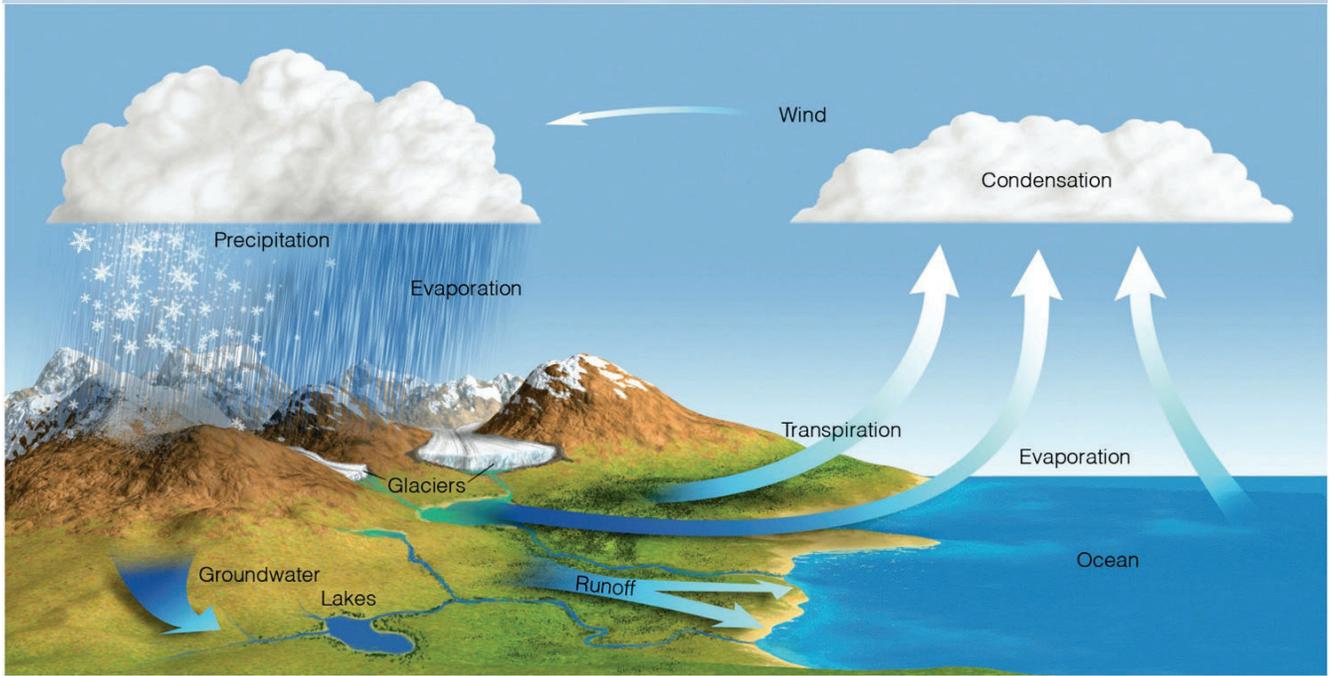


# The Water Cycle



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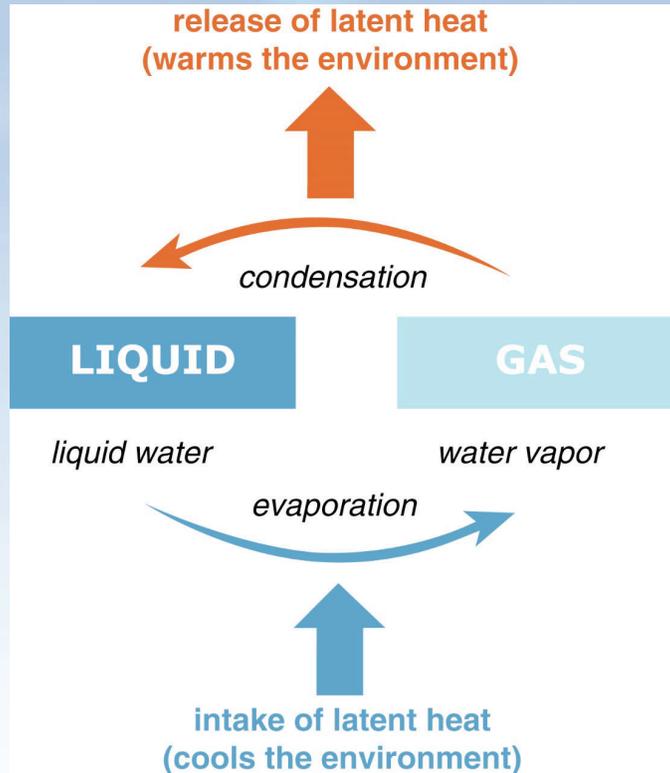
Fig 4.1: *Essentials of Meteorology*

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1

# The Water Cycle



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Fig 5.1 *Weather: A Concise Introduction*

2

## Ways to get water to condense:

- 1) Decrease the air temperature
- 2) Increase the amount of water vapor

### College Park, MD Weather

Sep 26, 2019 10:02 AM  
Reagan National Airport

**74°**   
Feels Like 74° Partly Cloudy  
Hi 88°F Lo 59°F

#### WEATHER DETAILS - COLLEGE PARK, MD

Windchill 74°	Daily Rain 0"
Dewpoint 63°	Monthly Rain --
Humidity 69%	Avg. Wind S 9.2 mph
Pressure 29.83"	Wind Gust S 9.2 mph
Sunrise 6:58 AM	Moon Waning Crescent
Sunset 6:58 PM	UV Index 4 (Moderate)

