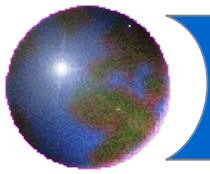


Chapter 5
Atmospheric Water and
Weather

Elemental Geosystems 5e

Robert W. Christopherson
Charles E. Thomsen





Water and Atmospheric Moisture

● **Water on Earth: Location and Properties**

● **Humidity**

● **Atmospheric Stability**

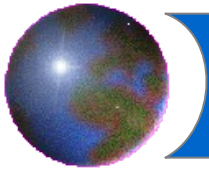
● **Clouds and Fog**

● **Air Masses**

● **Atmospheric Lifting Mechanisms**

● **Midlatitude Cyclonic Systems**

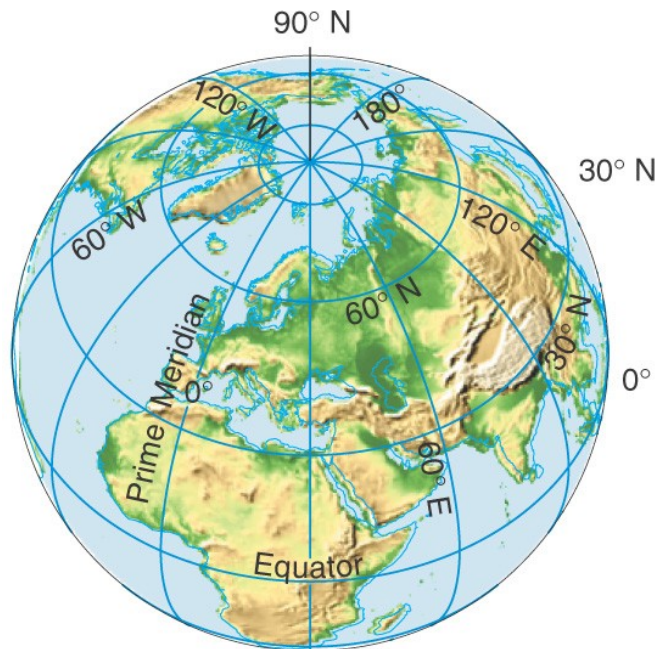
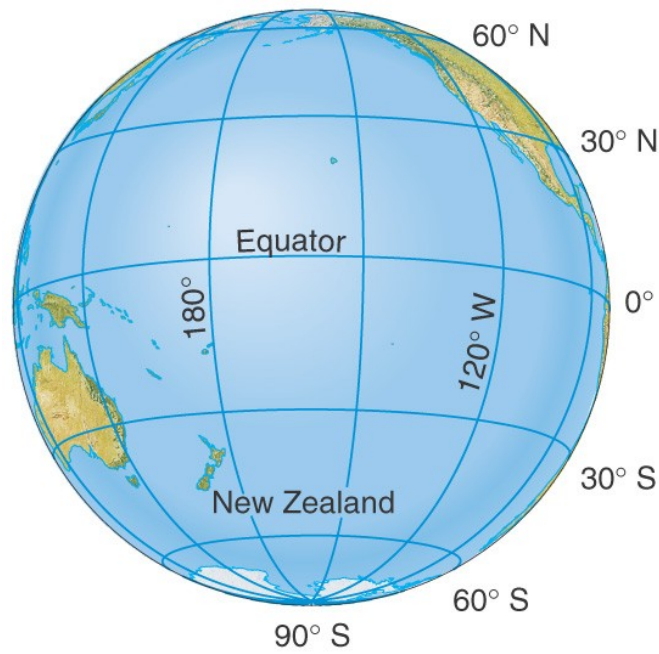
● **Violent Weather**



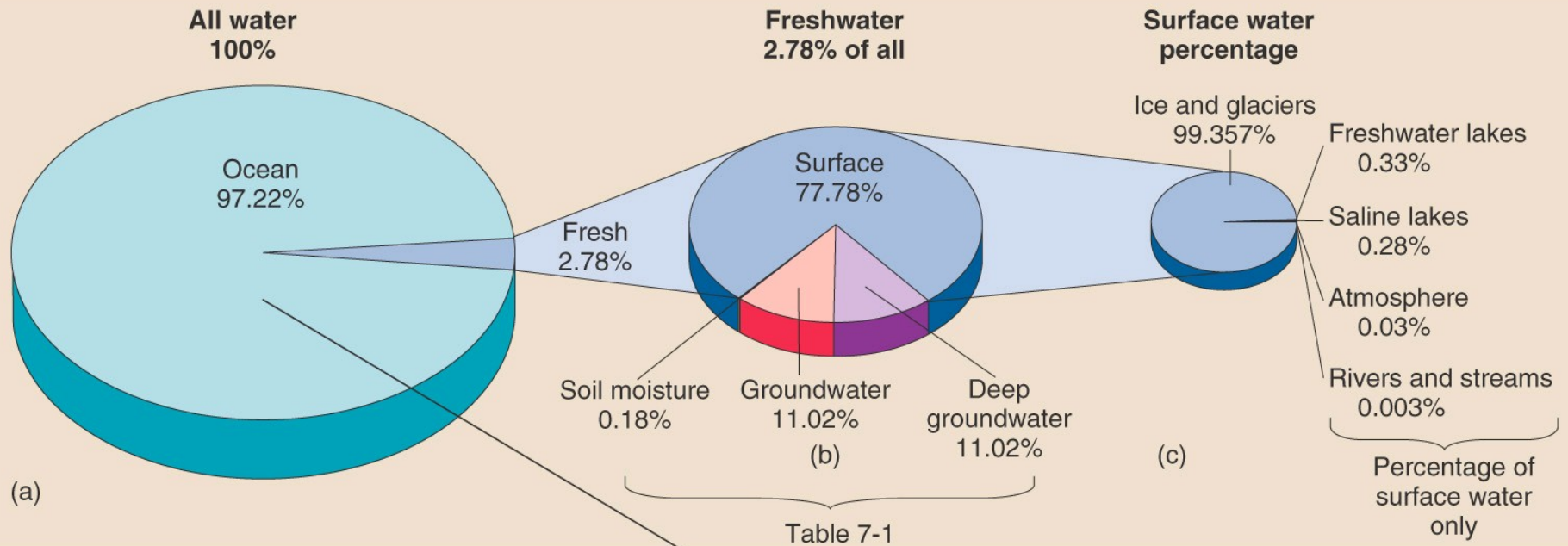
Water on Earth

- Quantity Equilibrium
- Distribution of Earth's Water Today
- Unique Properties of Water
- Heat Properties
 - ❑ Ice
 - ❑ Water
 - ❑ Water vapor
 - ❑ Heat properties of water in nature

