Fog and Cloud Development

Bows and Flows of Angel Hair…

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Ch. 5: Condensation

- **Achieving Saturation**
  - → **Evaporation**
  - → **Cooling of Air**
    - Adiabatic and Diabatic Processes
    - Lapse Rates
- **Condensation**
  - → **Condensation Nuclei**
  - → **Dew, Frost, Fog**
  - → **Cloud Droplets**
    - Dry and Moist Adiabatic Processes and Lapse Rates

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Ch. 6: Cloud Development

- **Cloud Lifting Mechanisms**
- **Equilibrium States and Atmospheric Stability**
  - → **Stability vs. Environmental Lapse Rate**
  - → **Clouds vs. Stability**
  - → **Factors Affecting Parcel Buoyancy and Environmental Lapse Rate**

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Achieving Saturation

- **The purpose of saturating or supersaturating air is to produce condensation of water vapor into cloud or fog droplets or ice crystals**
  - **→ Add water vapor to air**
  - **→ Reduce the air temperature to the dew point temperature**
    - Cool the air by contact with a cold surface
    - Mix warm moist air with cooler air

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Cooling of Air to Get Condensation

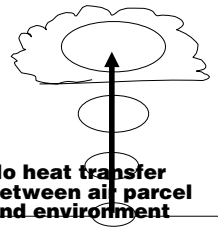
Diabatic

Cold ground cools air by conduction

➡ Heat transfer involved

Fog

Adiabatic



No heat transfer between air parcel and environment

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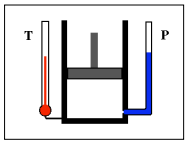
Adiabatic Process



- **Adiabatic: no heat exchange between a system and its surroundings**
  - **→ Adiabatic expansion: P↓, T↓**
  - **→ Adiabatic compression: P↑, T↑**

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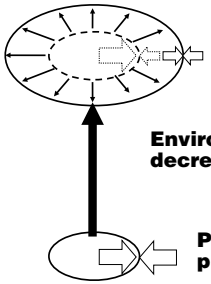
Rising Air Parcels



Parcel expands, loses pressure

Environmental pressure decreases as altitude increases

Parcel starts with same pressure as environment

Rising parcel → adiabatic expansion
→ temperature decreases

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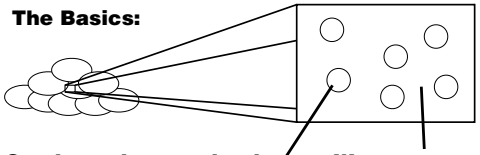
Clouds and Fog

The Basics:



Condensed water droplets

Water vapor + Air

- Get condensation to occur by reducing air temperature
  - ➡ Saturate air by lowering the air temperature until it is less than or equal to the dew point temperature

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Condensation Nuclei

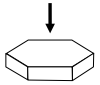
- Cloud Condensation Nuclei (CCN) and Ice-forming Nuclei (IN)
  - → These are aerosol particles that provide the surfaces on which condensation of a water droplet or ice crystal takes place

CCN

(salt—water-soluble)

IN

(dust—non-soluble)



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Dew and Frost

- Water condenses onto cold surfaces
  - → Temperature of air in contact with a cold surface is reduced to the dew point temperature or below
- Favorable conditions for dew formation: coldest air temperatures
  - → Clear night sky
  - → Calm night winds

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Types of Dew/Frost

(Liquid) Dew
T_{min} and DP > 0°C

Frost
T_{min} and DP < 0°C

Frozen Dew
T_{min} < 0°C
DP > 0°C

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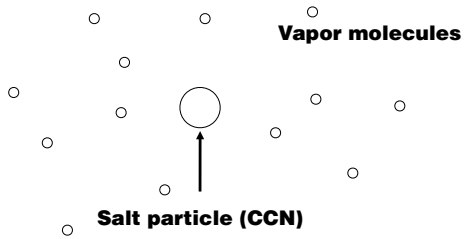
Hazes and Hygroscopic Nuclei

Hygroscopic: "water seeking"



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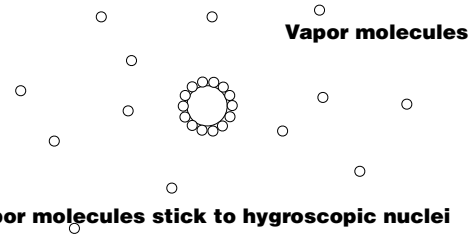
Hazes and Hygroscopic Nuclei

Hygroscopic: "water seeking"



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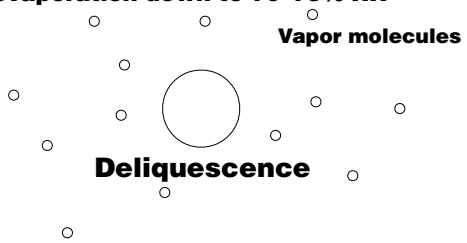
Hazes and Hygroscopic Nuclei