#### LIVE RADAR



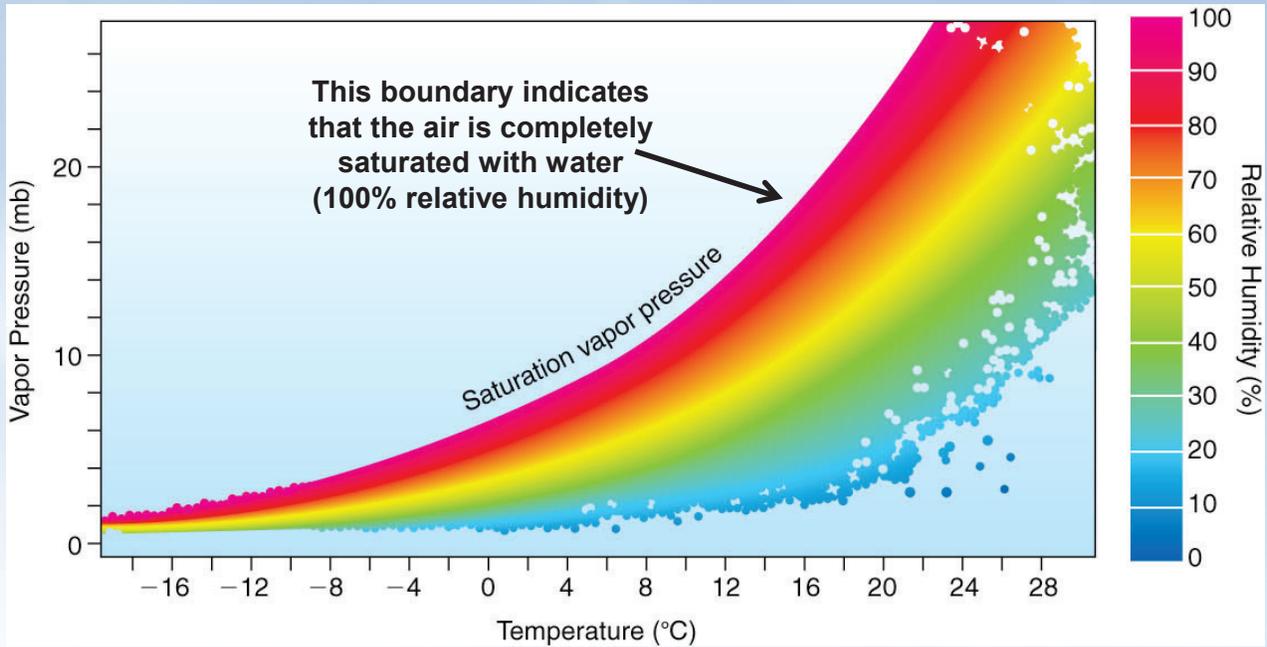
#### COLLEGE PARK WEATHER FORECAST

**Today** HI 88°F  
 Partly sunny. Isolated showers this afternoon. Highs in the upper 80s. Southwest winds 10 to 15 mph. Chance of rain 20 percent.

**Tonight** Lo 59°F  
 Partly cloudy with isolated showers in the evening then m...

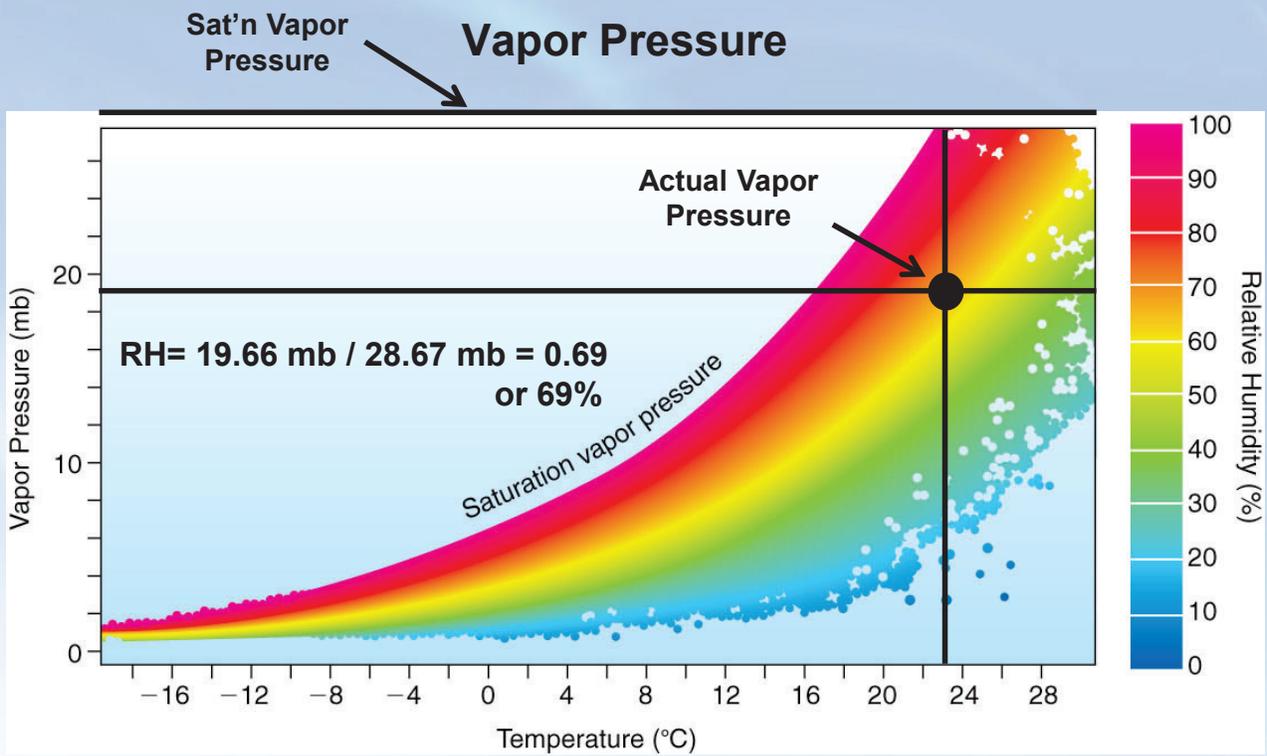
<http://weather.weatherbug.com/MD/College%20Park-weather.html>

# Vapor Pressure



**Actual vapor pressure: the atmospheric pressure due to water**  
**Saturation vapor pressure: the atmospheric pressure if the air was saturated**

Fig 4-3 Meteorology: Understanding the Atmosphere



**Actual vapor pressure: the atmospheric pressure due to water**  
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Fig 4-3 Meteorology: Understanding the Atmosphere