Land and Water Hemispheres



Ocean and Freshwater Distribution



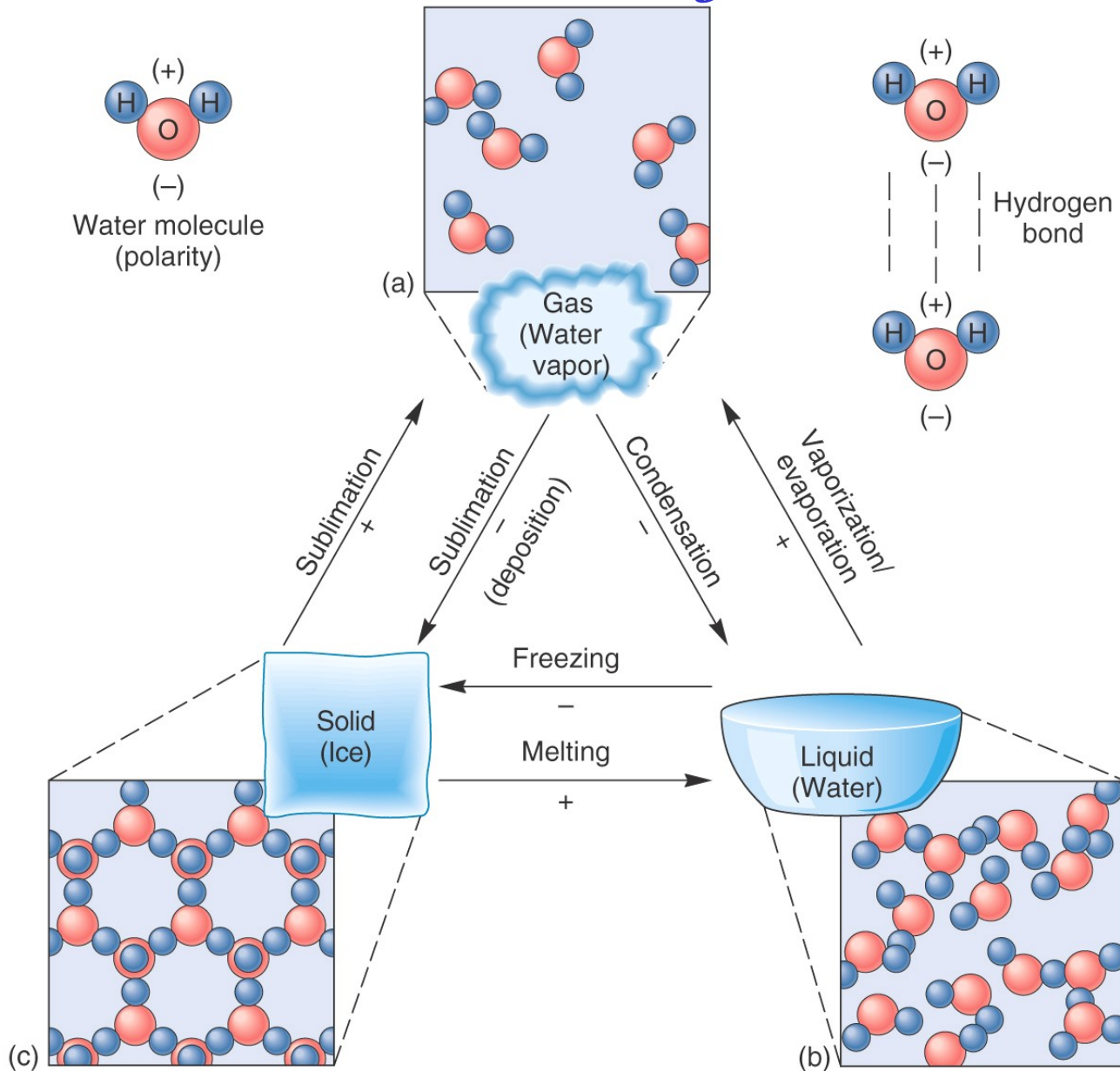
Ocean	Earth's Ocean Area (%)	*Area (km ² [mi ²])	*Volume (km ³ [mi ³])	Mean Depth of Main Basin (m [ft])
Pacific	48	179,670 (69,370)	724,330 (173,700)	4280 (14,040)
Atlantic	28	106,450 (41,100)	355,280 (85,200)	3930 (12,890)
Indian	20	74,930 (28,930)	292,310 (70,100)	3960 (12,900)
Arctic	4	14,090 (5440)	17,100 (4100)	1205 (3950)

*Data in thousands (000): includes all marginal seas.

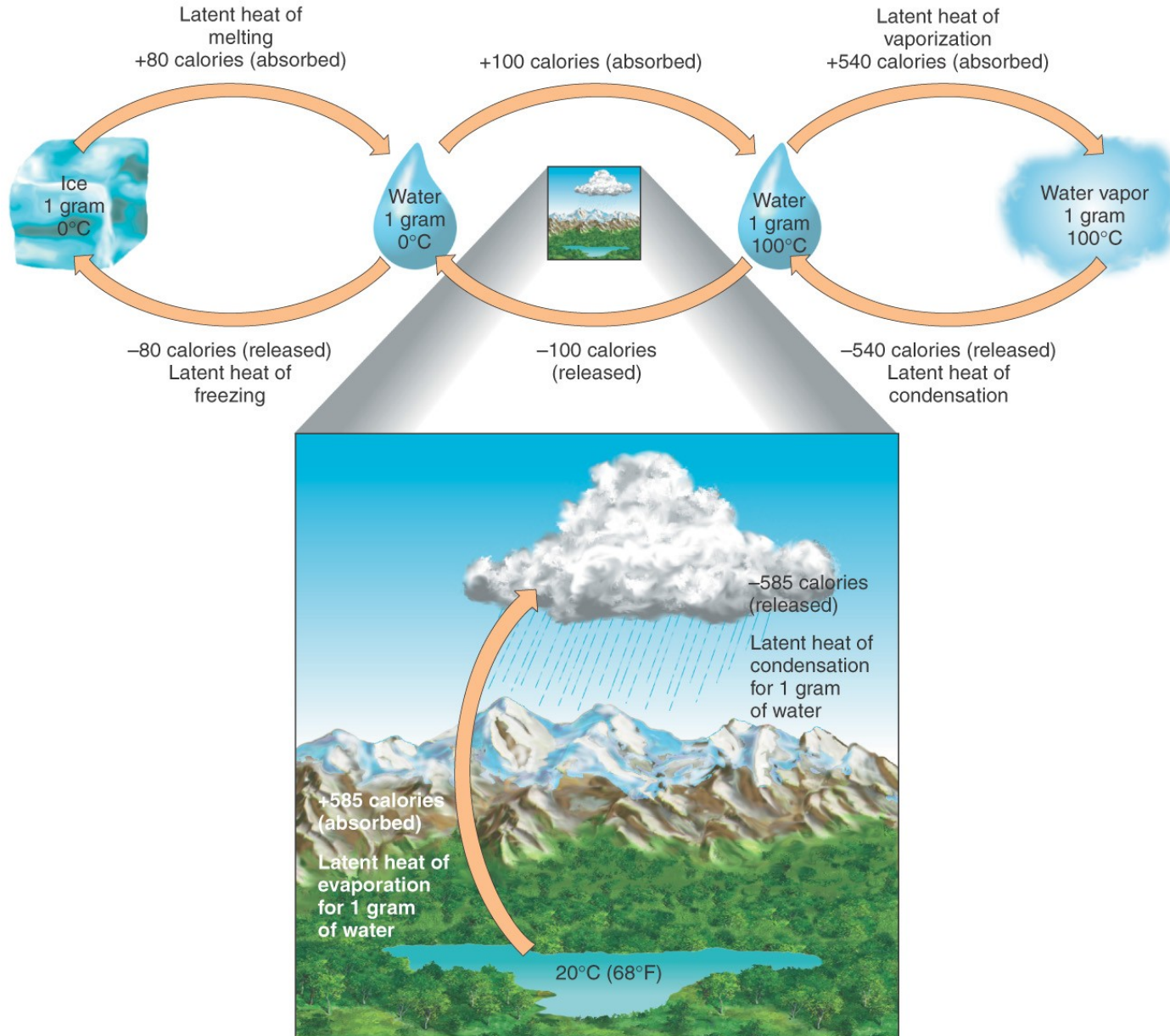
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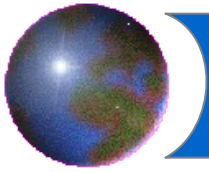
Figure 5.3