Salty haze droplet resists evaporation down to 70–75% RH



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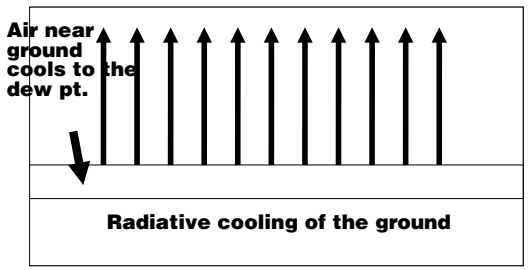
Radiation Fog



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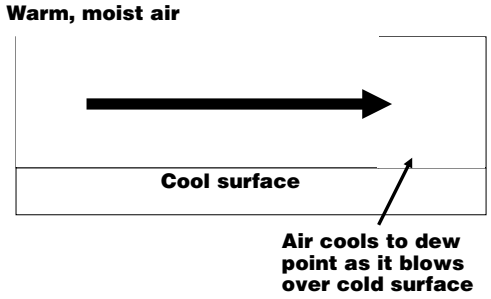
Advection Fog



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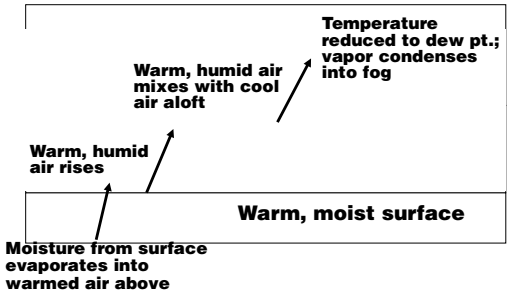
Evaporation Fog



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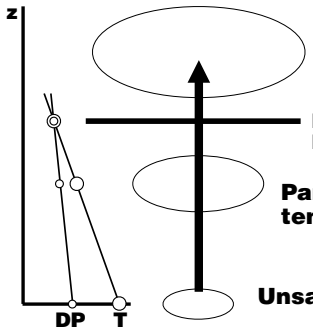
Condensation in Rising Air



When parcel's T drops below the DP, condensation occurs

Lifting Condensation Level (LCL)

Parcel rises; loses temperature

Unsaturated air parcel

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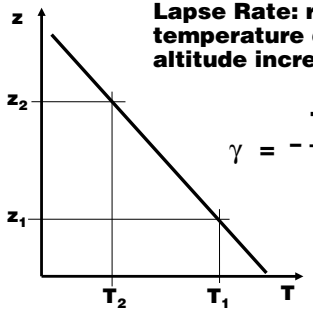
Lapse Rates



Lapse Rate: rate at which temperature decreases as altitude increases

$$\gamma = -\frac{T_2 - T_1}{z_2 - z_1} = -\frac{\Delta T}{\Delta z}$$

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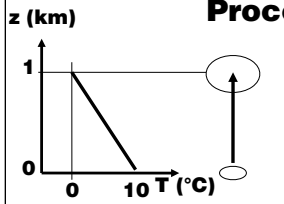
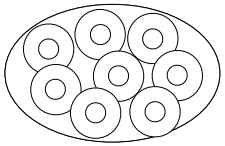
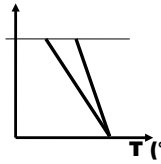
Dry and Moist Adiabatic Processes







Condensation releases latent heat into the air parcel

➡ Warms it up; parcel loses temperature less rapidly

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Dry Adiabatic Lapse Rate Γ_d = 10°C/km

Moist Adiabatic Lapse Rate: varies with temperature and moisture content

Range: 4 to 10°C/km

Average:

Γ_m = 6°C/km

Environmental Lapse Rate (γ): varies with weather conditions, such as solar heating, cloud cover, winds, . . .

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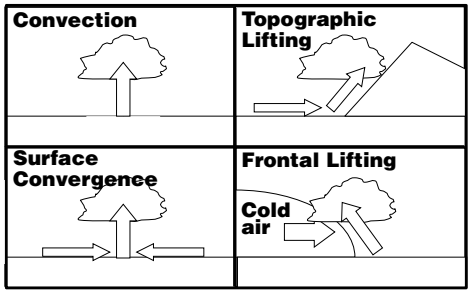
Lifting Mechanisms



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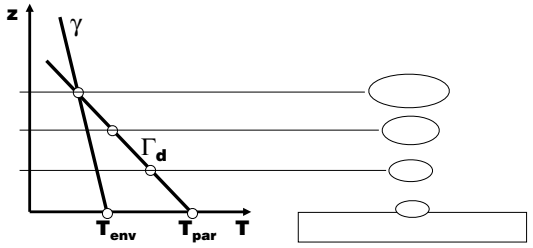
Cloud Formation by Simple Convection

- **Warm air is less dense and more buoyant than cold air**



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Equilibrium States

- **Equilibrium: steady-state; balance**
- **Disturb a system at equilibrium; subsequent behavior characterizes "stability" of system**

