Cloud Formation

GEOG/ENST 2331 – Lecture 11

Ahrens et al. Chapters 5 & 6

Course Stuff

- Midterm
  - Midterm: October 28
  - Lab quiz: Following week

Last lecture

- Lifting mechanisms
  - Orographic lifting
  - Frontal lifting
  - Convergence
  - Convection
- Atmospheric stability

Cloud formation

- **Changing atmospheric stability**
  - **Surface warming**
  - **Advection**
  - **Lifting**
- Condensation
- Types of clouds

Causes of Instability

- DALR is 10°C/km and SALR is 6°C/km
    - Conditional stability when ELR > 6°C/km
    - Absolute instability when ELR > 10°C/km

- Two mechanisms for increasing the lapse rate:
    1. Temperature change
        a. Heat the surface air
        b. Cool the upper air
    2. Potential instability
        - Lifting of a layer of air

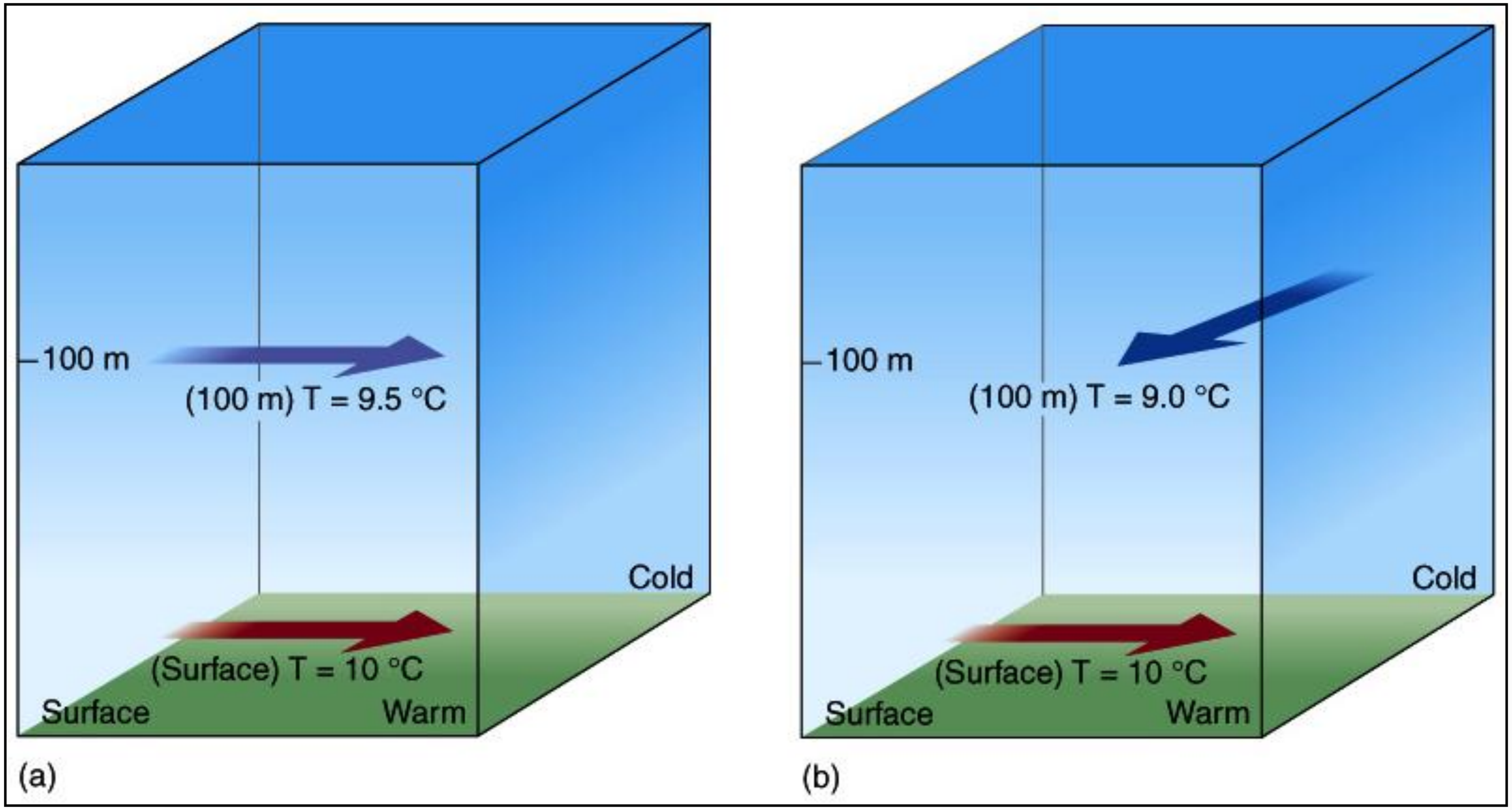
1a Surface Warming

	7°C/km		12°C/km
1000 m	10°C	→	10°C
0 m	17°C	→	22°C

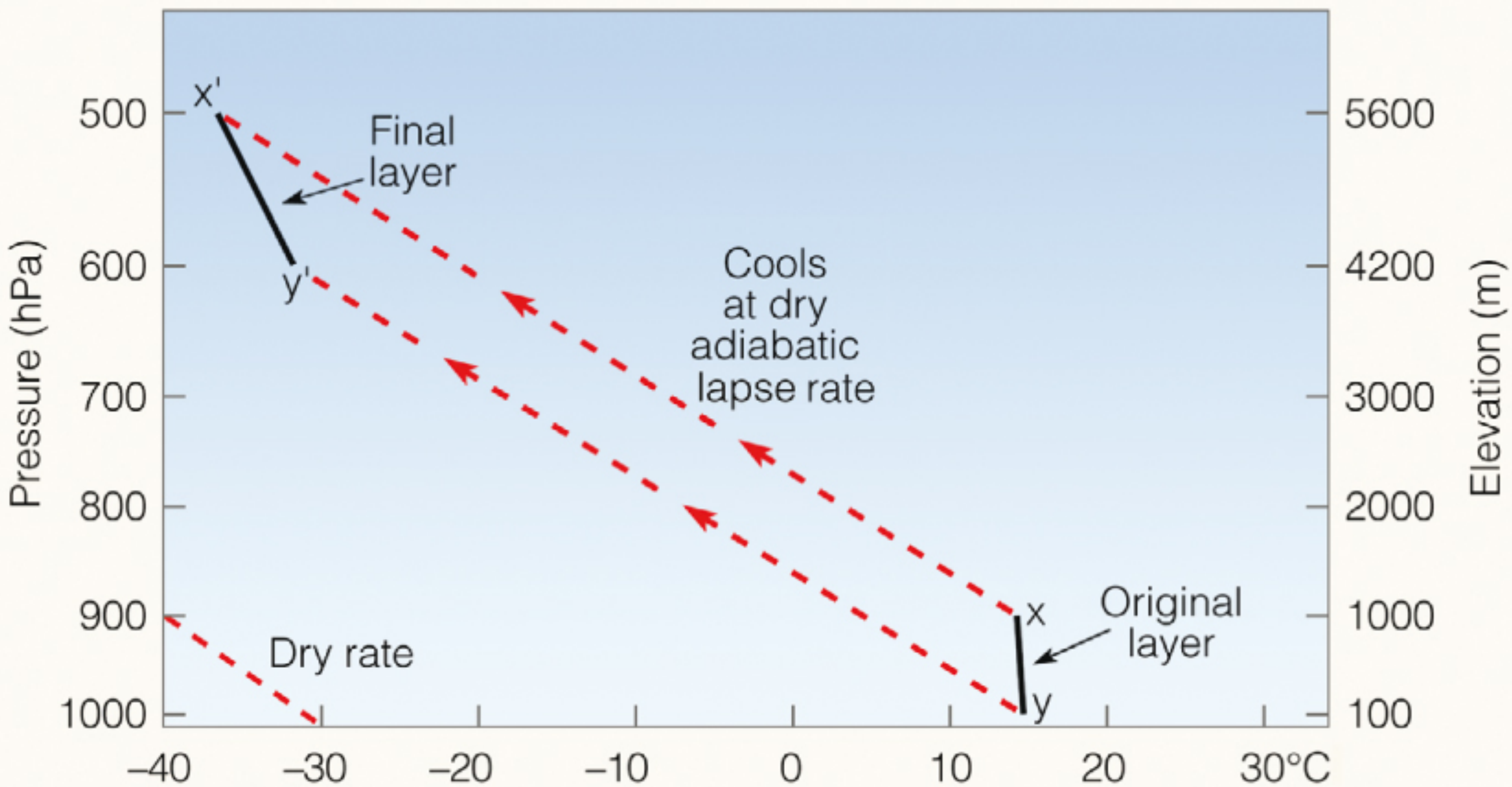
1b Cooling aloft

	7°C/km		12°C/km
1000 m	10°C	→	5°C
0 m	17°C	→	17°C

Example: Cool air advection

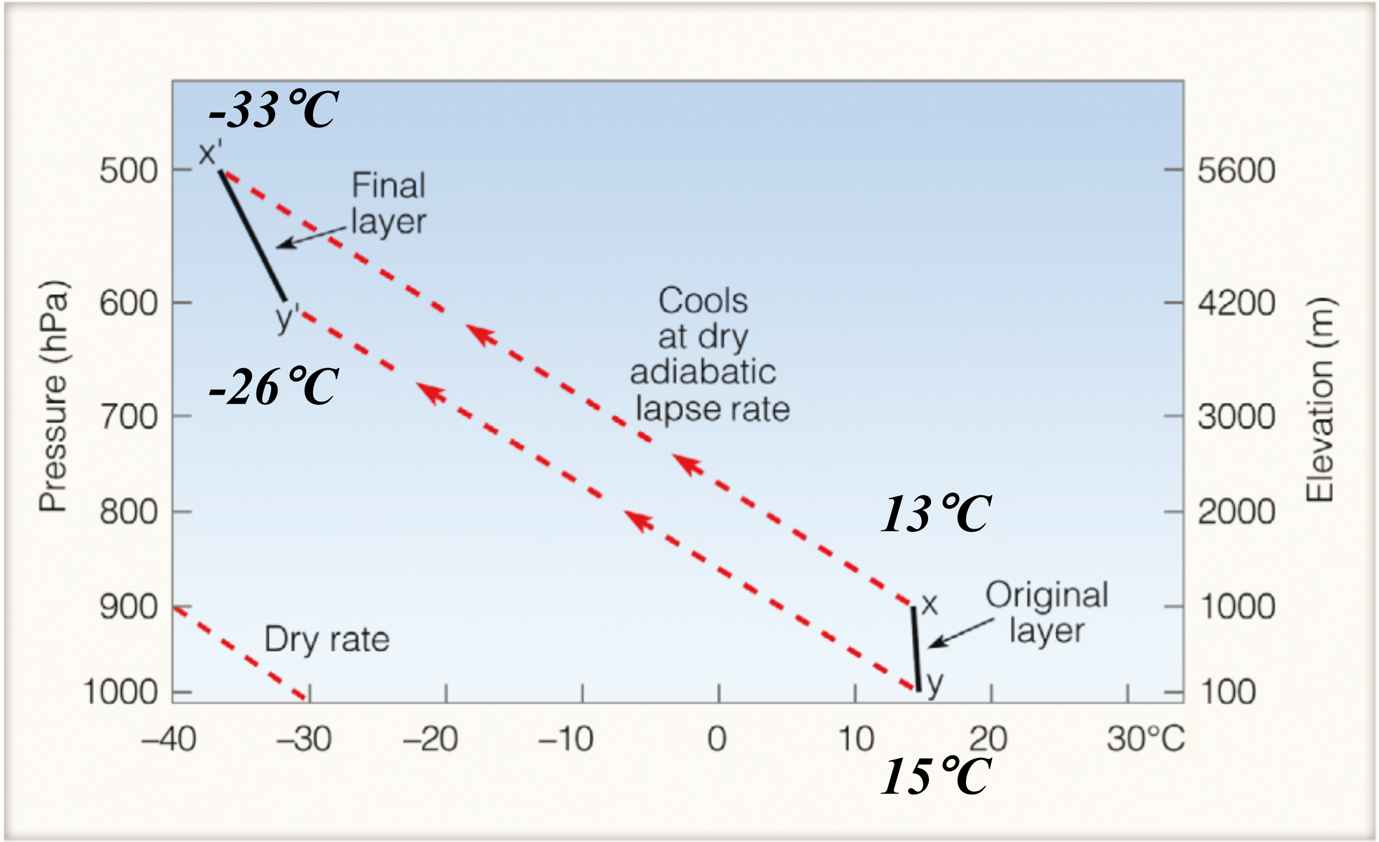


2a Potential instability



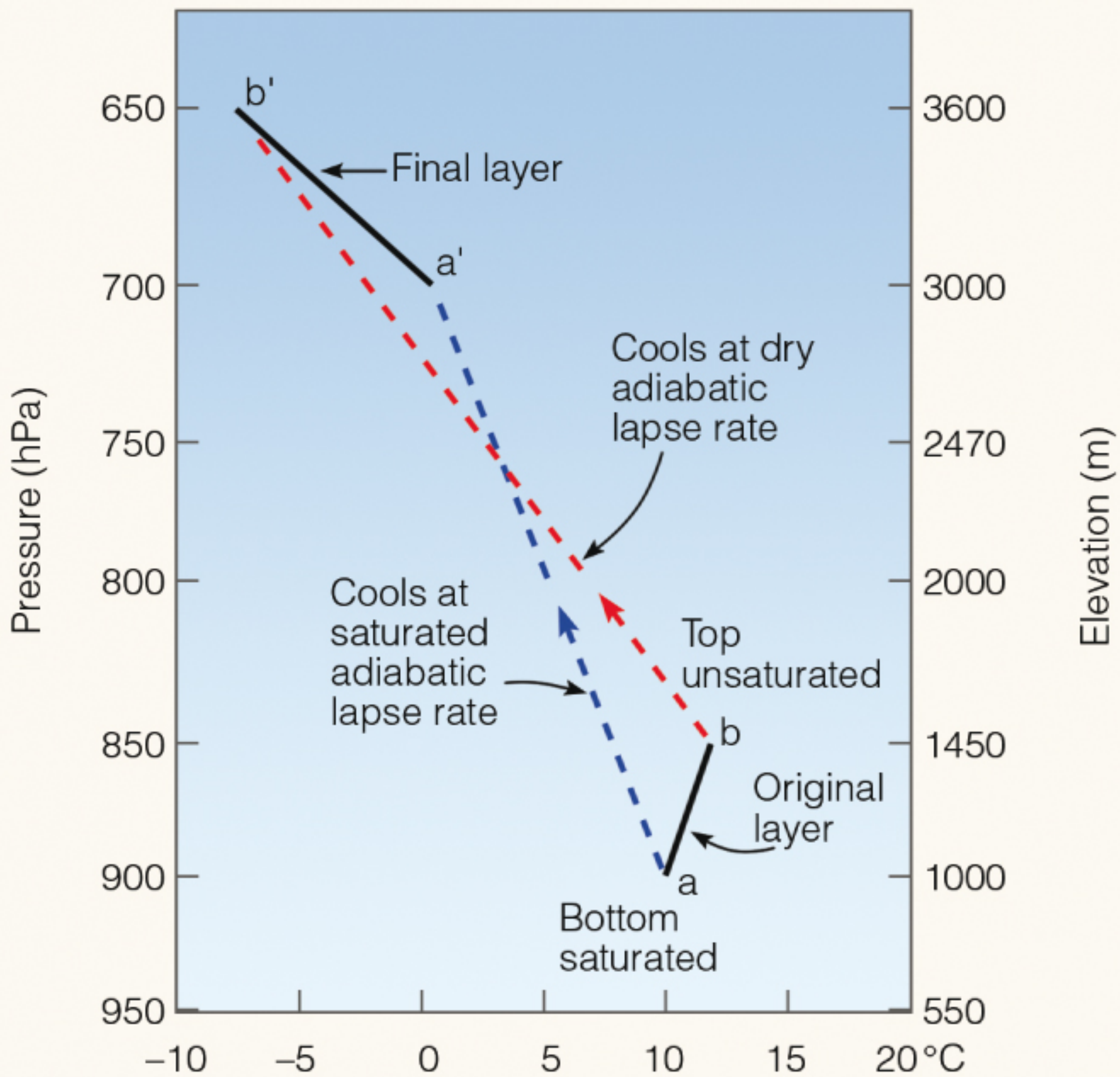
Expansion

- Initial lapse rate: 2.2°C / km (absolutely stable)
- Final lapse rate: 7°C / 1.4 km = 5°C / km (close to conditionally unstable)
- Layer of air expands, so top rises farther and cools more than bottom