Three States of Water



Water's Heat Energy Characteristics





Humidity

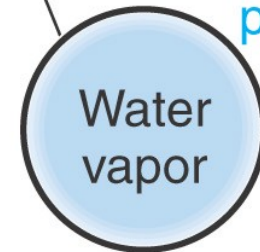
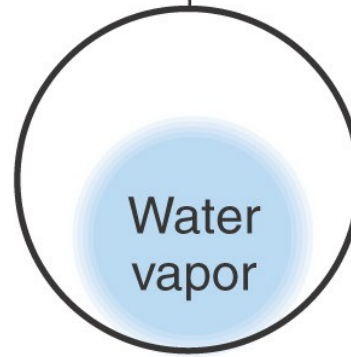
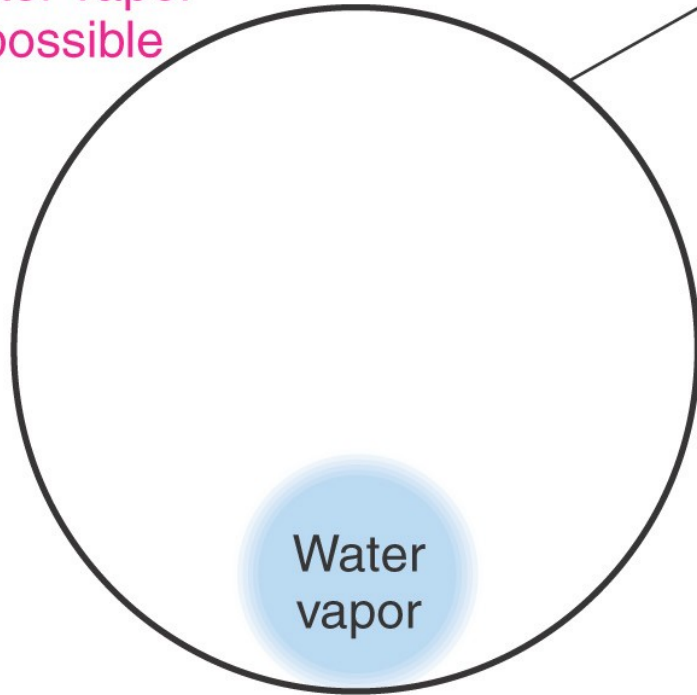
- Relative Humidity
- Expressions of Humidity
 - ❖ Vapor pressure
 - ❖ Specific humidity
 - ❖ Instruments for measurement