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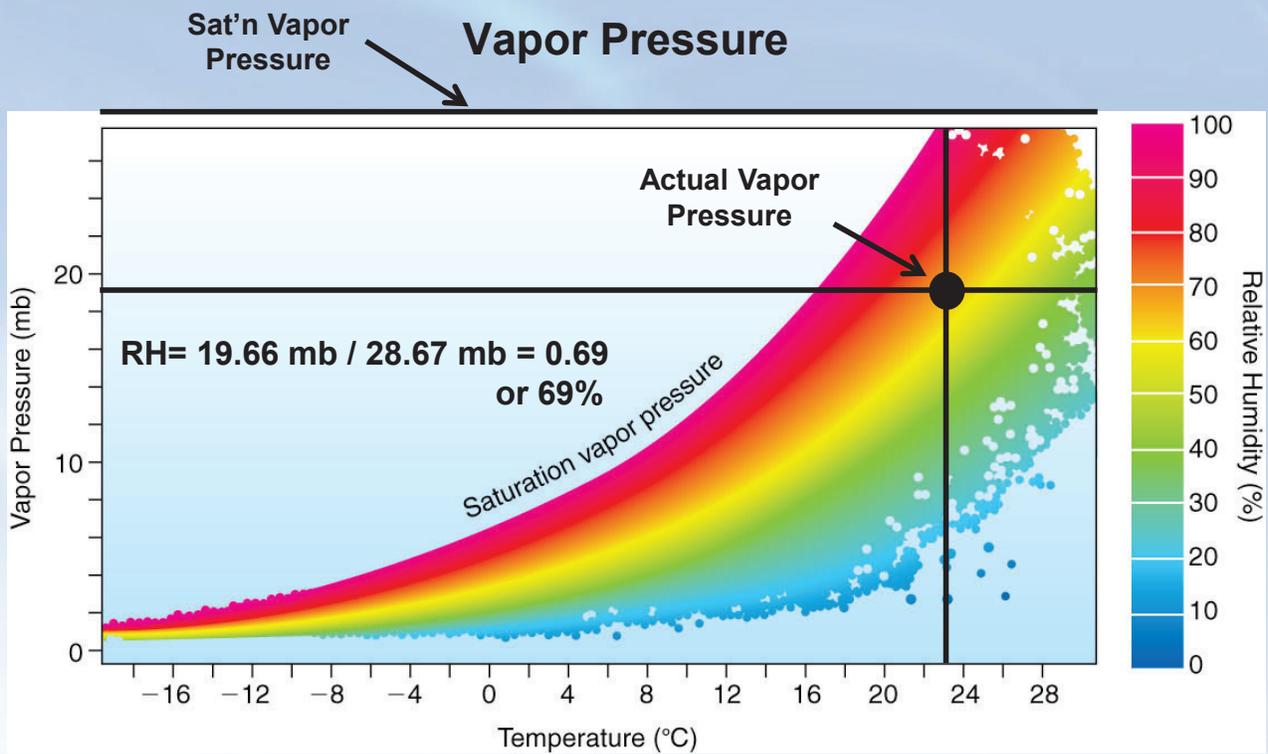
**Tonight**    Lo 59°F

Partly cloudy with isolated showers in the evening then m...

<http://weather.weatherbug.com/MD/College%20Park-weather.html>

## Different ways to think about humidity

1. **Absolute humidity:** the mass of water vapor per volume
2. **Specific humidity:** the mass of water vapor per mass of dry air
3. **Relative humidity:** percent of water vapor present in air compared to the maximum at saturation;  $RH = e/e_s$

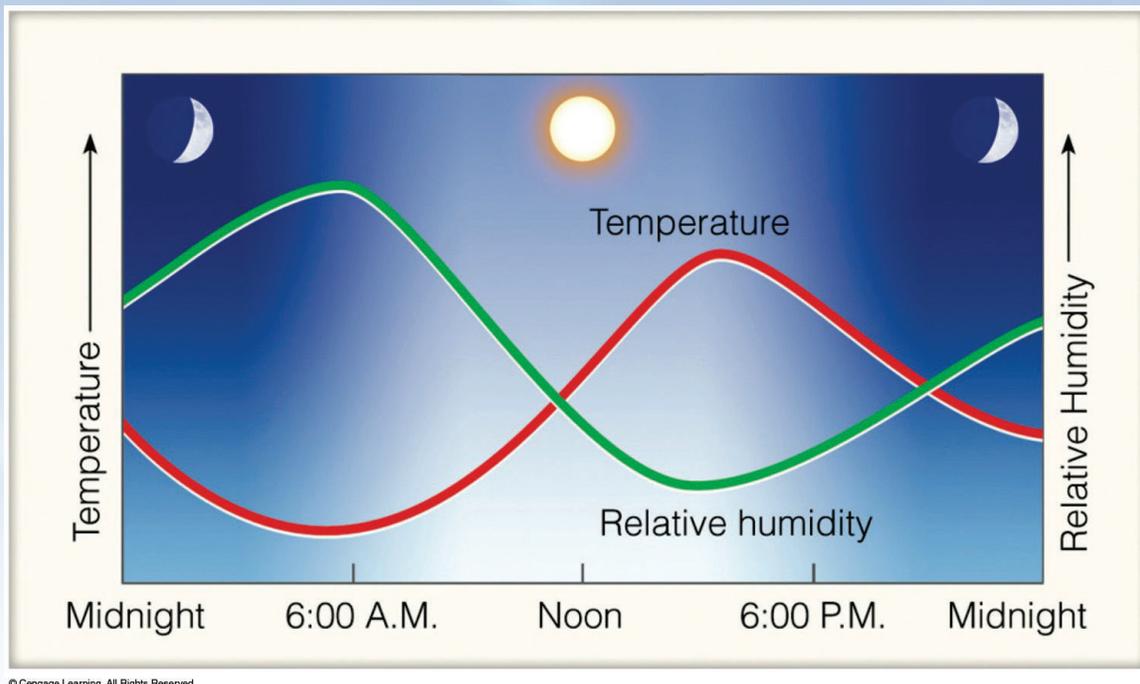


**Actual vapor pressure: the atmospheric pressure due to water**  
**Saturation vapor pressure: the atmospheric pressure if the air was saturated**

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Fig 4-3 *Meteorology: Understanding the Atmosphere*