Ahrens: Fig. 6.13

2b Potential Instability



Ahrens: Fig. 6.14

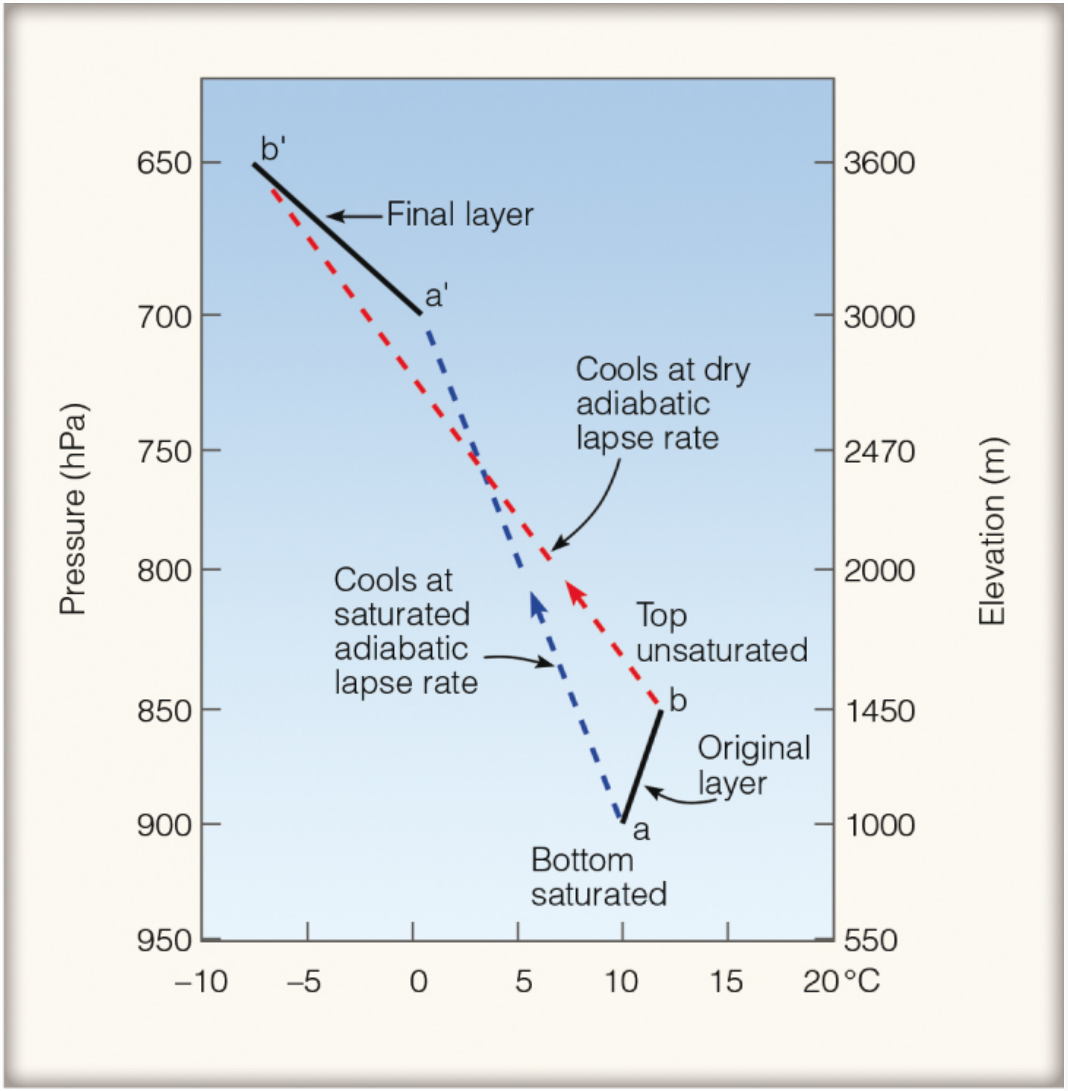
Potential Instability

Top of layer cools at DALR

Bottom cools at SALR

Initially, -3°C over 450 m =
-6.7°C / km

Finally, 9°C over 600 m =
15°C / km

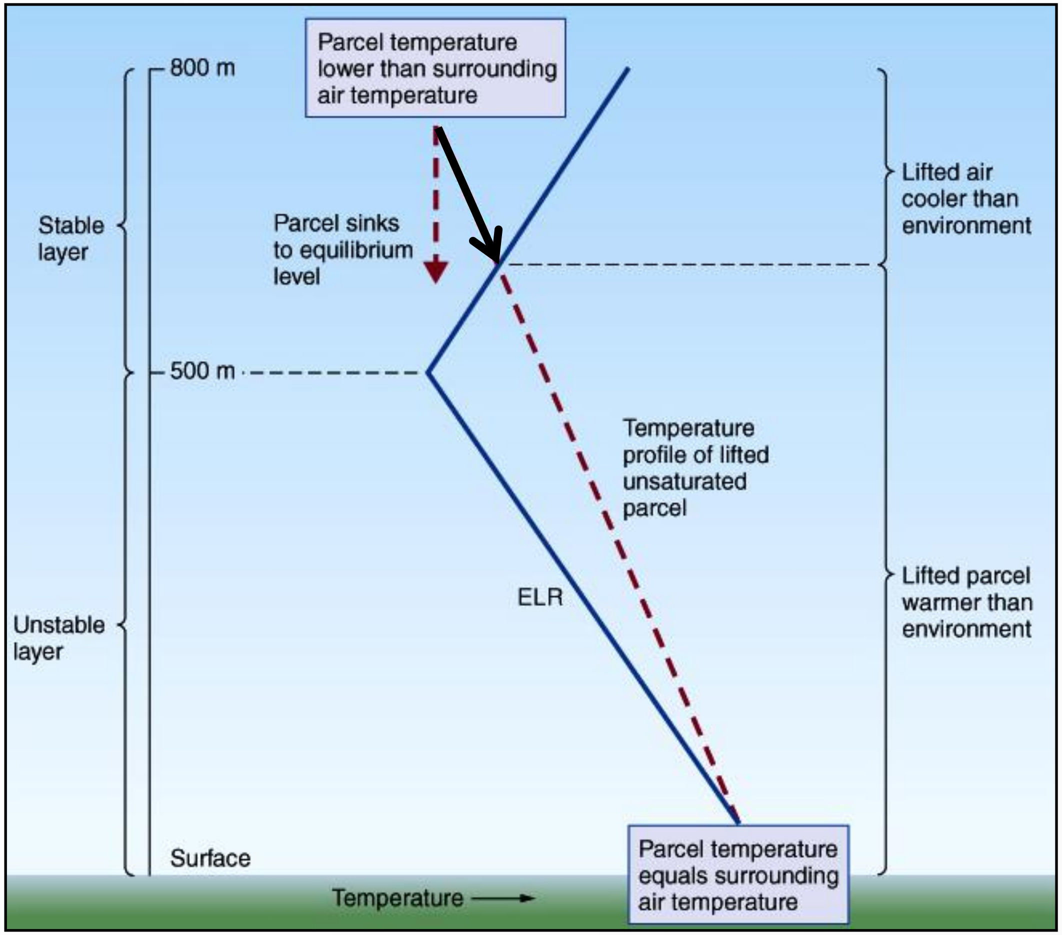


Entrainment

- Rising parcel creates turbulence
  - Small eddy circulations
- Mixes air from the environment into the parcel
  - Very likely unsaturated
  - Evaporating water cools the parcel back down
- Most evident at the cloud boundaries

Stable air

- Eventually a rising parcel will encounter stable air
- A "lid"
- Stops rising
  - Lag while *T* catches up
  - May continue briefly due to momentum