Relative Humidity

Warmer air—
greater maximum
water vapor
possible

Maximum
water-vapor
possible

Cooler air—
lesser maximum
water vapor
possible



20%
relative
humidity

50%
relative
humidity

100%
relative
humidity

5 P.M.

11 A.M.

5 A.M.

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Figure 5.7

Humidity Patterns

July 22

July 23

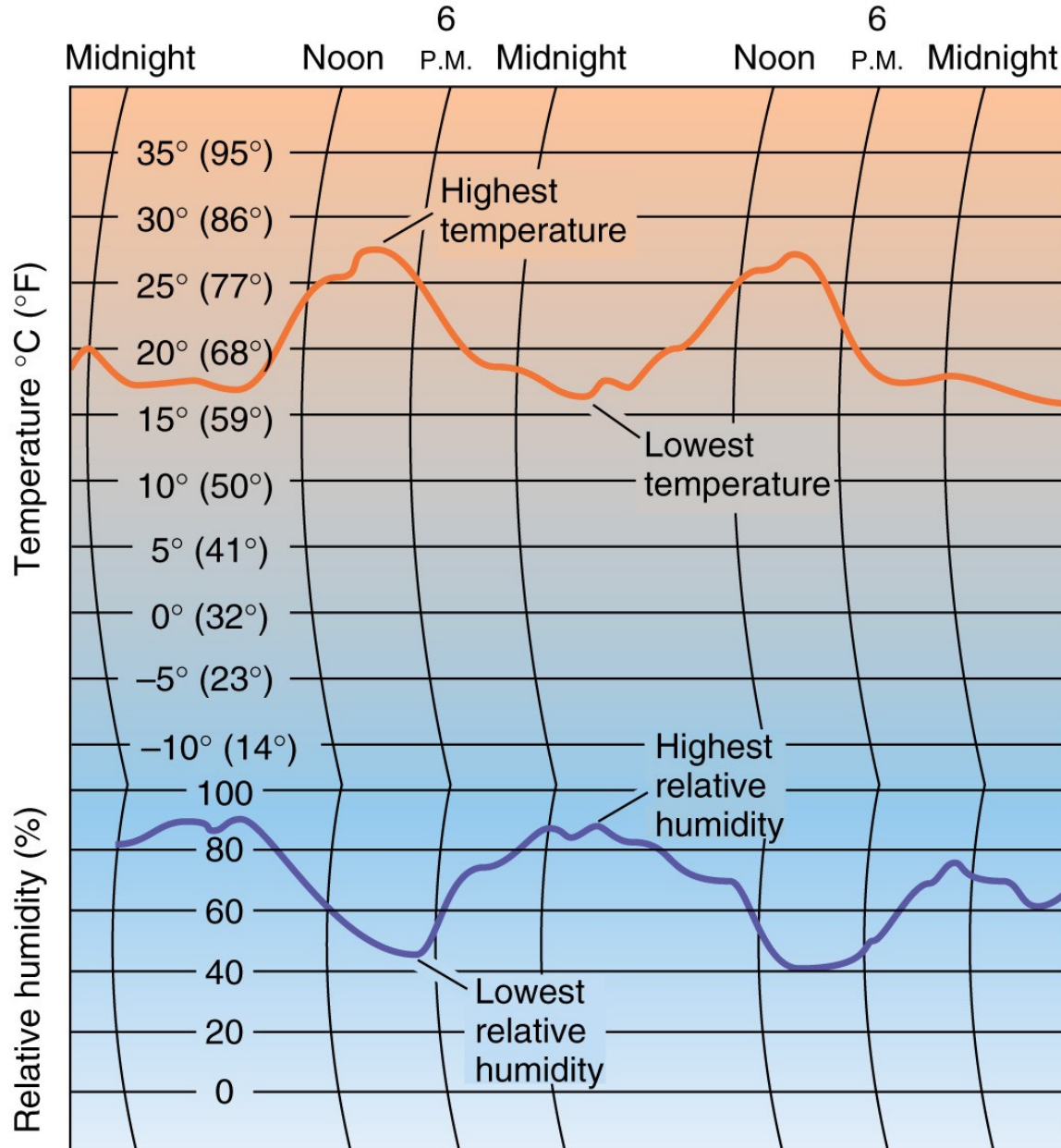


Figure 5.10

Maximum Specific Humidity

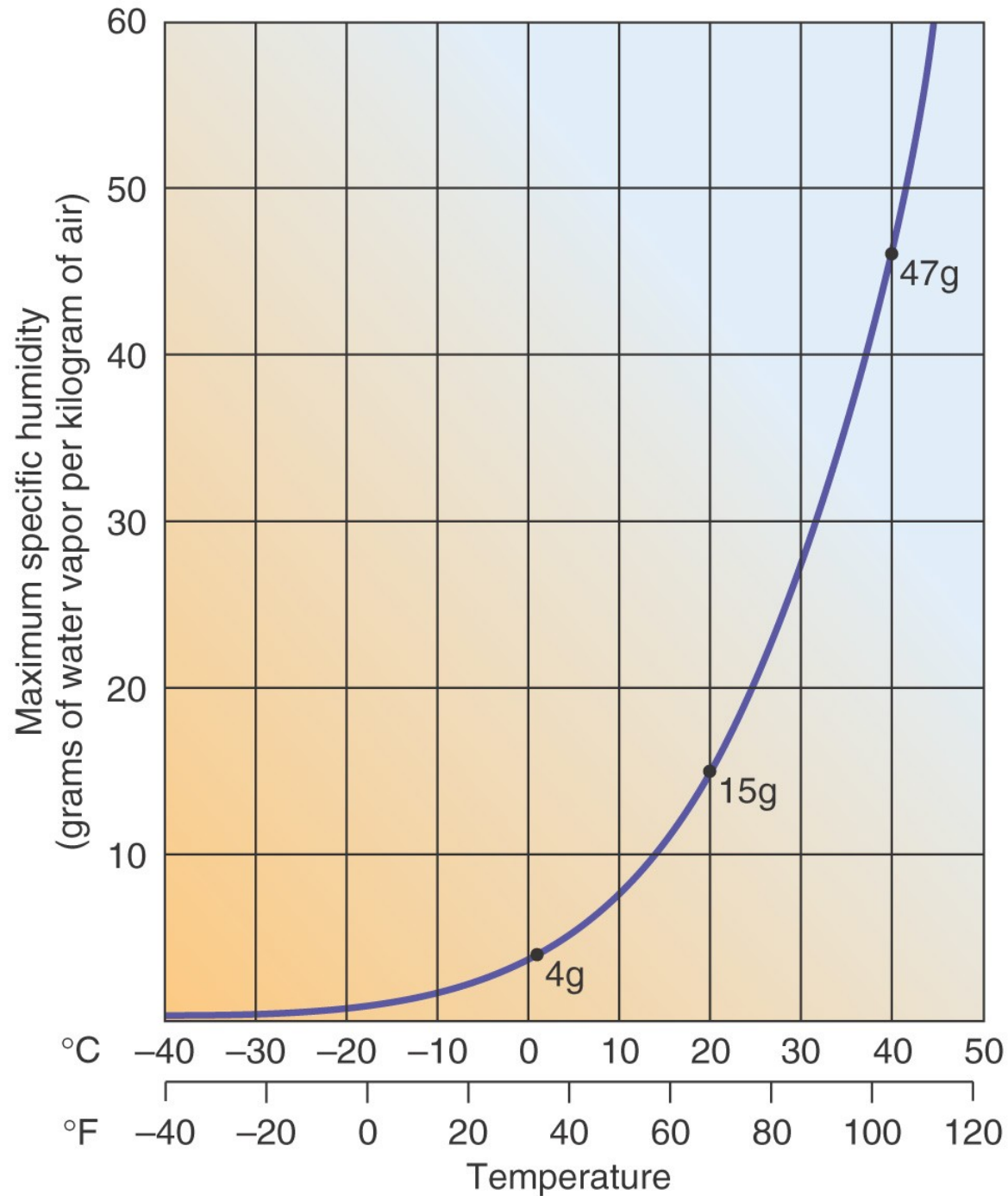
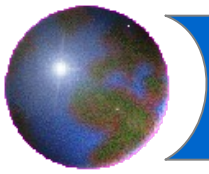
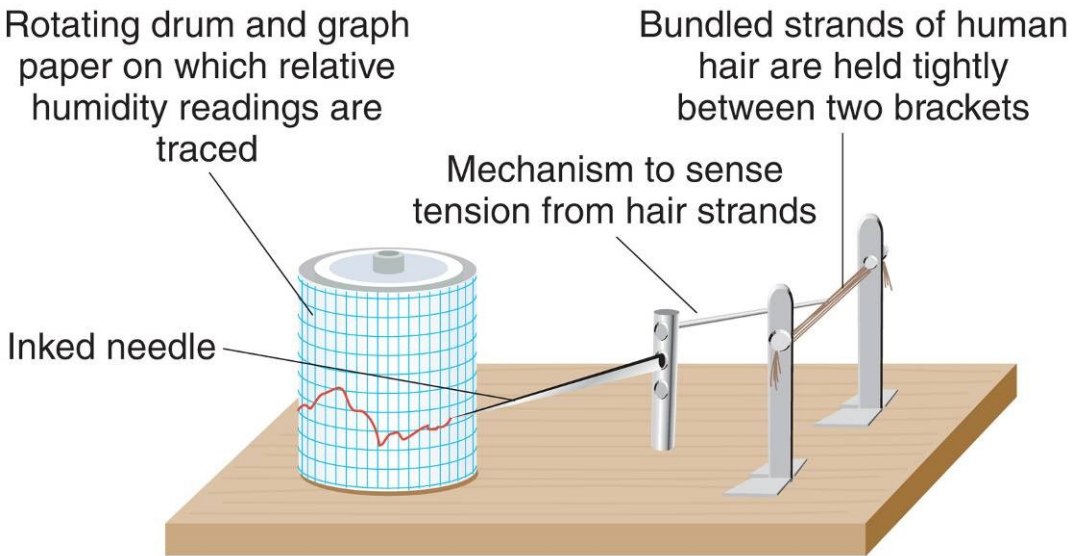


Figure 5.12



Humidity Instruments



(a)

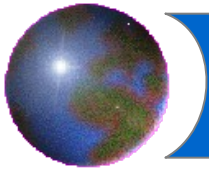
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(b)

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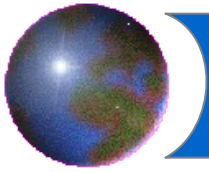
Figure 5.13



Atmospheric Stability

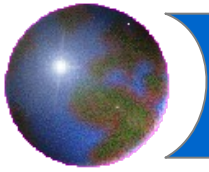
● Adiabatic Processes

- ❑ Dry adiabatic rate (DAR)
- ❑ Moist adiabatic rate (MAR)
- ❑ Stable and unstable atmospheric conditions



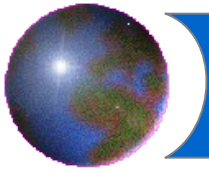
Atmospheric Stability

- Adiabatic Processes
- Adiabatic processes apply to MOVING parcels of air
- ELR (Environmental Lapse Rate) refers to static (UNMOVING) atmosphere
- Stable and Unstable Atmospheric Conditions



Atmospheric Stability

- Stability: tendency of a parcel of air to rise (unstable conditions) or not rise (stable conditions)
- Determined by relationship of ELR to DAR or MAR



