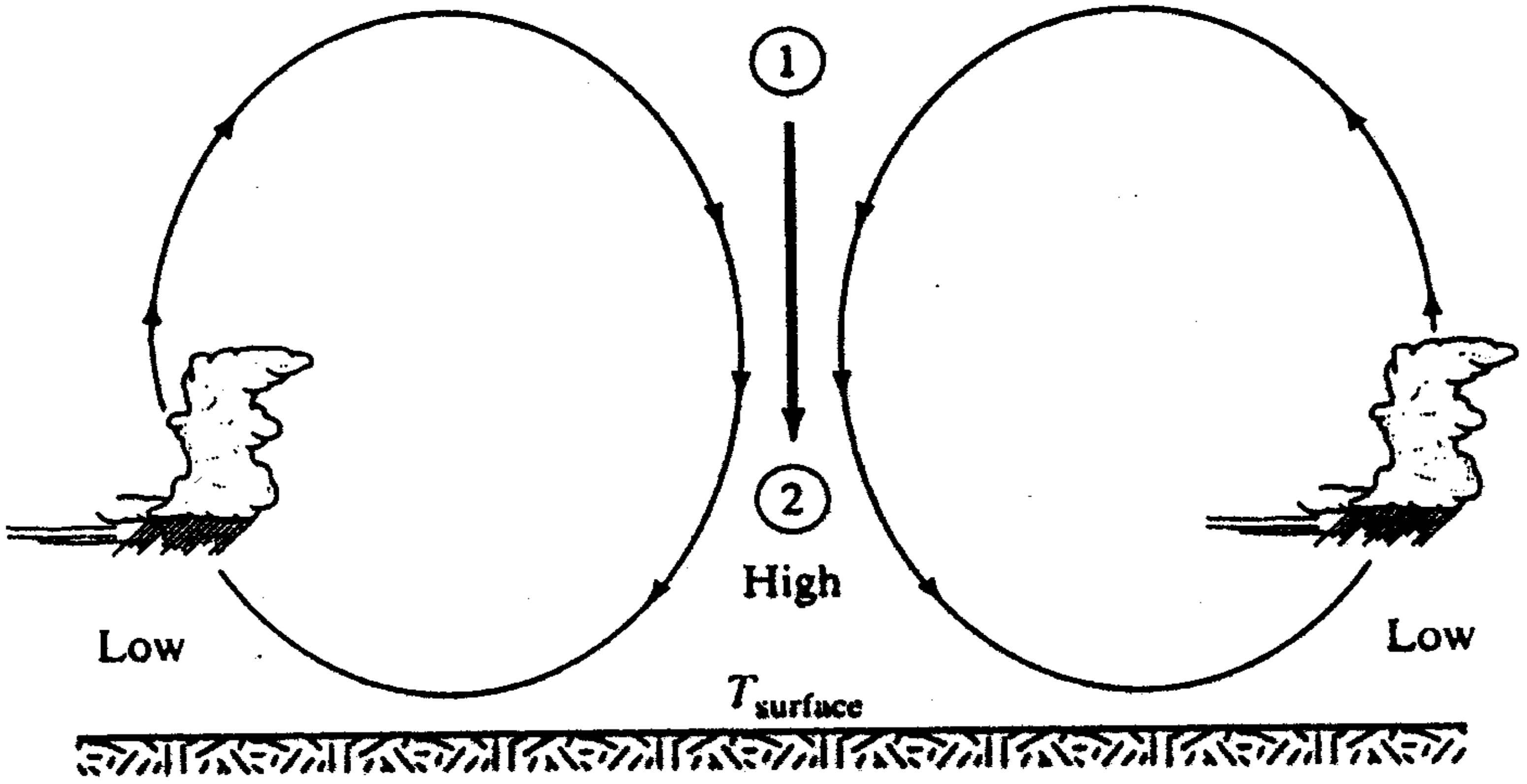
Temperature Inversion: Subsidence Inversion

Inversion aloft:

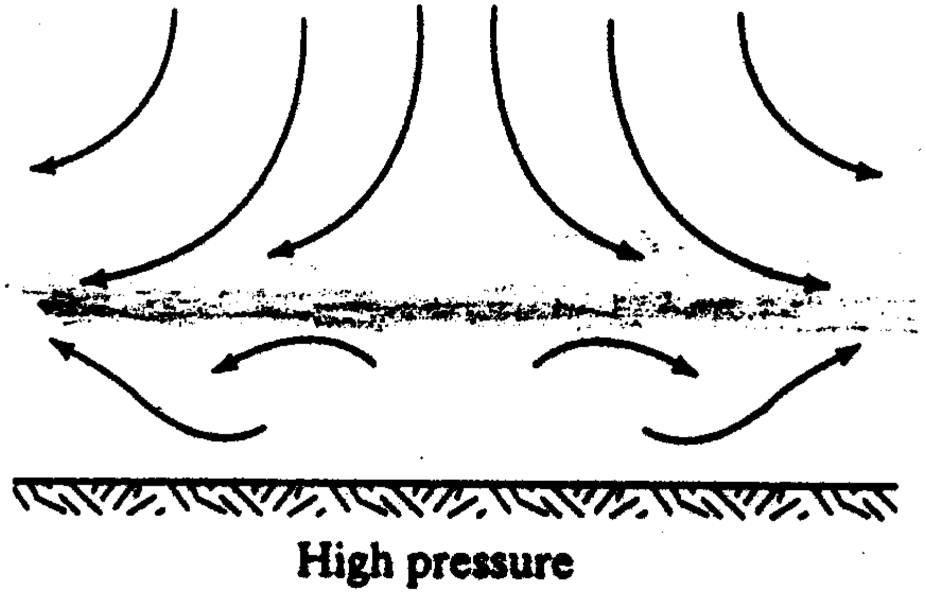
- last for months
- associated with high-pressure weather systems



Source: Introduction to Environmental Engineering and Science by G.M. Masters, Prentice Hall, New Jersey, 1997