## Relative Humidity



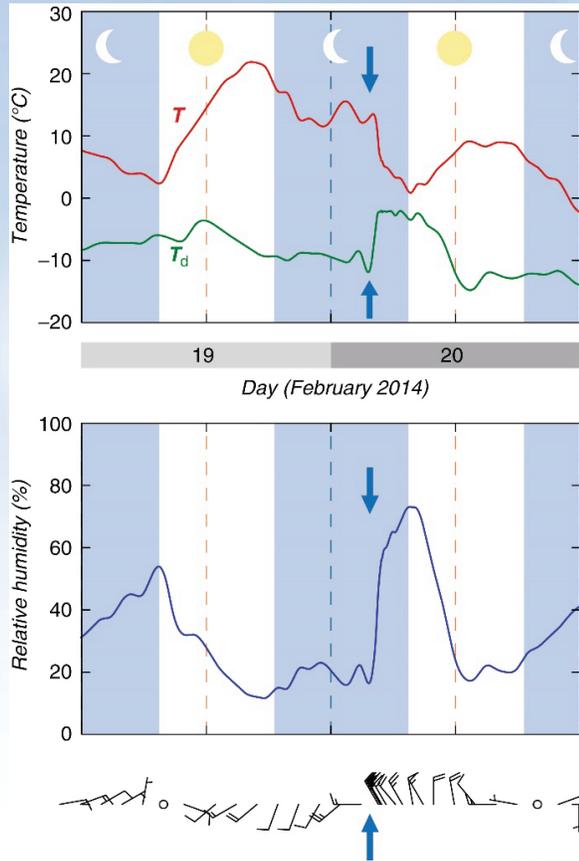
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**Temperature and relative humidity are “anti-correlated”**

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Fig 4.7: *Essentials of Meteorology*

## Relative Humidity



As  $T$  and  $T_d$  get closer, relative humidity increases

The blue arrows indicate when a cold front passed through

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Fig 5.8 *Weather: A Concise Introduction* 11

## Relative Humidity

T (°C)	$e_s$ (hPa)	$e$ (hPa)	RH (%)
20	23	15	65
19	22	15	68
18	21	15	72
17	19	15	75
16	18	15	83
15	17	15	88
14	16	15	94
<b>13</b>	15	15	<b>100</b>
12	14	14	100
11	13	13	100
10	12	12	100

As  $T$  decreases, saturation vapor pressure ( $e_s$ ) decreases while vapor pressure ( $e$ ) stays constant

Relative humidity increases

Vapor pressure does start to decrease after RH reaches 100% and  $e_s$  continues to drop

Why?

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Table 5.1 *Weather: A Concise Introduction* 12

## Dew Point



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**Fig 5.5** *Weather: A Concise Introduction* 13

## Frost Point (when $T_d$ is at or below freezing)



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**Fig 5.6** *Weather: A Concise Introduction* 14

# Fog

If air in contact with the ground cools enough, water will condense and form a suspension of tiny water drops

This is called a fog

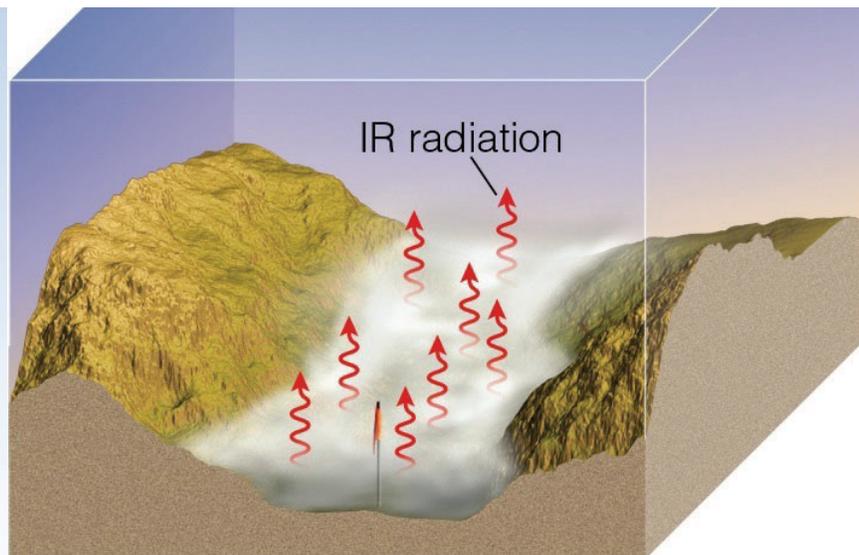


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15

# Radiation Fog

The surface cools as heat radiates away.  
Air close to the ground cools enough for water to condense in the air



(a) Radiation fog

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Fig 4.21: *Essentials of Meteorology*

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16

## Radiation Fog

The surface cools as heat radiates away to space.  
Air close to the ground cools enough for water to condense in  
the air

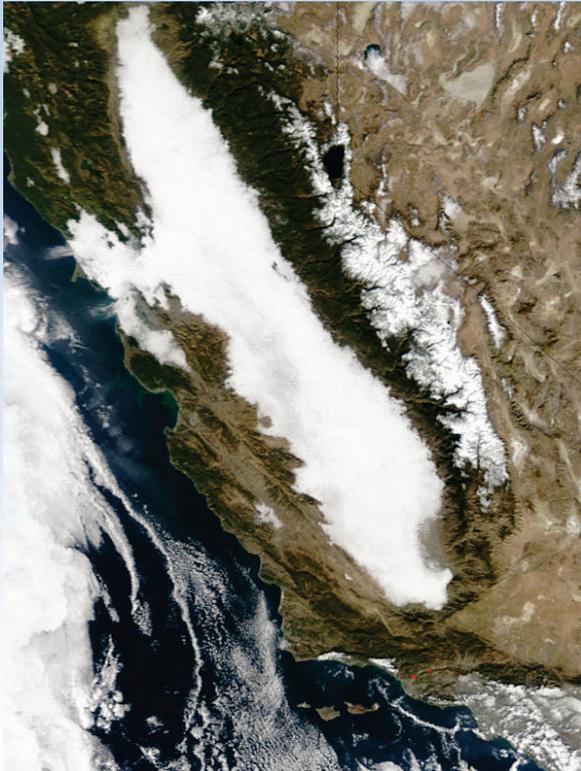


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Fig 6.1.2 *Weather: A Concise Introduction*, 17

## Tule Fog



Tule fog: radiation fog that occurs in the  
central valley of California from late Fall  
to early Spring.