Adiabatic Processes

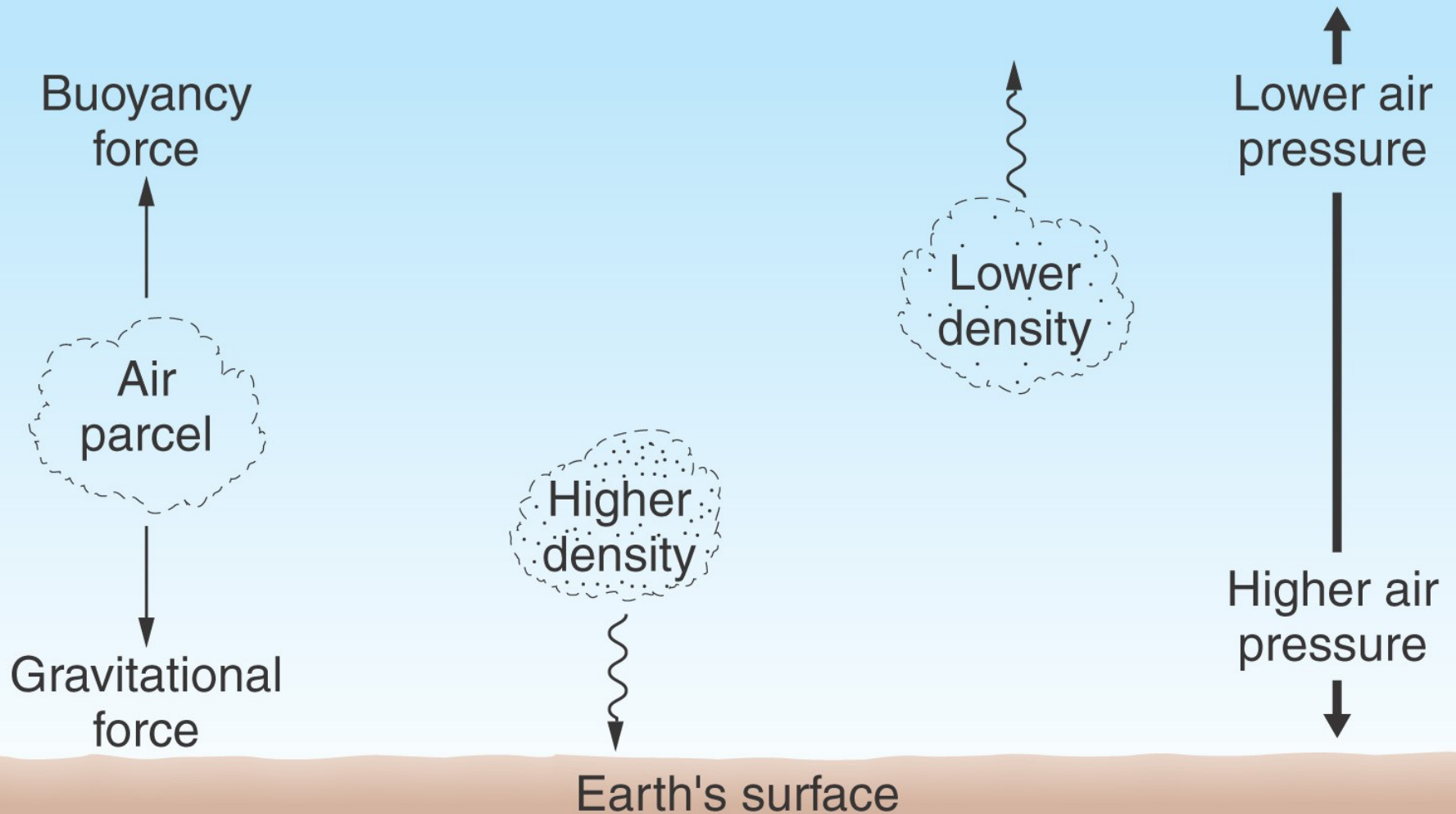
- Dry adiabatic rate

 - ▣ $10\text{ C}^\circ / 1000\text{ m}$

- Moist adiabatic rate

 - ▣ $6\text{ C}^\circ / 1000\text{ m}$

Buoyancy



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Figure 5.14

Adiabatic Processes

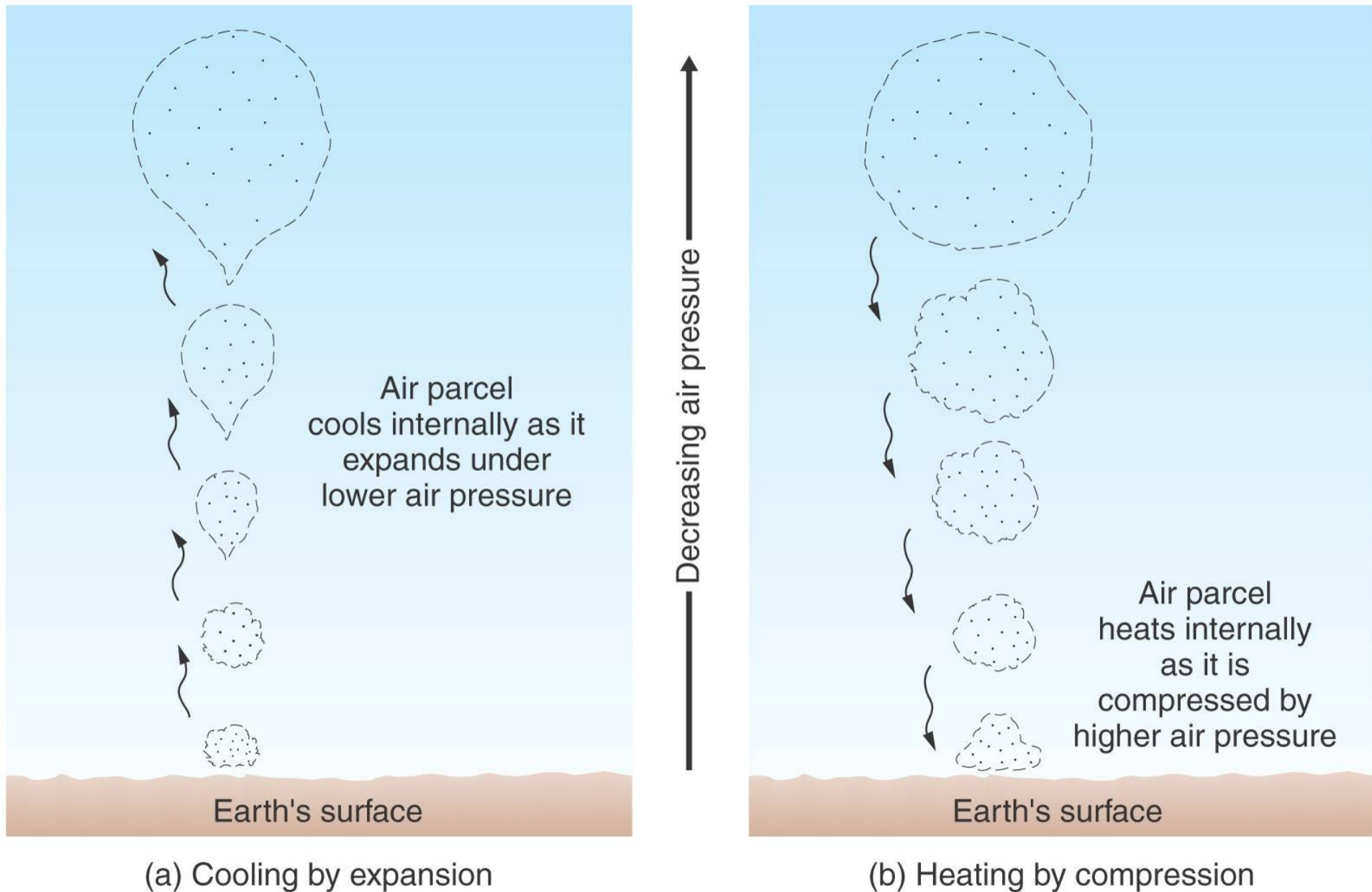


Figure 5.15

Atmospheric Temperatures and Stability

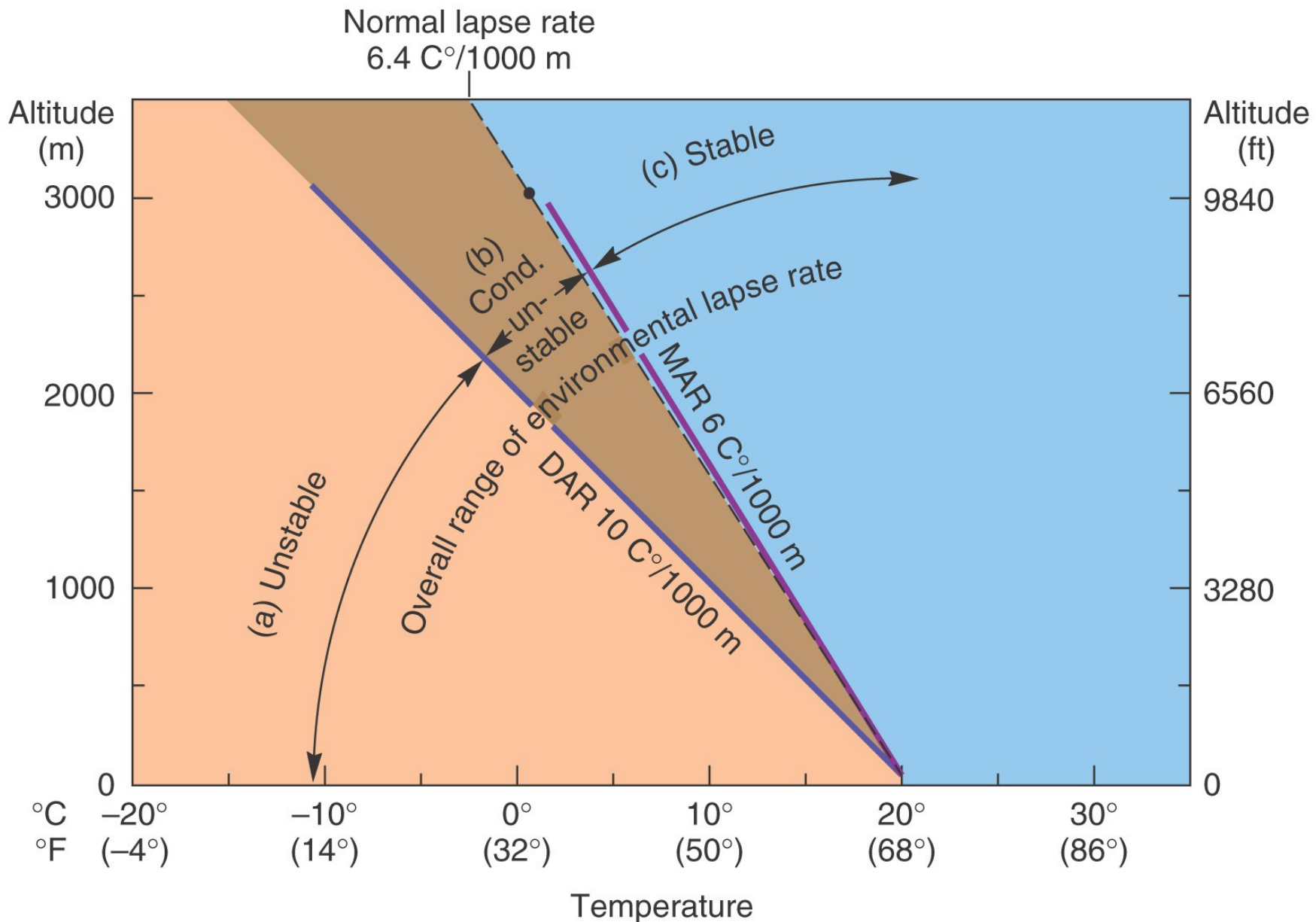
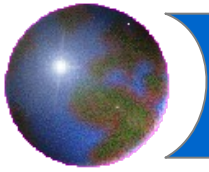