Temperature Inversion: Subsidence Inversion

Subsidence close to ground level before aloft



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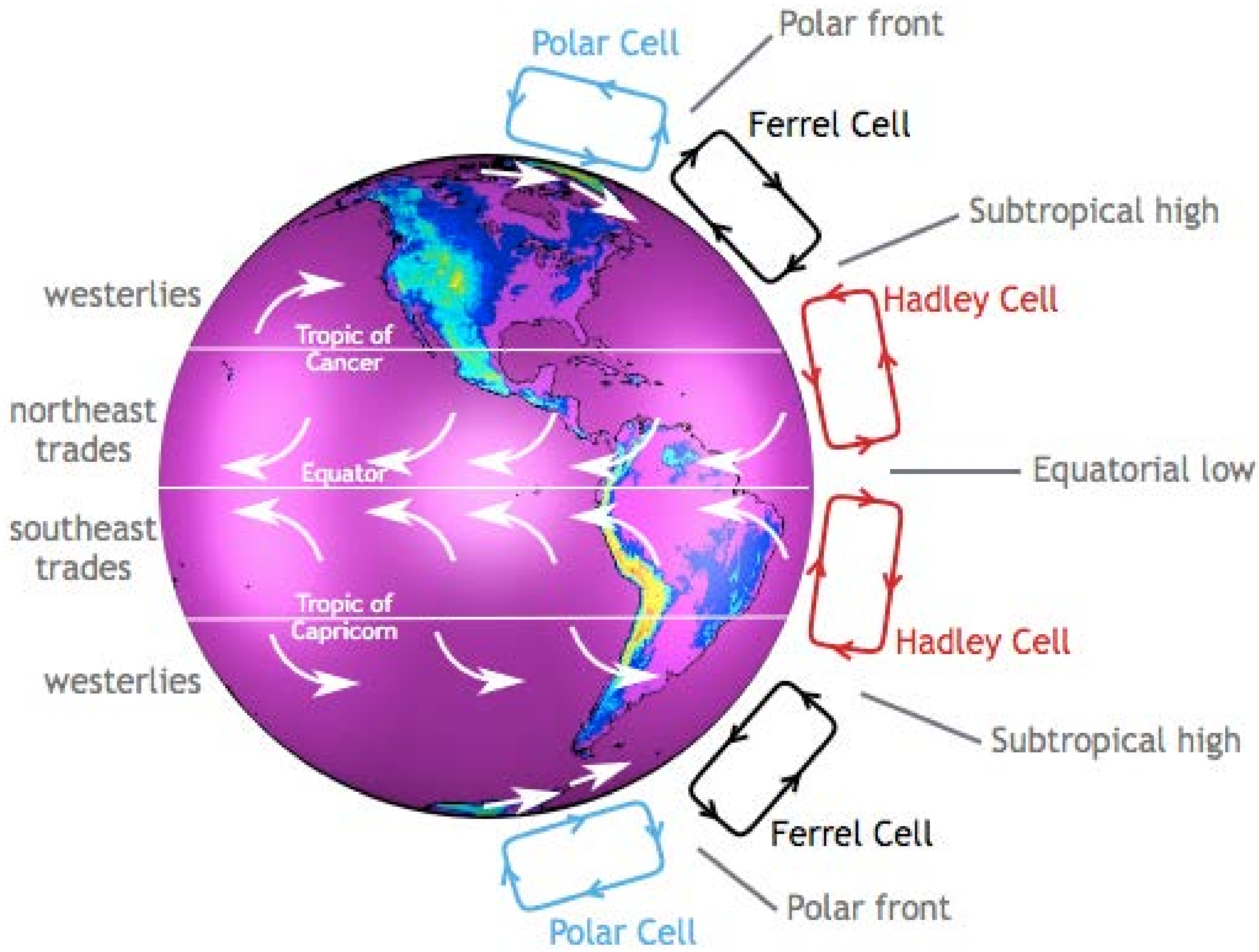
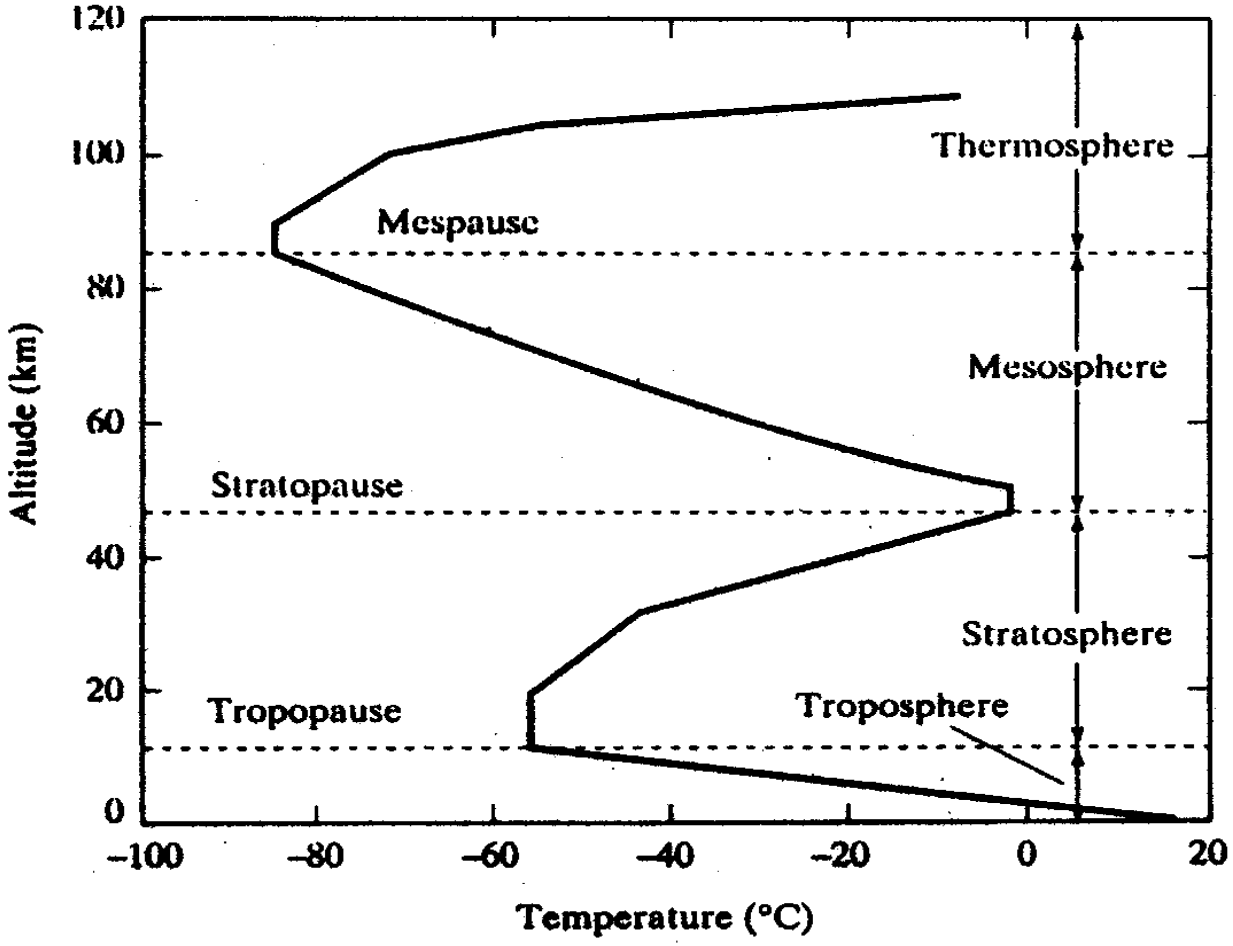
General Air Circulation Pattern