Stable

Neutral

Unstable

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Equilibrium States

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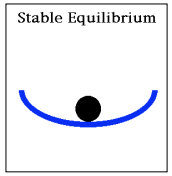
Stable



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Equilibrium States

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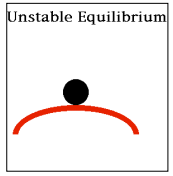
Unstable



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Equilibrium States

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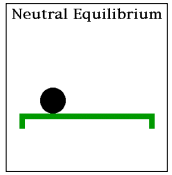
Neutral



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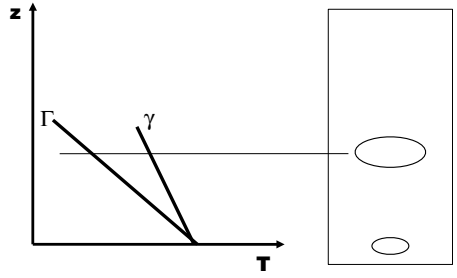
Stable

$\gamma < \Gamma$



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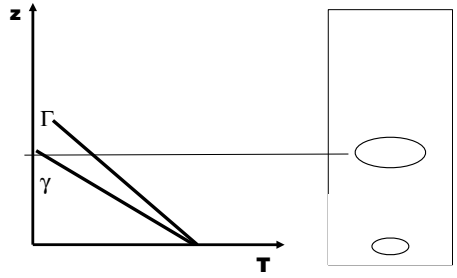
Unstable

$\gamma > \Gamma$



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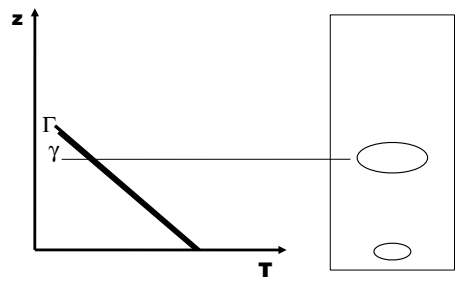
$\gamma = \Gamma$ **Neutral**



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Absolute vs. Conditional Stability

$$\gamma < \Gamma_m < \Gamma_d$$

Absolutely Stable

$\gamma < \Gamma$	**Stable**
$\gamma > \Gamma$	**Unstable**
$\gamma = \Gamma$	**Neutral**

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Absolute vs. Conditional Stability

$$\Gamma_m < \Gamma_d < \gamma$$

Absolutely Unstable

$\gamma < \Gamma$	**Stable**
$\gamma > \Gamma$	**Unstable**
$\gamma = \Gamma$	**Neutral**

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Absolute vs. Conditional Stability

$$\Gamma_m < \gamma < \Gamma_d$$

Conditionally Unstable

$\gamma < \Gamma$	**Stable**
$\gamma > \Gamma$	**Unstable**
$\gamma = \Gamma$	**Neutral**

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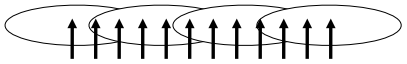
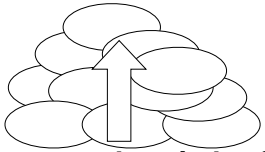
Clouds vs. Stability

Stable



Convection suppressed; horizontal layer formed

Unstable



Convection encouraged; vertical, puffy development

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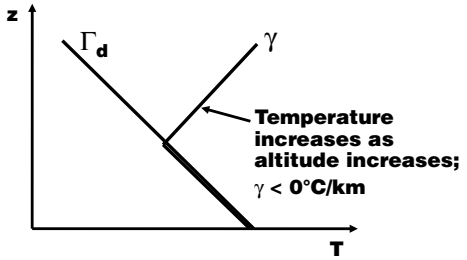
Temperature Inversions



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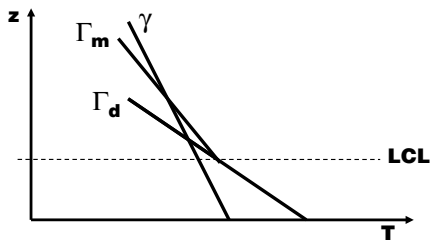
Typical Situations

Parcels are superheated by the ground



(Ex.: absolutely stable atmosphere)

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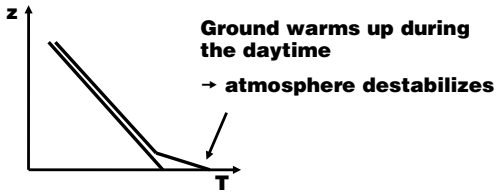
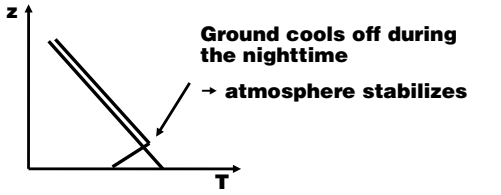


Ground warms up during the daytime

→ atmosphere destabilizes



Ground cools off during the nighttime

→ atmosphere stabilizes

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