Figure 5.16



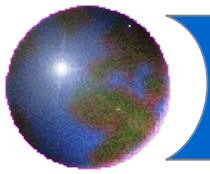
Clouds and Fog

- Cloud Types and Identification

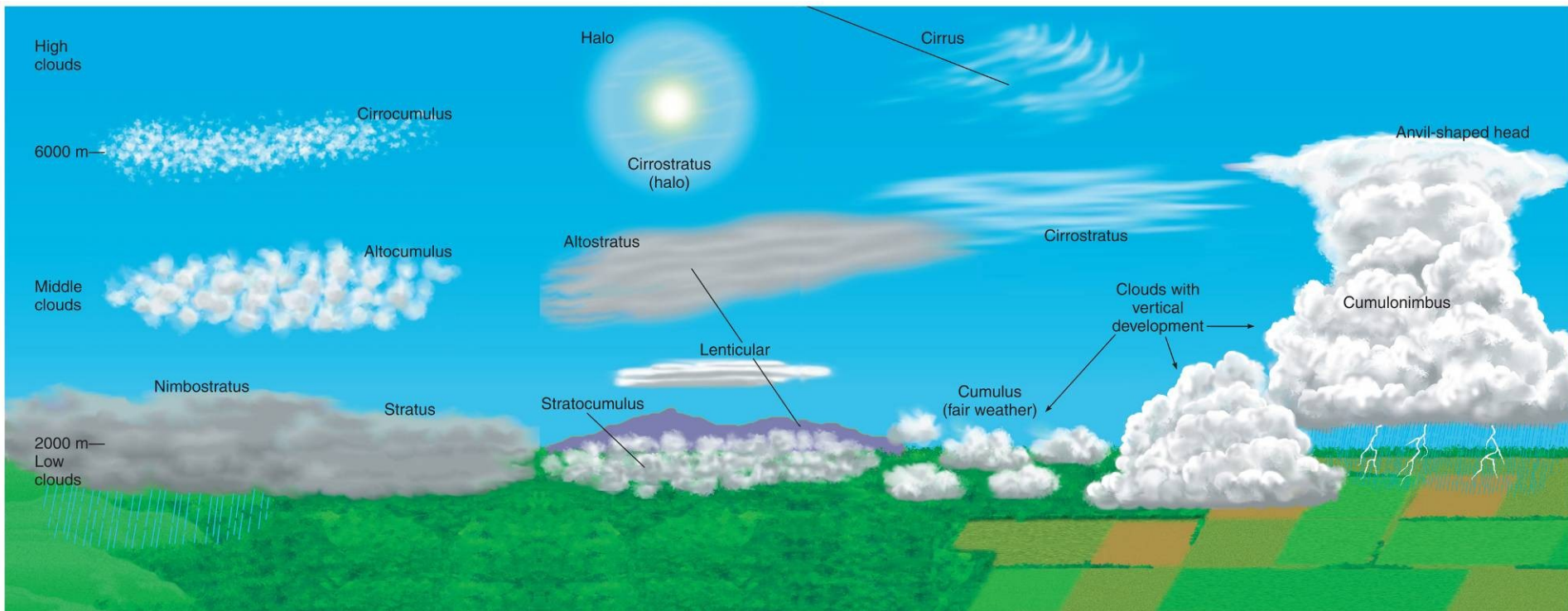
- Fog

 - ▣ Advection fog

 - ▣ Radiation fog



Cloud Types and Identification

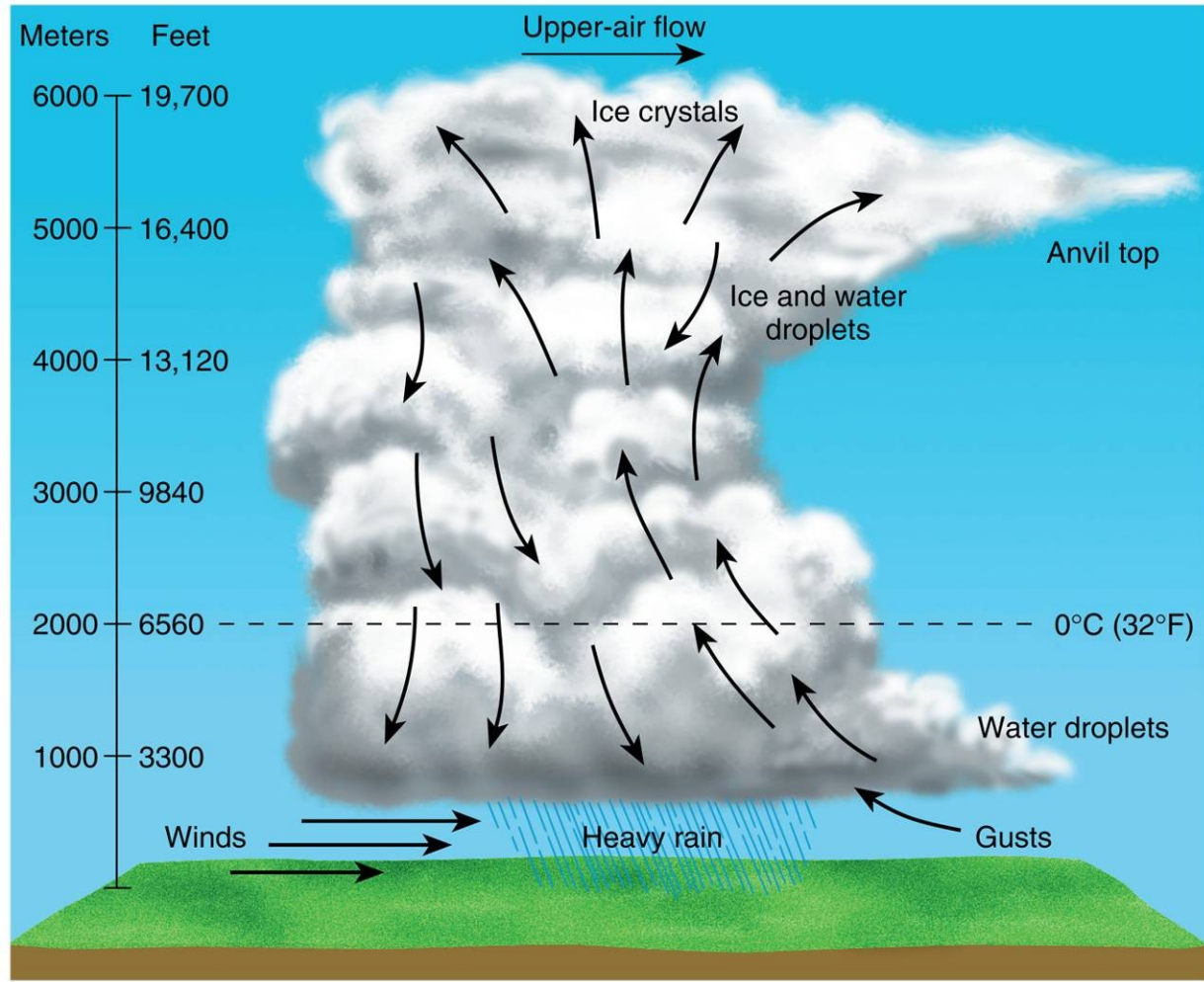


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Figure 5.18

Cumulonimbus Development



(a)