http://www.cmmap.org/learn/climate/circ1.html

Atmospheric Composition

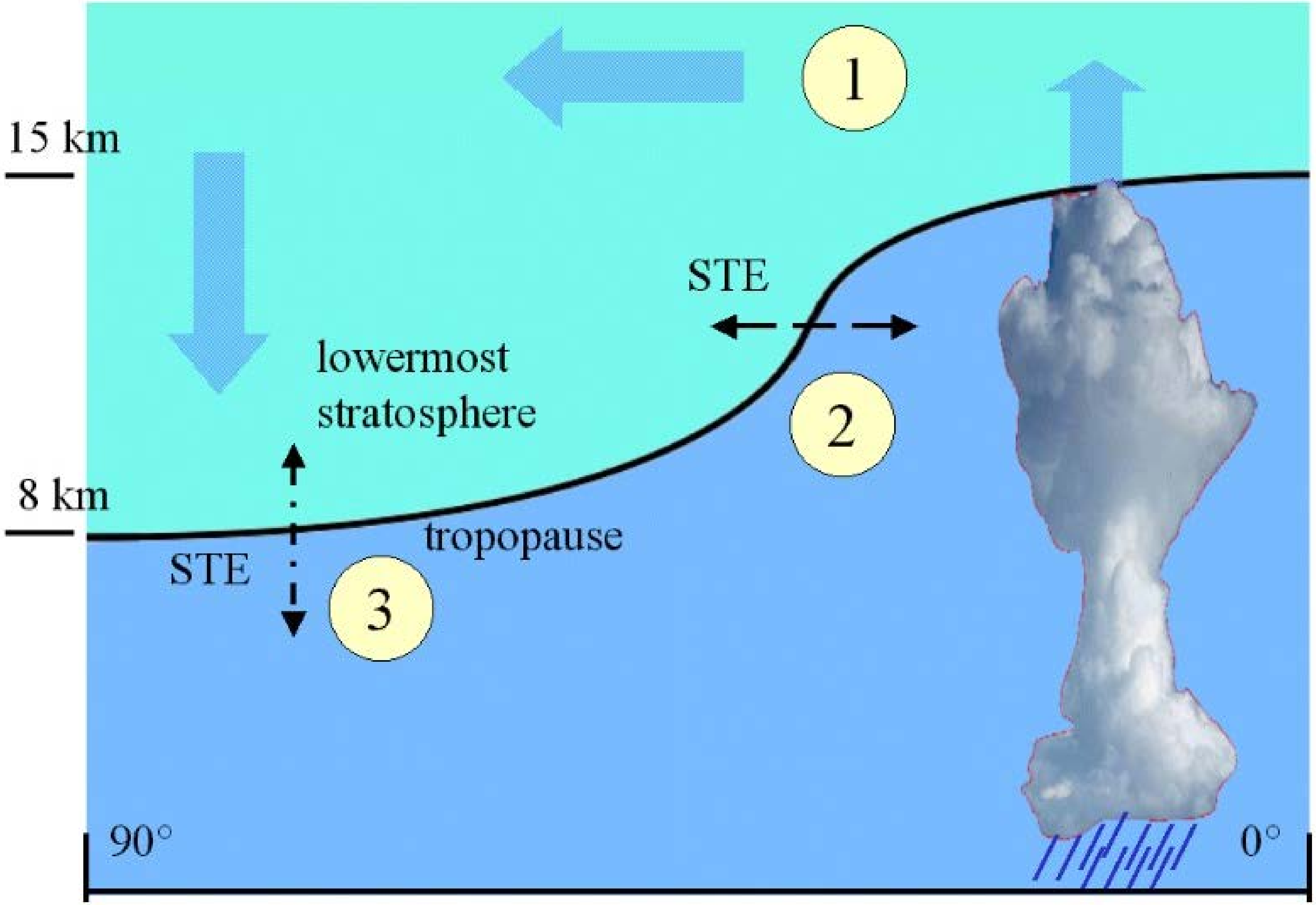
- Horizontal layer - characterized by temperature profile
- Consisting of troposphere (< 10–12 km), stratosphere, mesosphere, and thermosphere



Source: G.M. Masters, Introduction to Environmental Engineering and Science, by Prentice Hall, 1997