<http://eoimages.gsfc.nasa.gov/images/imagerecord/s/72000/72843/California.A2005350.1850.1km.jpg>

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## Valley Fog

The surface cools as heat radiates away to space.  
Air close to the ground cools enough for water to condense in the air.



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Fig 4.19: *Essentials of Meteorology*

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19

## Advection Fog

Warm, moist air blows over a cold surface (land or water) and cools enough for droplets to form



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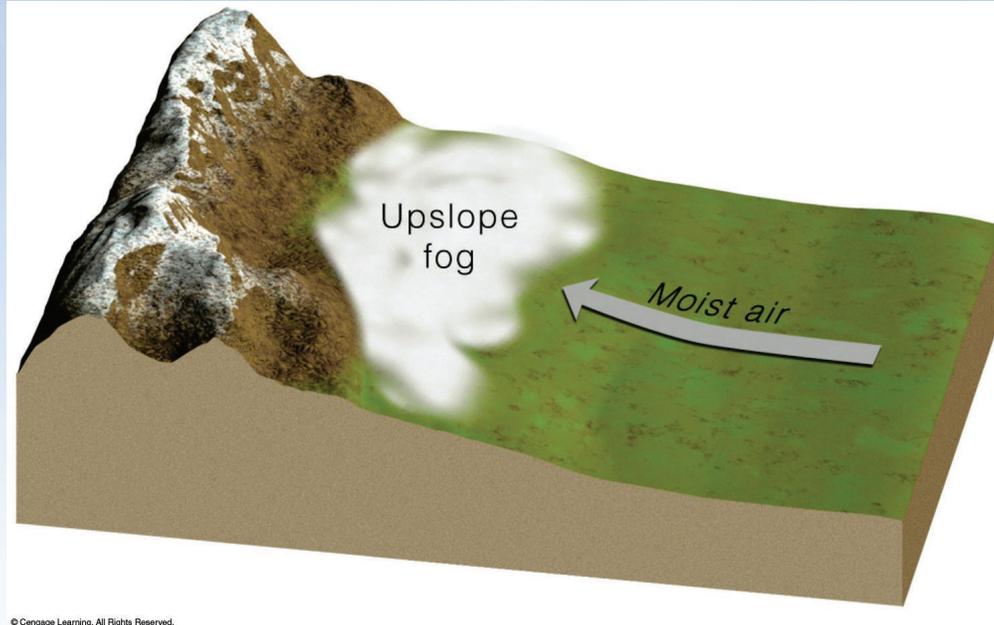
Fig 4.20: *Essentials of Meteorology*

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20

## Upslope Fog



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**Winds push moist air uphill to an altitude where temperatures are cold enough for condensation to occur**

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## Evaporation or Steam Fog



**Steam Fog: Cold air moves over warm water**

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Fig 6.1.1 *Weather: A Concise Introduction*

22

## Where do clouds come from?



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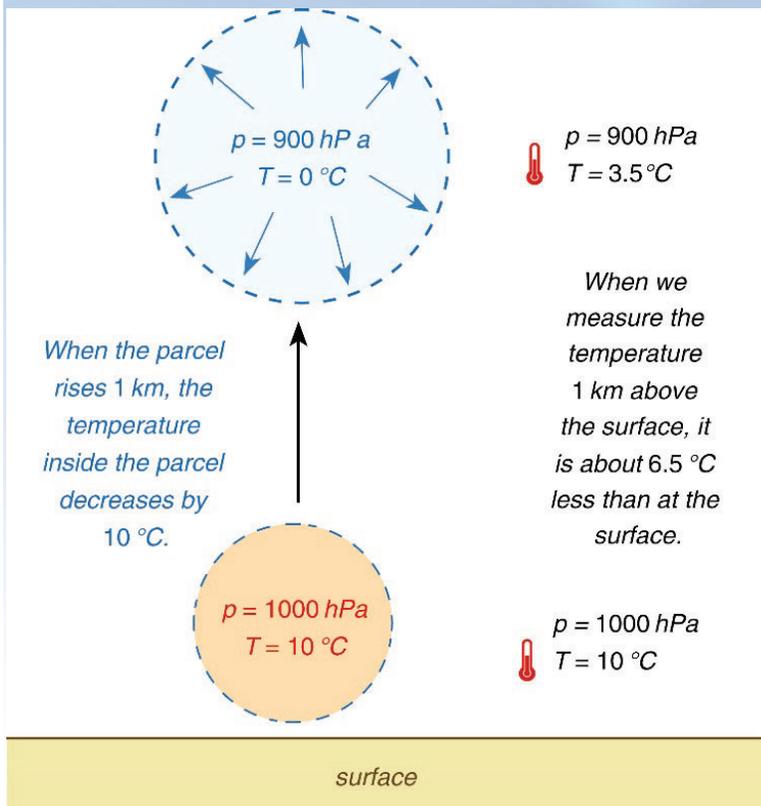
23

**Hot air rises!**  
**What happens then?**

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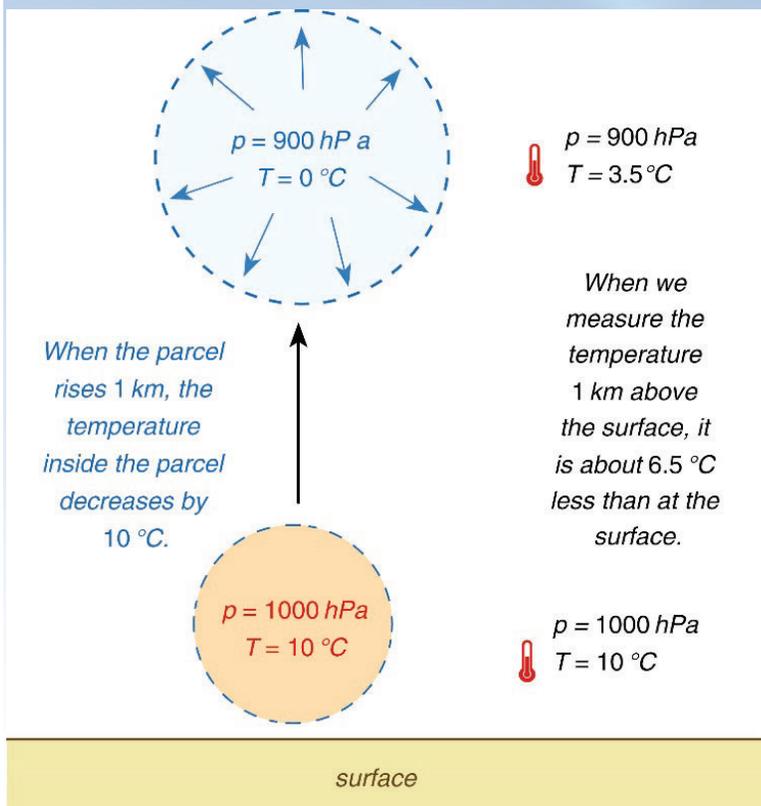
## Dry Adiabatic Lapse Rate