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(b)

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Figure 5.19

Advection Fog



Figure 5.20

Evaporation Fog

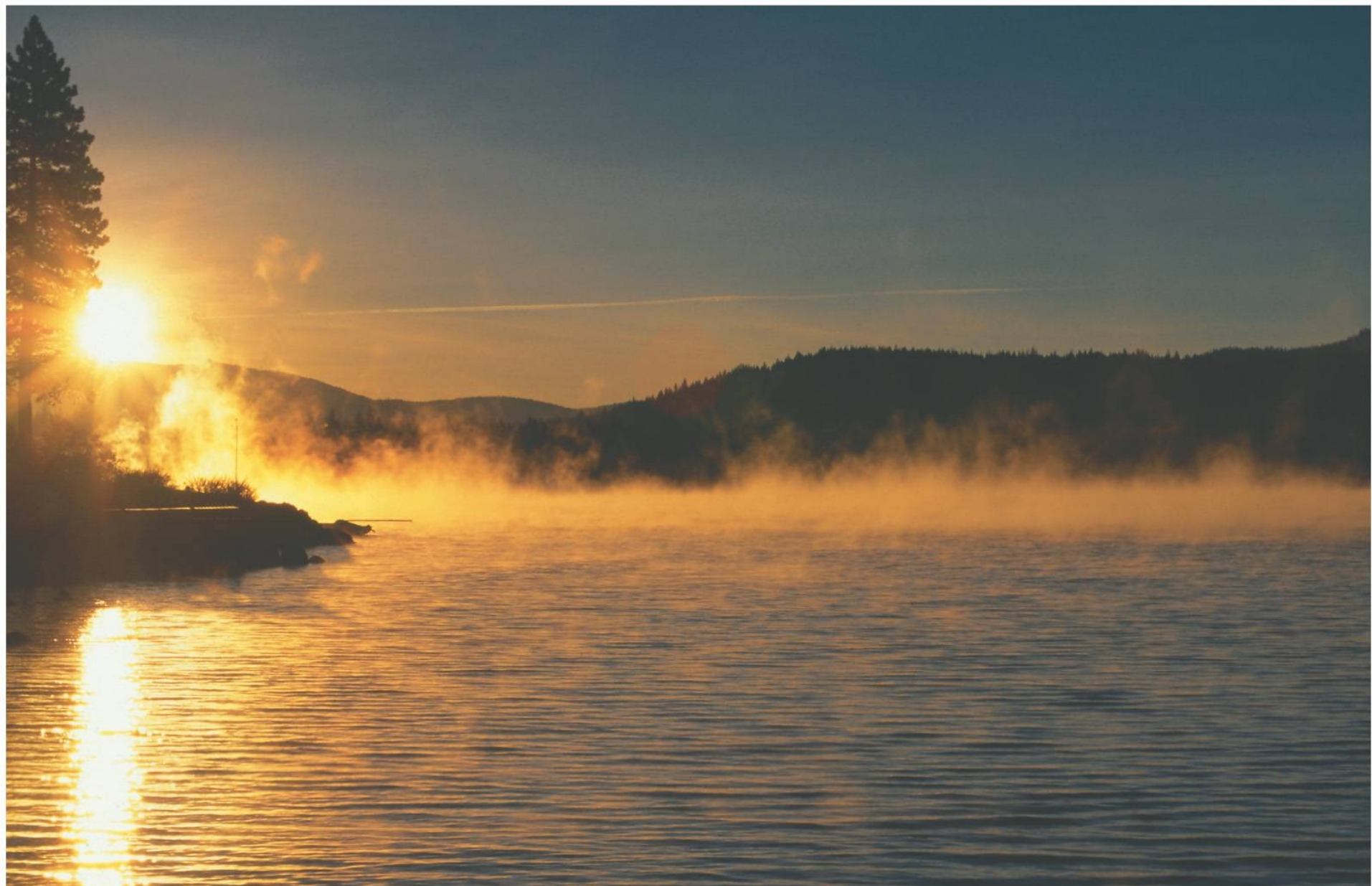


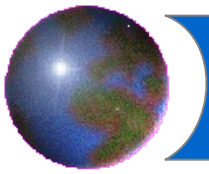
Figure 5.21

Valley Fog



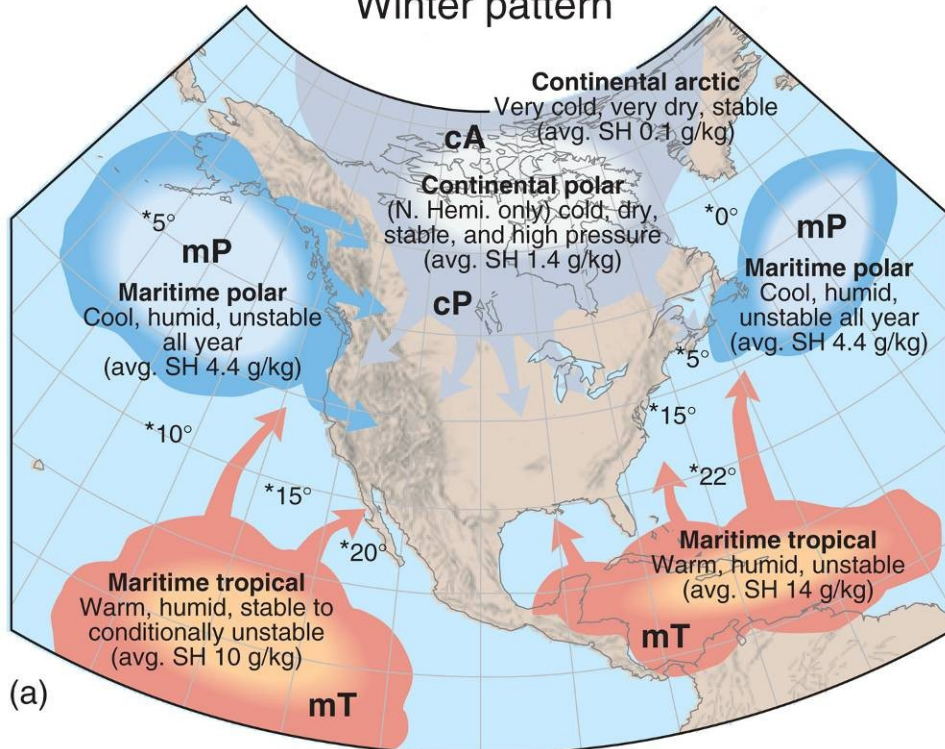
Radiation Fog





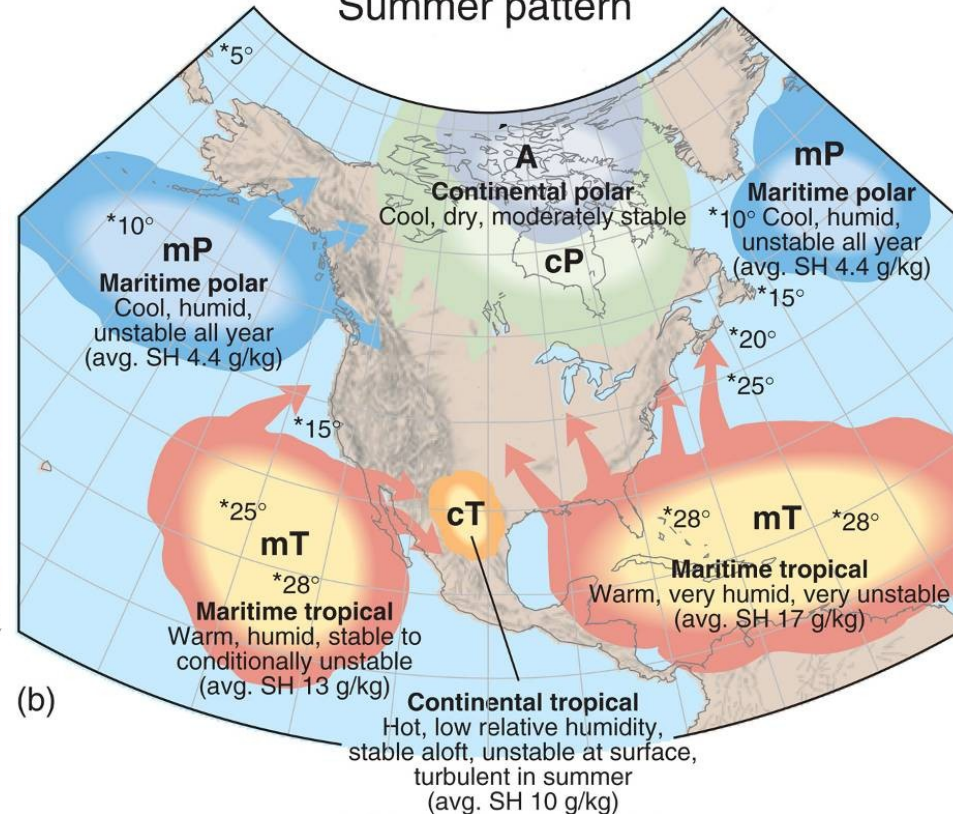
Air Masses

Winter pattern



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Summer pattern



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Figure 5.24

Lake Effect Snowbelts



AVERAGE ANNUAL SNOWFALL	
cm	in.
330 and over	130 and over
250–329	100–129