Atmospheric Composition & Interactions

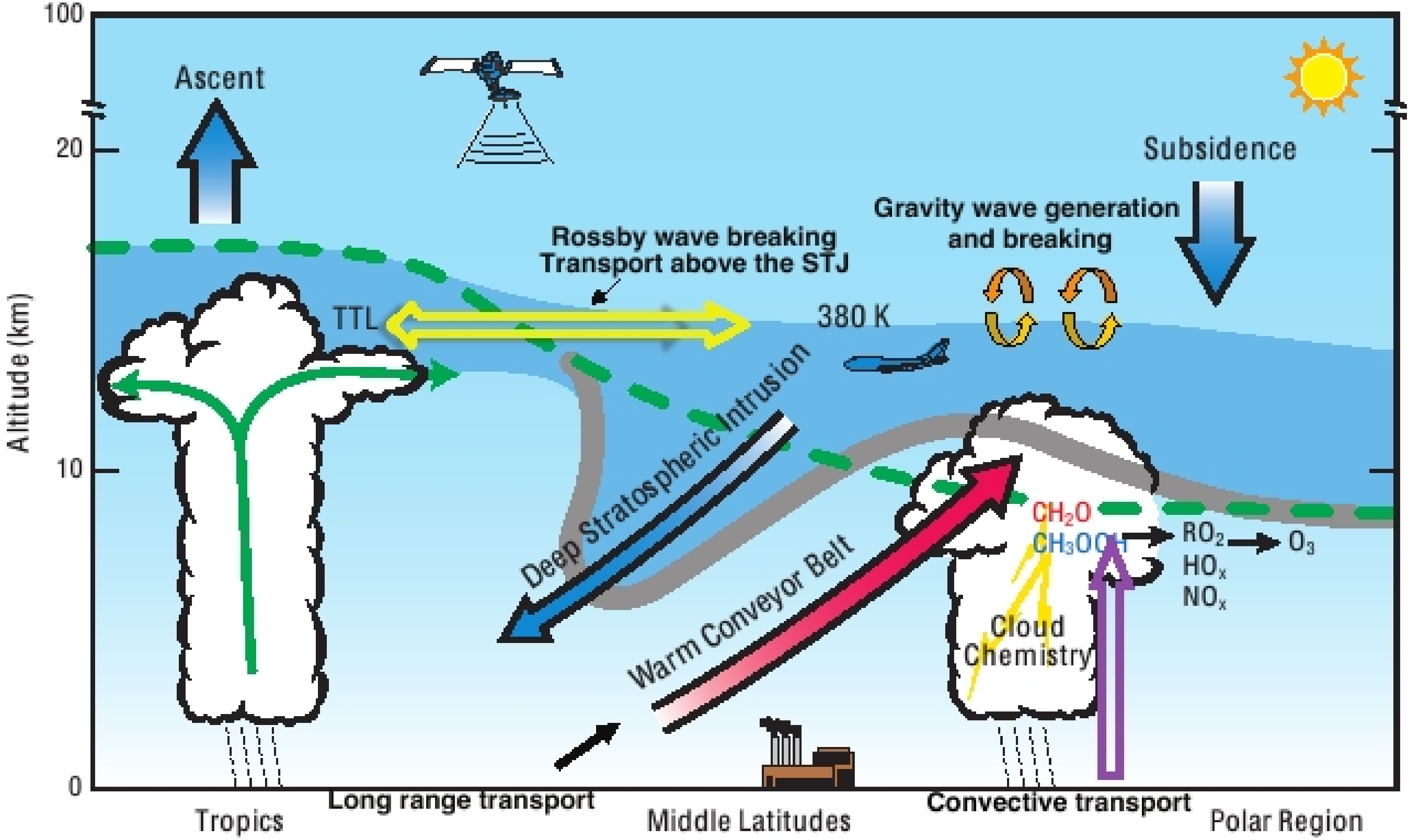
Upper troposphere & lower stratosphere (UTLS) region



Source: Geoff Tyndall, UCAR, https://www2.acd.ucar.edu/atmos-chem-class/

Atmospheric Composition & Interactions

Upper troposphere & lower stratosphere (UTLS) region



TTL: Tropical Transition Layer
STJ: Subtropical Jet

Source: UCAR, http://www.acd.ucar.edu/utls/

Self-Assessment: What Have I learned?

- Is the absolute value of the wet adiabatic lapse rate larger or smaller than that of the dry adiabatic lapse rate?
- How would the adiabatic lapse rate in Singapore differ from that in New Zealand, and why?
- What is the stability in individual atmosphere components?
- What are the differences between the radiative inversion and subsidence inversion?
- Can I describe the subsidence inversion as a part of the general pattern of the global air circulation?