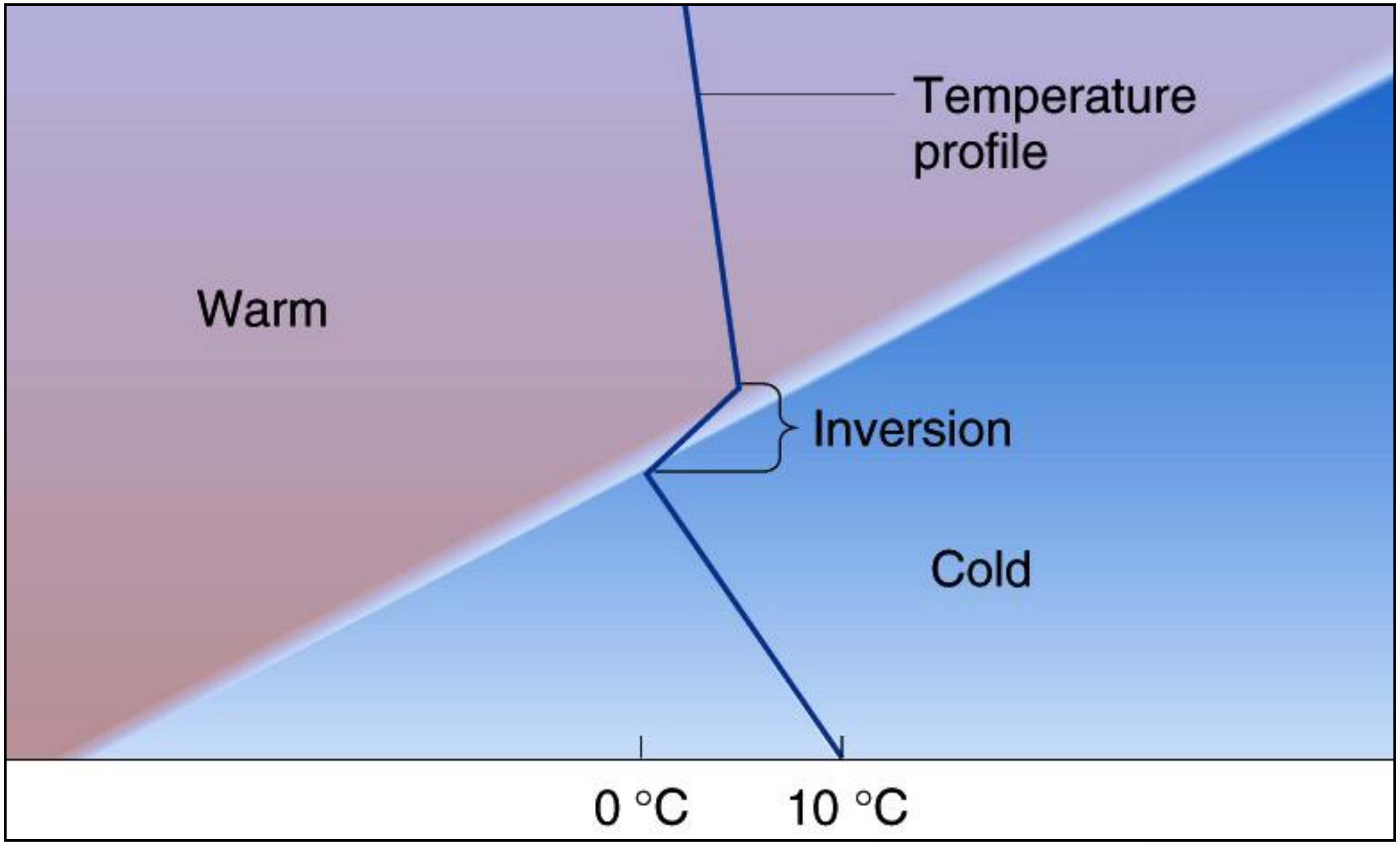


A&B: Figure 6-12

Radiation inversions

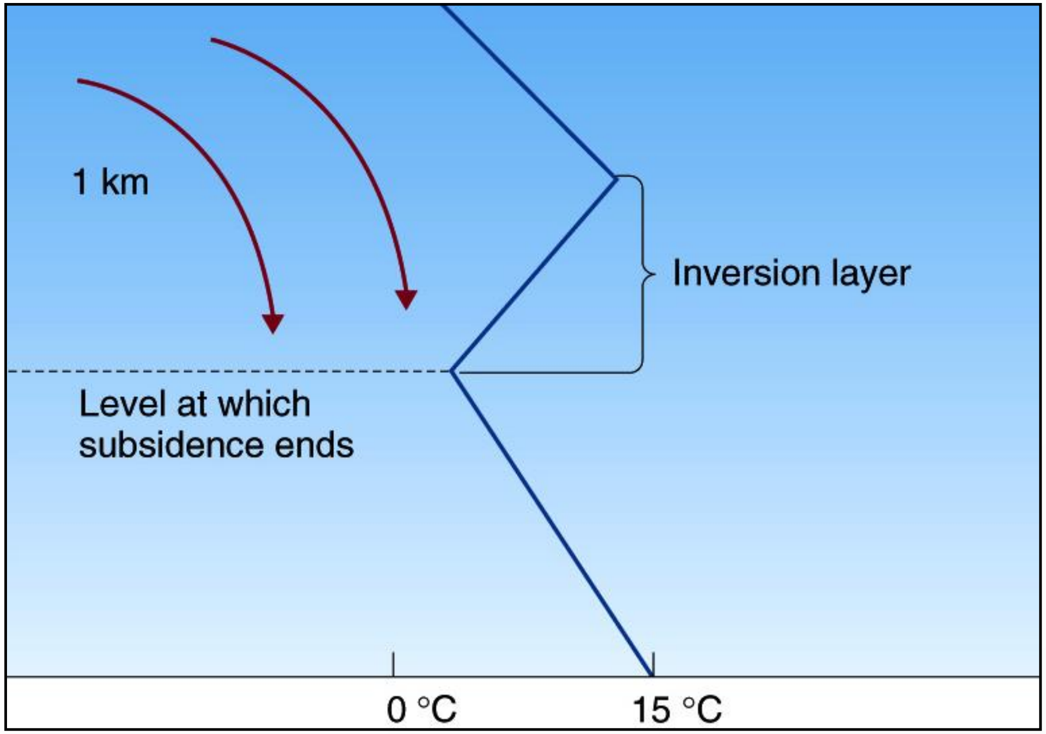
- Surface cools very quickly at night
  - Becomes colder than air above it
  - Temperature profile is inverted