As an air parcel rises, it expands into lower pressure air. As it expands, all of the energy inside is spread out over a larger volume so the temperature drops

If there's no interaction between the air inside the parcel and the outside environment the process is said to be **adiabatic**

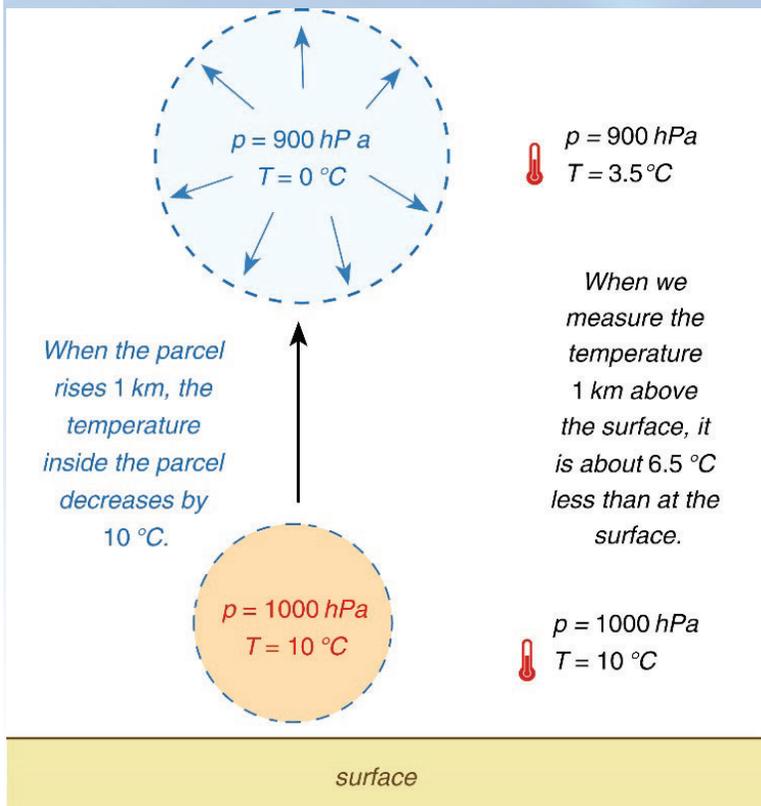
## Dry Adiabatic Lapse Rate



The drop in temperature is called "adiabatic cooling".

What is it called when temperature decreases with height?

## Dry Adiabatic Lapse Rate

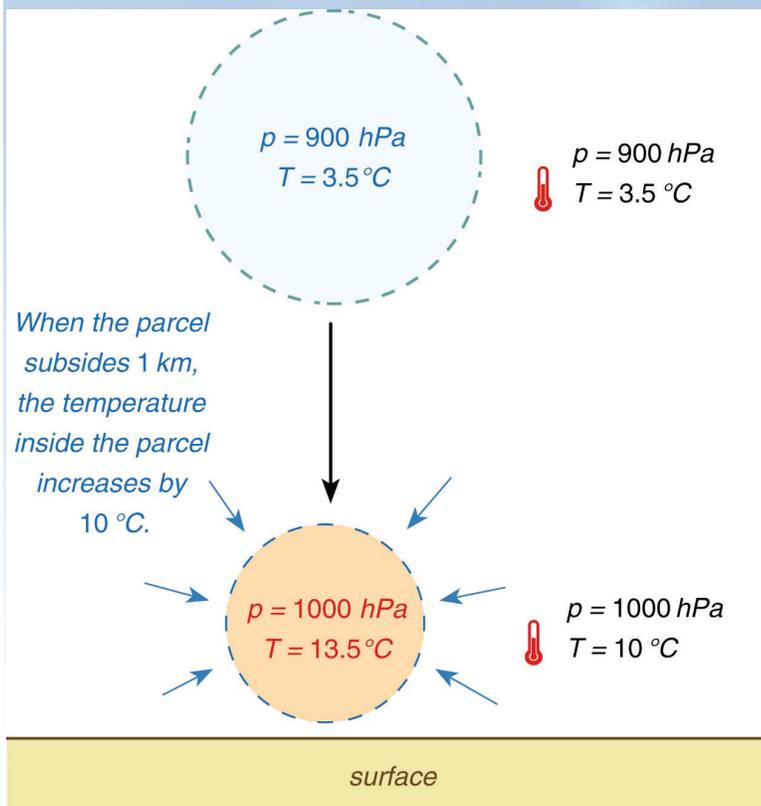


For every kilometer **increase**, the temperature inside the parcel **cools** by  $10^\circ\text{C}$

The environmental lapse rate is  $6.5^\circ\text{C}$  per km.

The air inside the parcel cools more quickly than the air outside.