Frontal inversions

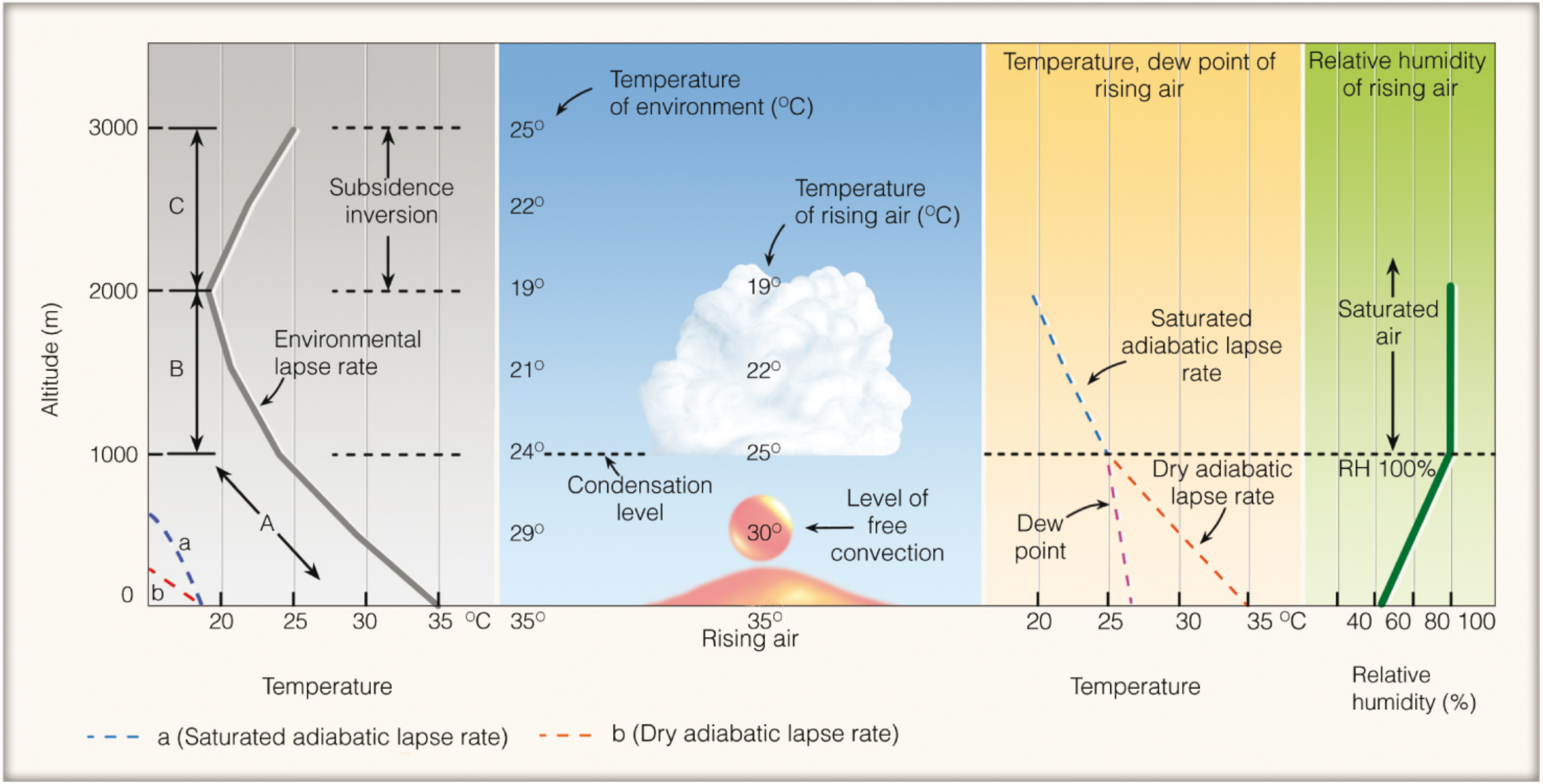


Subsidence inversion

- Warm air is less dense
- Lee side wind may be unable to push aside cold air



Development of a cumulus cloud



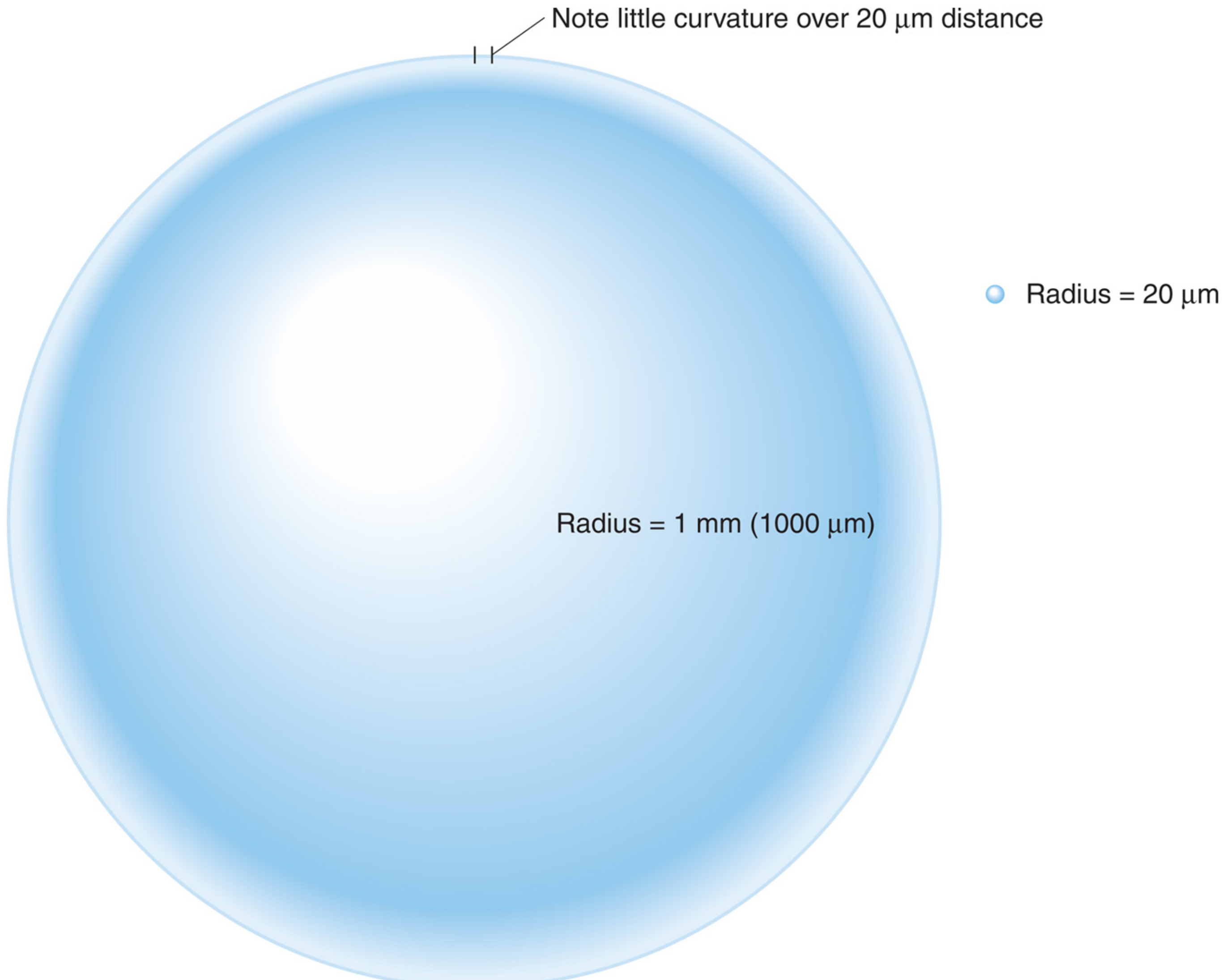
Ahrens: Active Fig. 6.18

Condensation

- Not as easy as it sounds
- Molecules must find each other and bond together
- Easily separated again by collisions with other air molecules

Curvature

High curvature means water molecules are more exposed to air molecules



A&B: Figure 5-11

Cloud condensation nuclei (CCN)

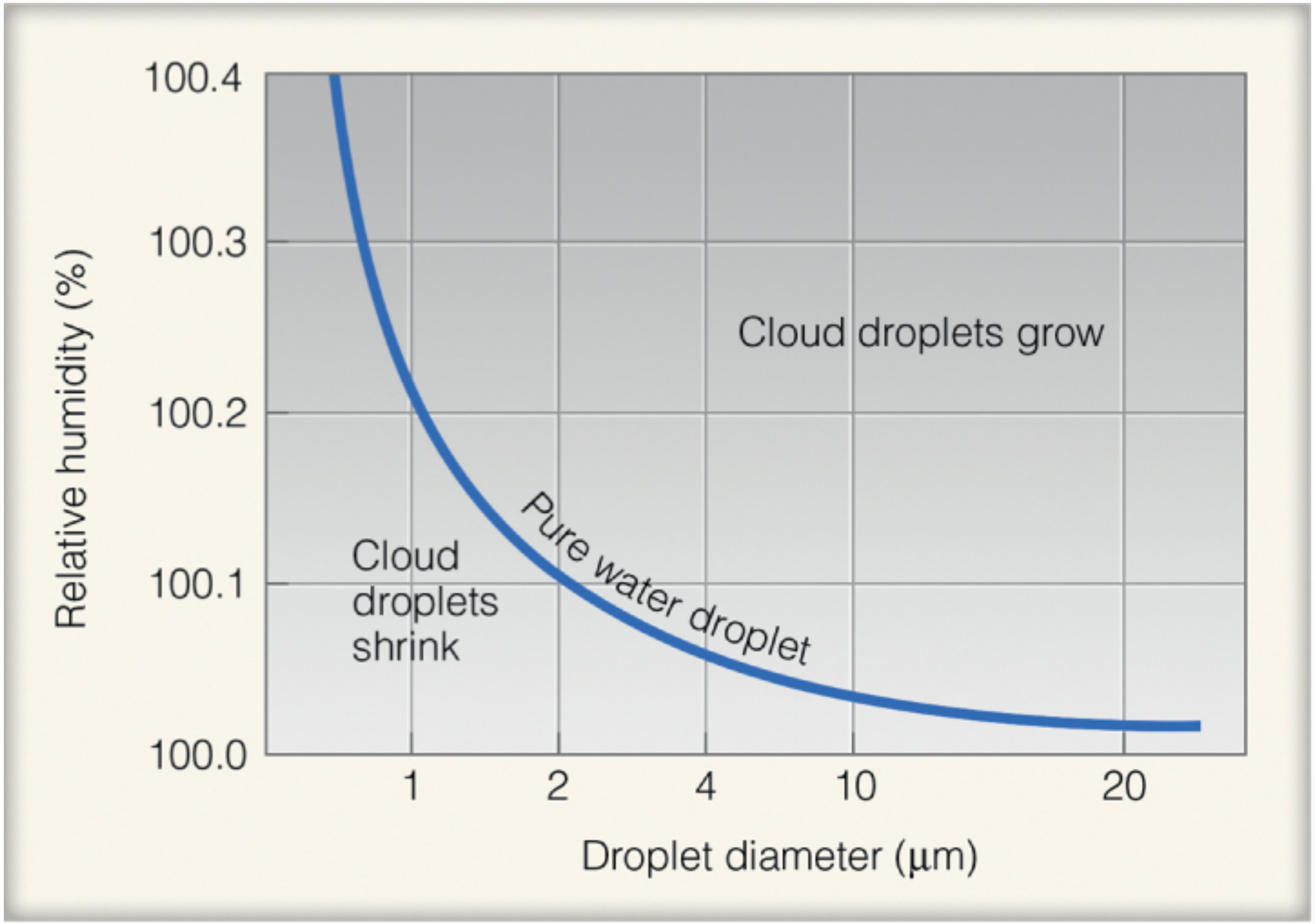
- Solid particles provide a surface to bond onto
  - Initially; eventually they dissolve