## Dry Adiabatic Lapse Rate

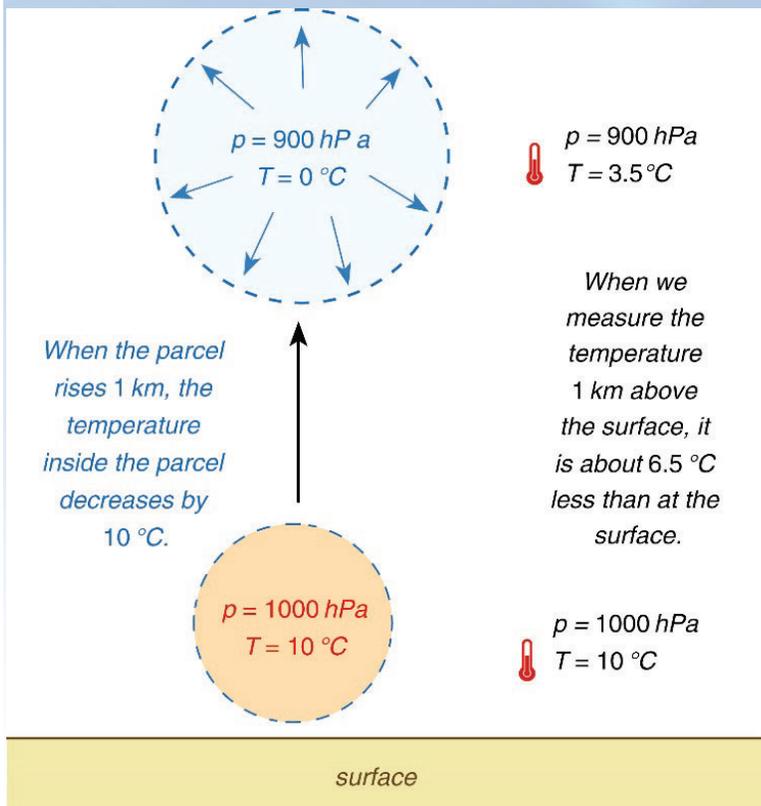


For every kilometer **decrease**, the temperature inside the parcel **warms** by  $10^\circ\text{C}$

The environmental lapse rate is  $6.5^\circ\text{C}$  per km.

The air inside the parcel warms more quickly than the air outside.

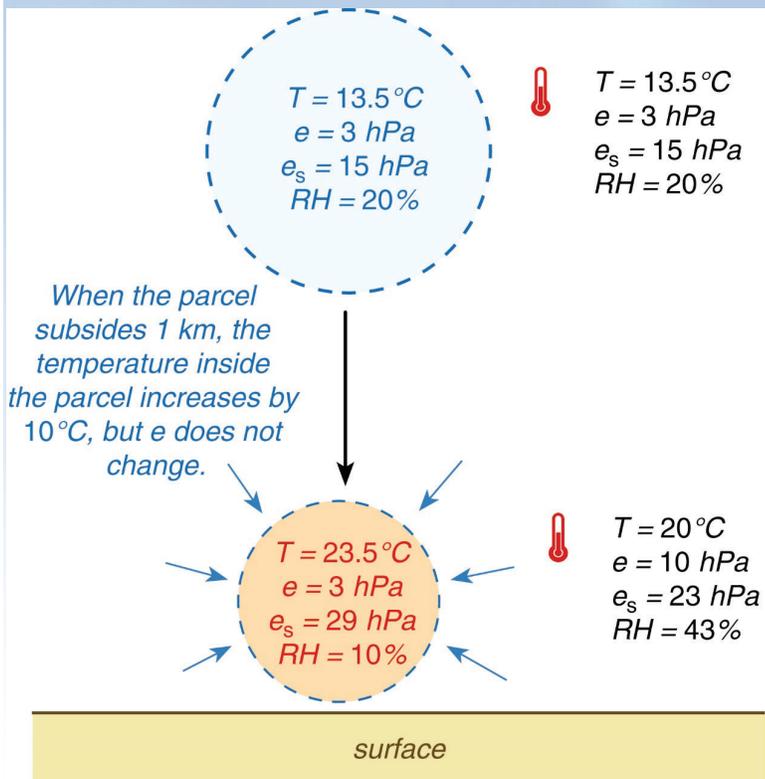
## Dry Adiabatic Lapse Rate



When the air parcel cools, what will happen to the RH inside the parcel?

Fig 6.2 Weather: A Concise Introduction 29

## Dry Adiabatic Lapse Rate



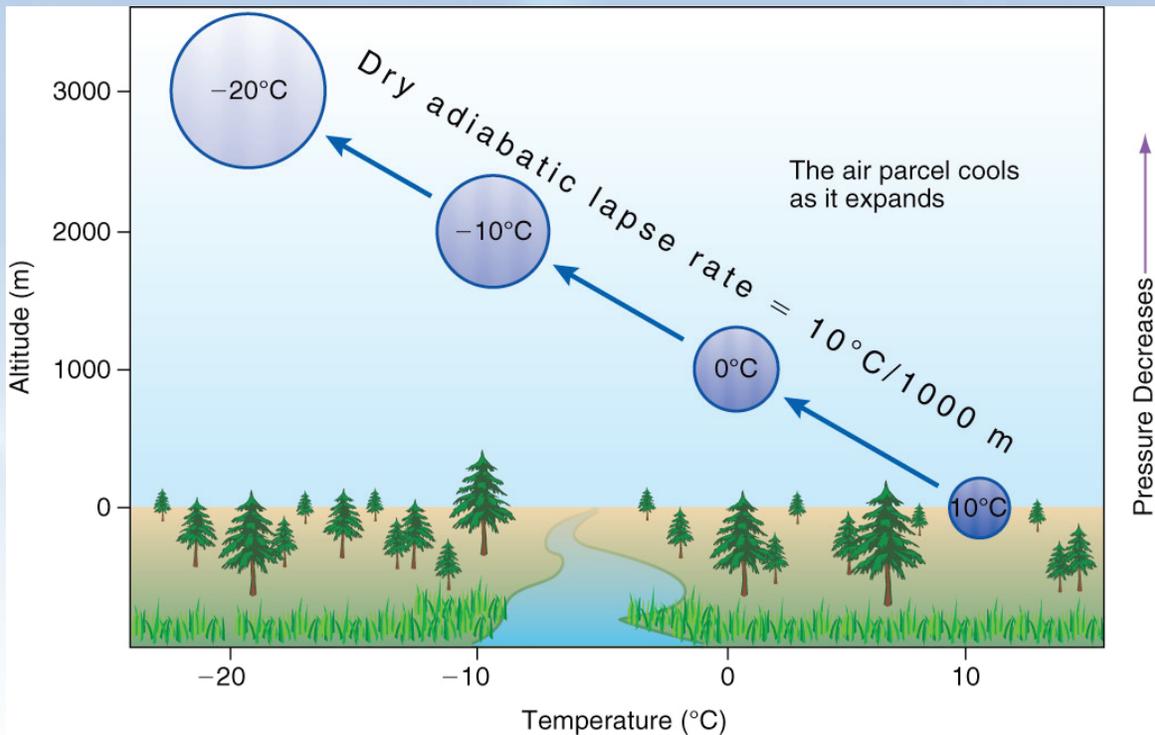
When the air parcel *subsides* (falls toward the surface) the parcel shrinks because of the higher pressure.

Temperature inside the parcel increases and the saturation vapor pressure increases.

RH goes down; the parcel dries out

Fig 6.6 Weather: A Concise Introduction 30

# Lapse Rate



**Dry adiabatic lapse rate: if no cloud forms, air will cool at  $10^{\circ}\text{C}$  per kilometer.**

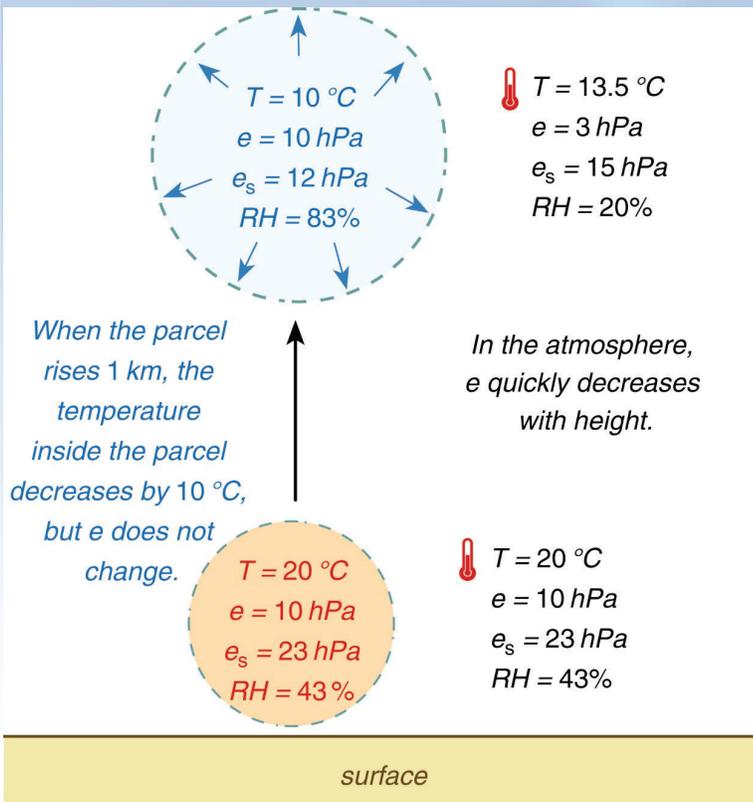
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Fig 3-19 Meteorology: Understanding the Atmosphere

31

## Dry Adiabatic Lapse Rate



What happens when the RH reaches 100% but the parcel keeps rising?

The parcel still cools at  $10^{\circ}\text{C}$  per km...

but...

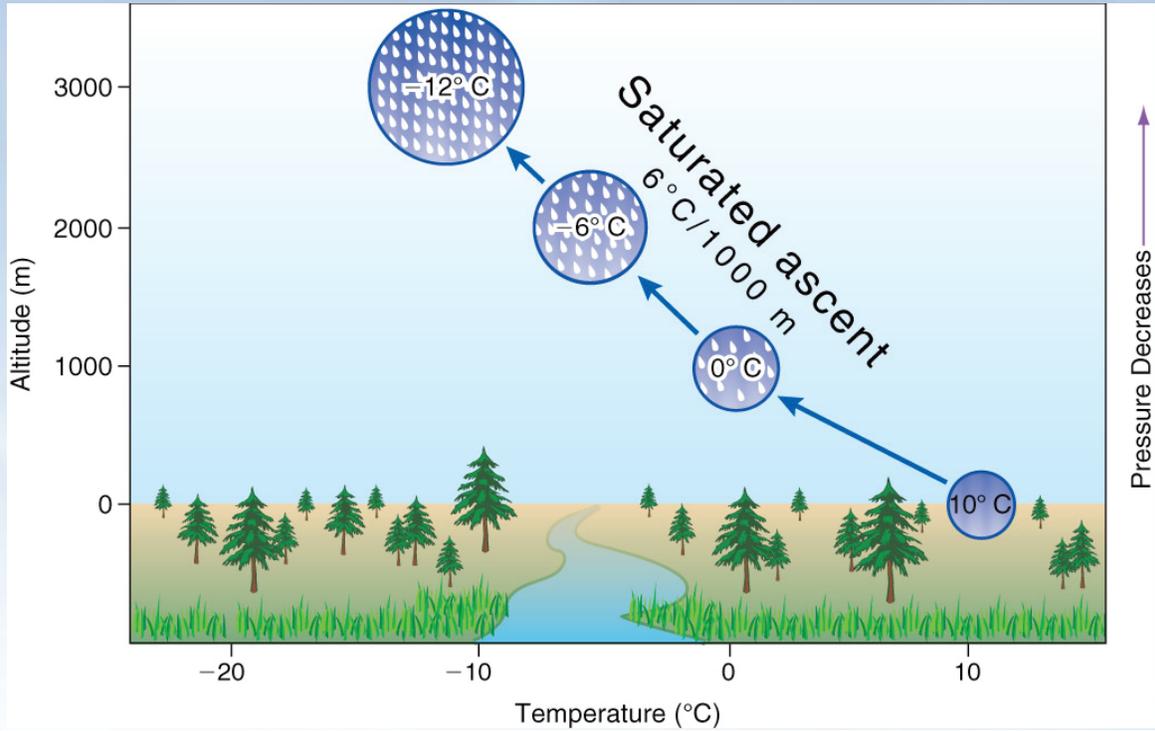
What is released when water vapor condenses???

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32

## Saturated Adiabatic Lapse Rate



**Once water begins to condense, latent heat is released. The air parcel cools at a slower rate than if the air parcel was dry**