- Solution effect
  - Molecules of the dissolved substance don’t evaporate
  - Some of the water molecules along the surface are replaced
  - Rate of evaporation is reduced

Cloud condensation nuclei

- *Hygroscopic* material aids droplet formation
  - CCN are roughly 0.2 μm
  - Cloud droplets are roughly 20 μm or 0.02 mm
- *Supersaturation* occurs if no CCN are available
  - RH can exceed 100% - *supersaturation*
  - Liquid molecules evaporate again before they can collect together and form droplets

Supersaturation



Ahrens: Fig. 7.3

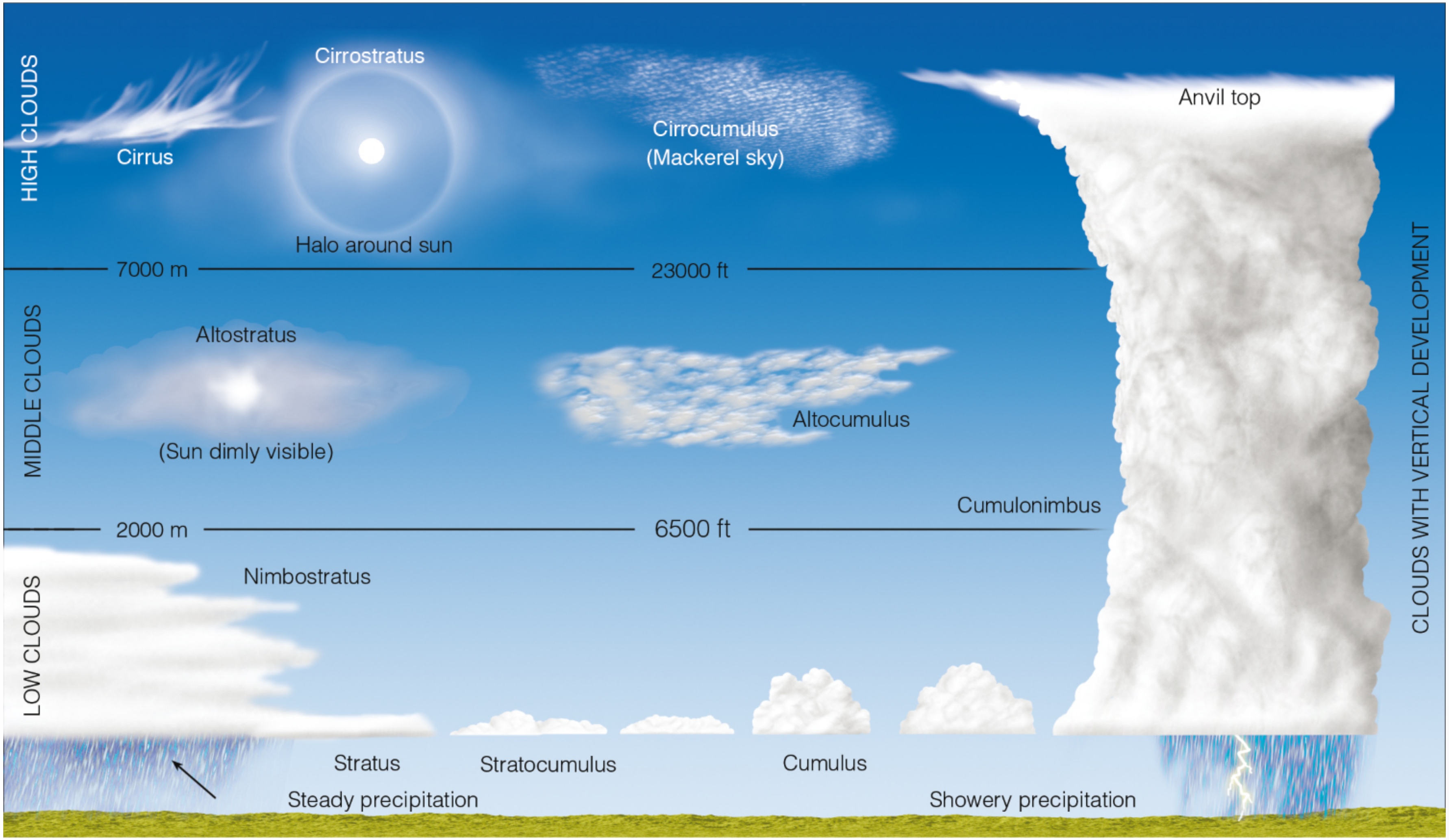
Lecture outline

- Changing atmospheric stability
- Limits on instability
- Condensation
- **Types of clouds**
  - **Nomenclature**
  - **Pretty pictures**
  - **Unusual clouds**

Cloud Nomenclature

- Stratus, strato-
  - Layer clouds
- Cumulus, cumulo-
  - ‘puffy’ clouds
- Alto
  - Middle clouds (2000 – 7000 m)
- Cirrus, cirro-
  - High clouds (above 7000 m)
- Nimbus, nimbo-
  - Rain clouds

Cloud types



Ahrens: Fig. 5.27

Cloud Nomenclature

Strato (layered)

- Stratus
- Nimbostratus
- Altostratus
- Cirrostratus

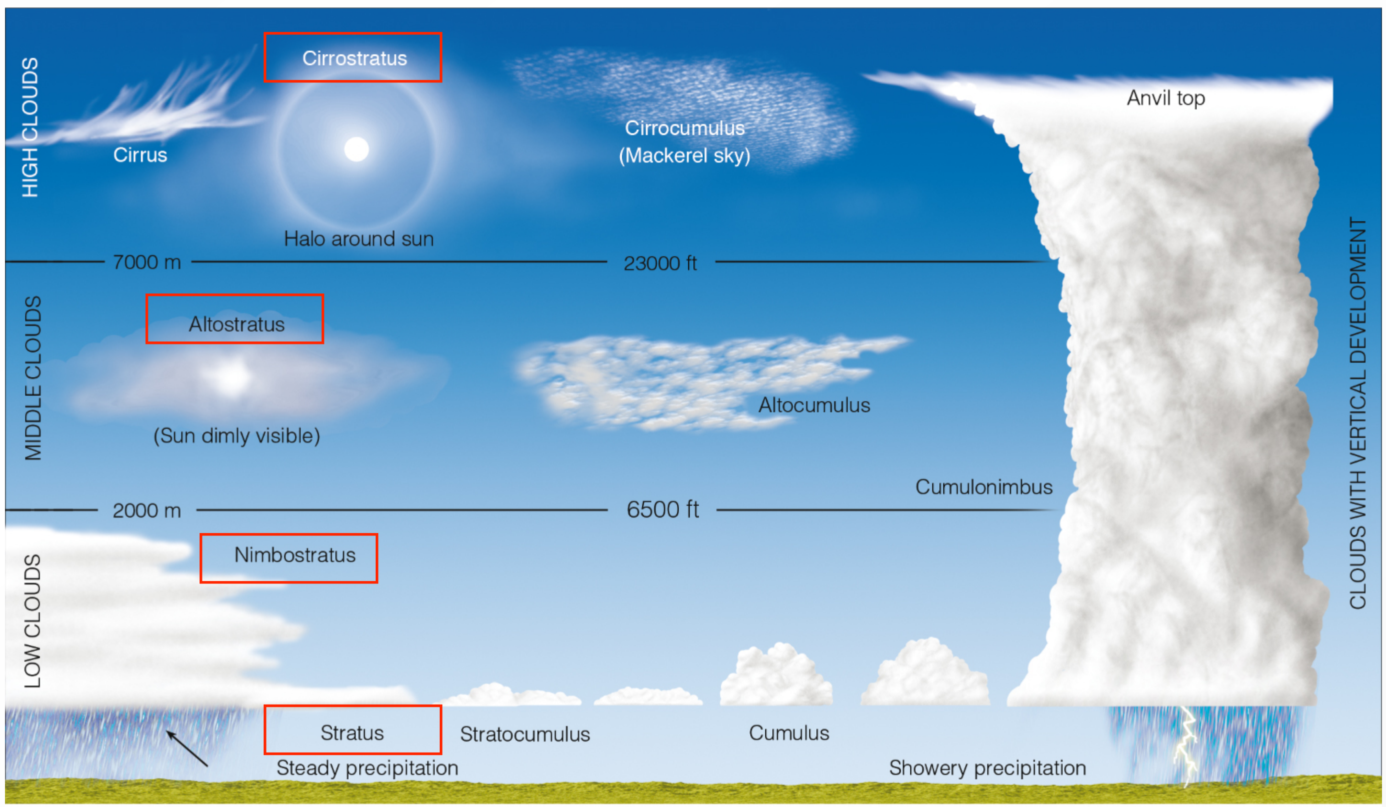
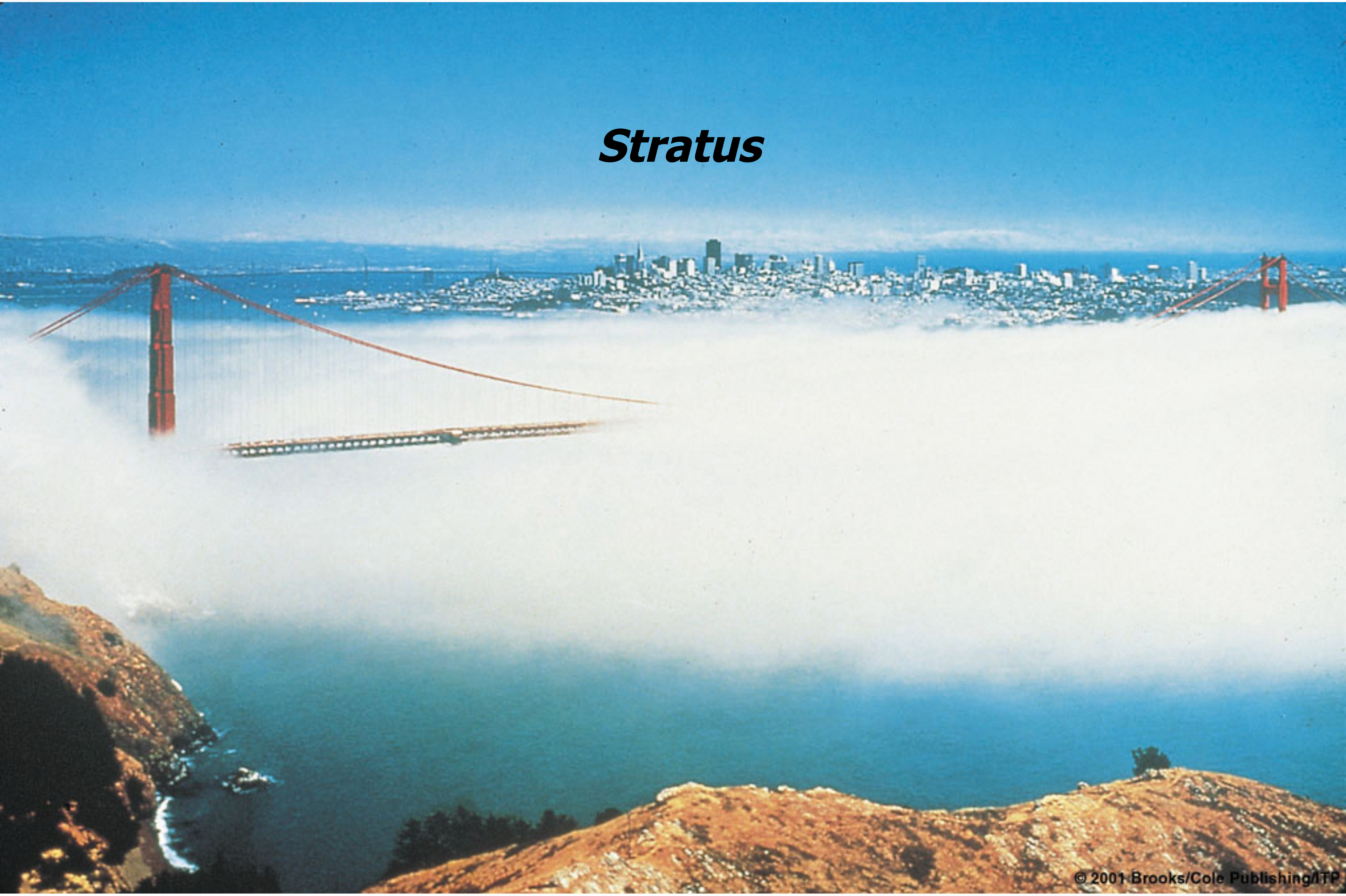


FIGURE 5.27 A generalized illustration of basic cloud types (genera) based on height above Earth's surface and the extent of vertical development.

Stratus

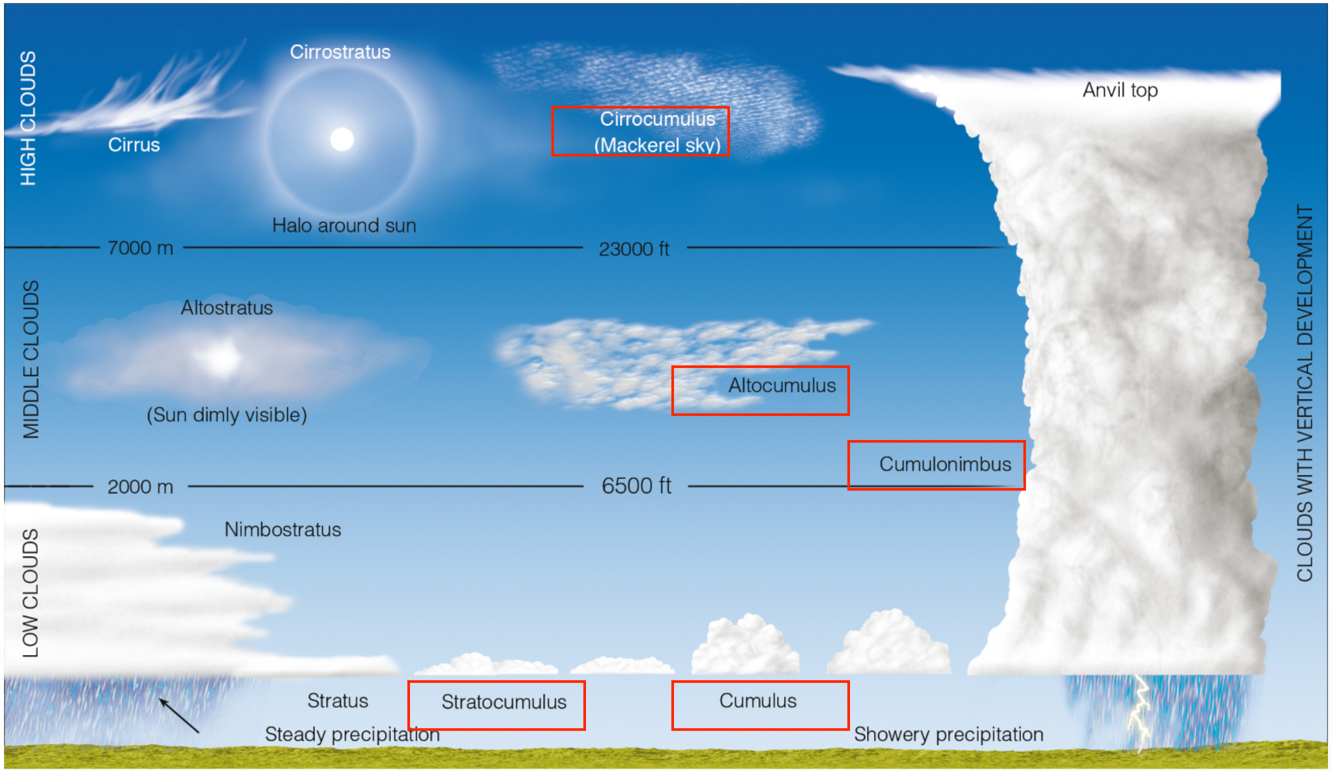


Altostratus


Cirrostratus

Cloud Nomenclature

- Cumulo (heaped)
  - Cumulus
  - Stratocumulus
  - Altocumulus
  - Cirrocumulus
  - Cumulonimbus



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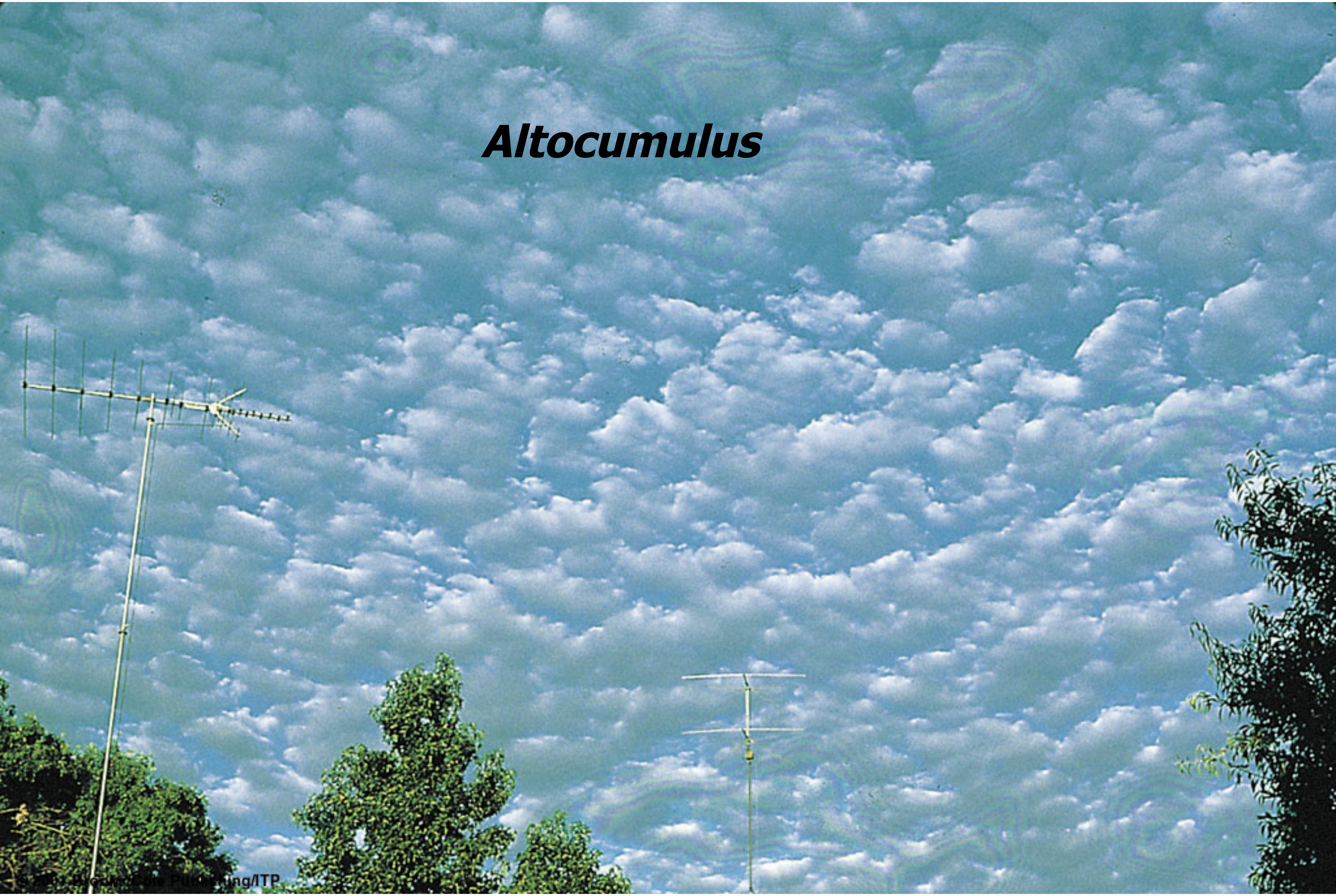
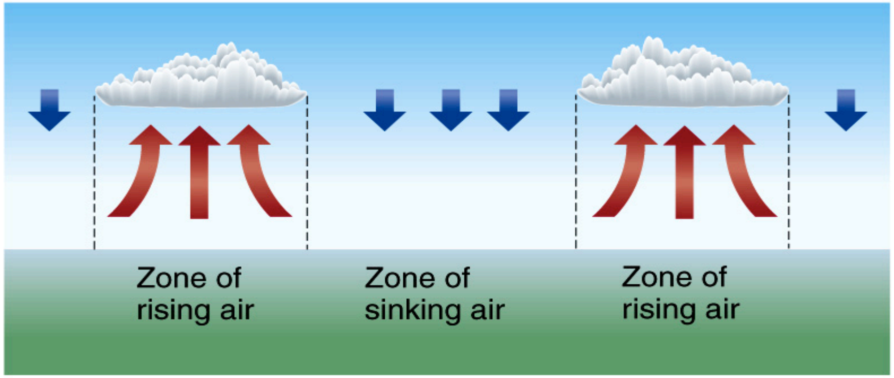
Cumulus

Stratocumulus


Altocumulus

Cirrocumulus

Cumulus humilis ‘Fair Weather’

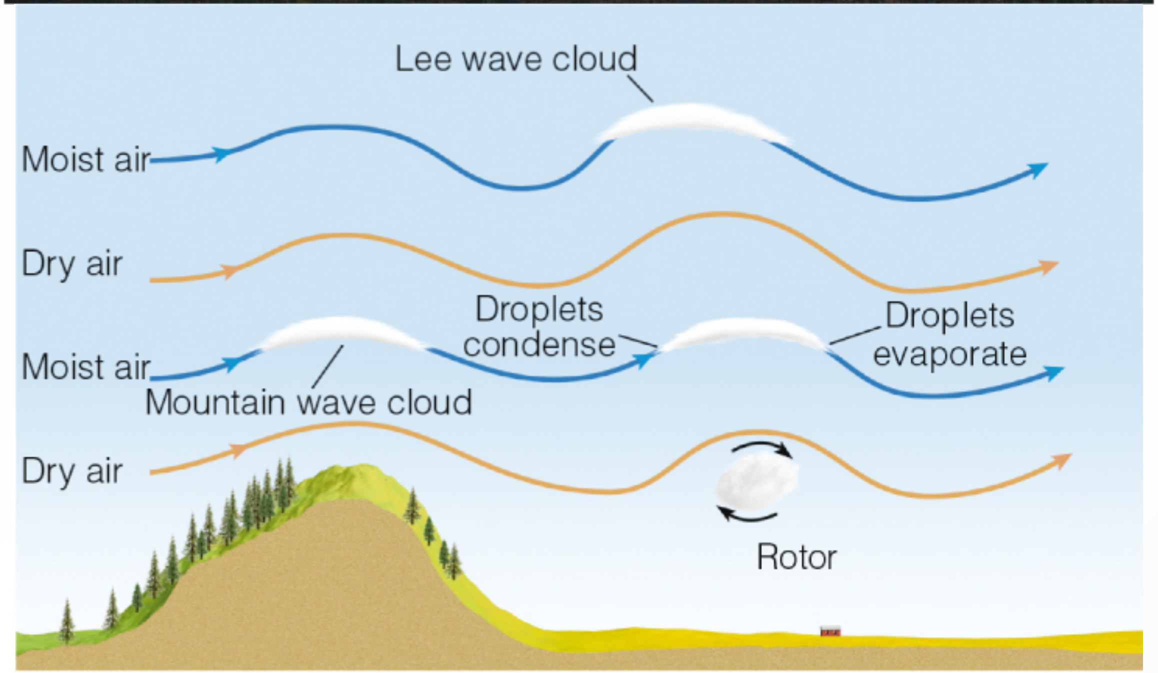


Cumulus congestus

Cumulonimbus

Lenticular Clouds

Ahrens: Fig. 5.28



Ahrens: Fig. 6.24

Banner clouds

Nacreous Clouds – Stratosphere

Noctilucent Clouds - Mesosphere

Next lecture

- Precipitation
- Ahrens: Chapter 7