150–249	60–99
90–149	36–59
60–89	24–35
Under 60	Under 24

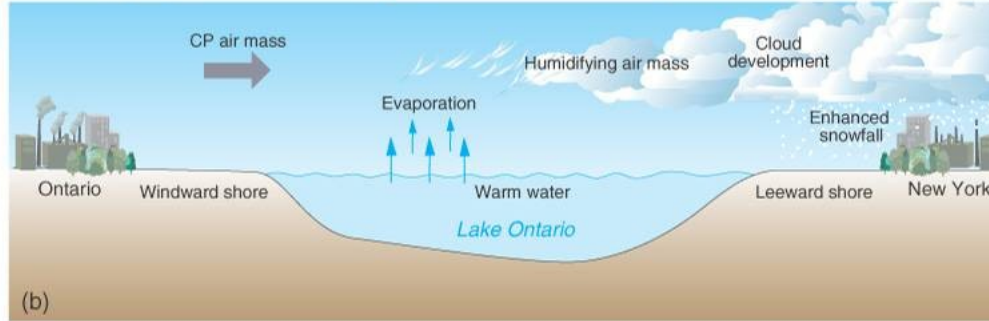
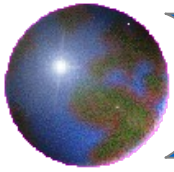


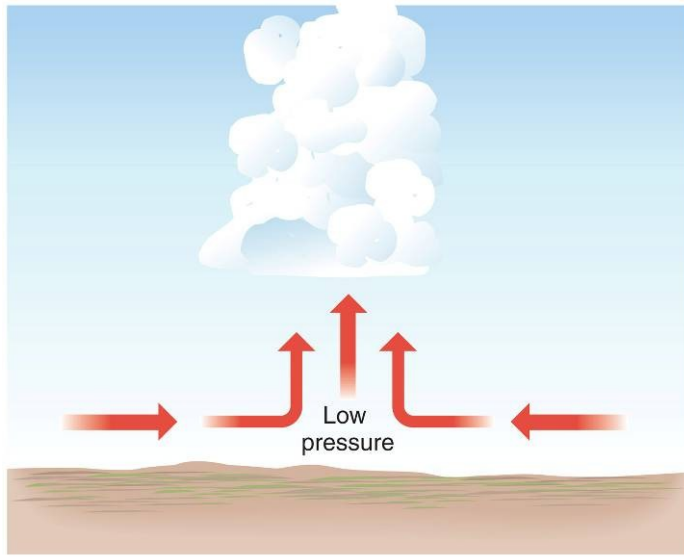
Figure 5.26



Atmospheric Lifting Mechanisms

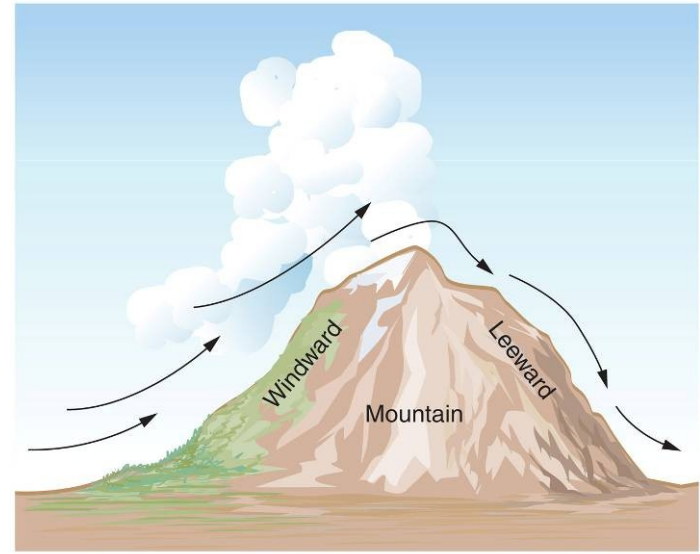
- Convective Lifting
- Orographic Lifting
- Frontal Lifting
 - ▣ Cold fronts
 - ▣ Warm fronts

Atmospheric Lifting Mechanisms



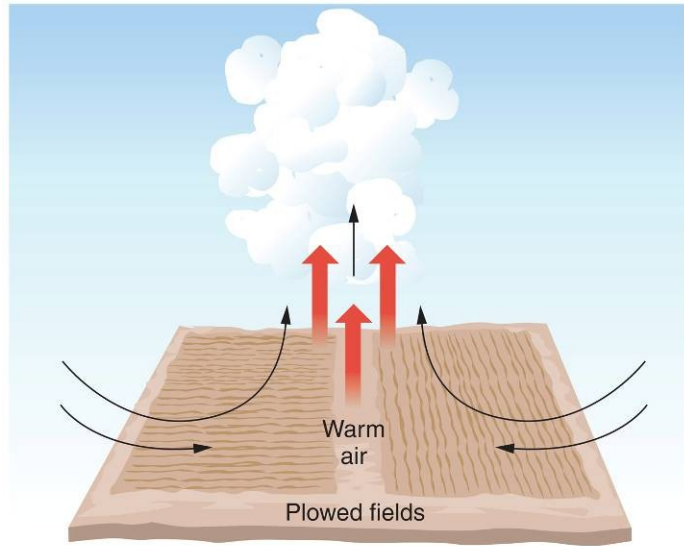
(a) Convergent

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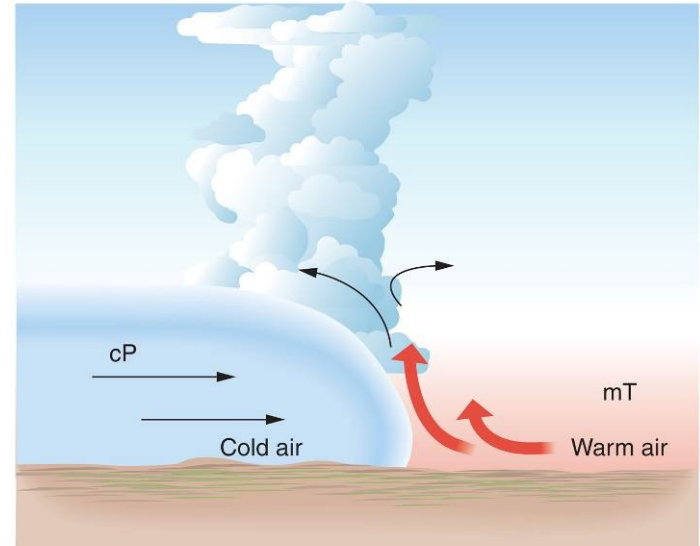
(c) Orographic (barrier)

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(b) Convective (local heating)

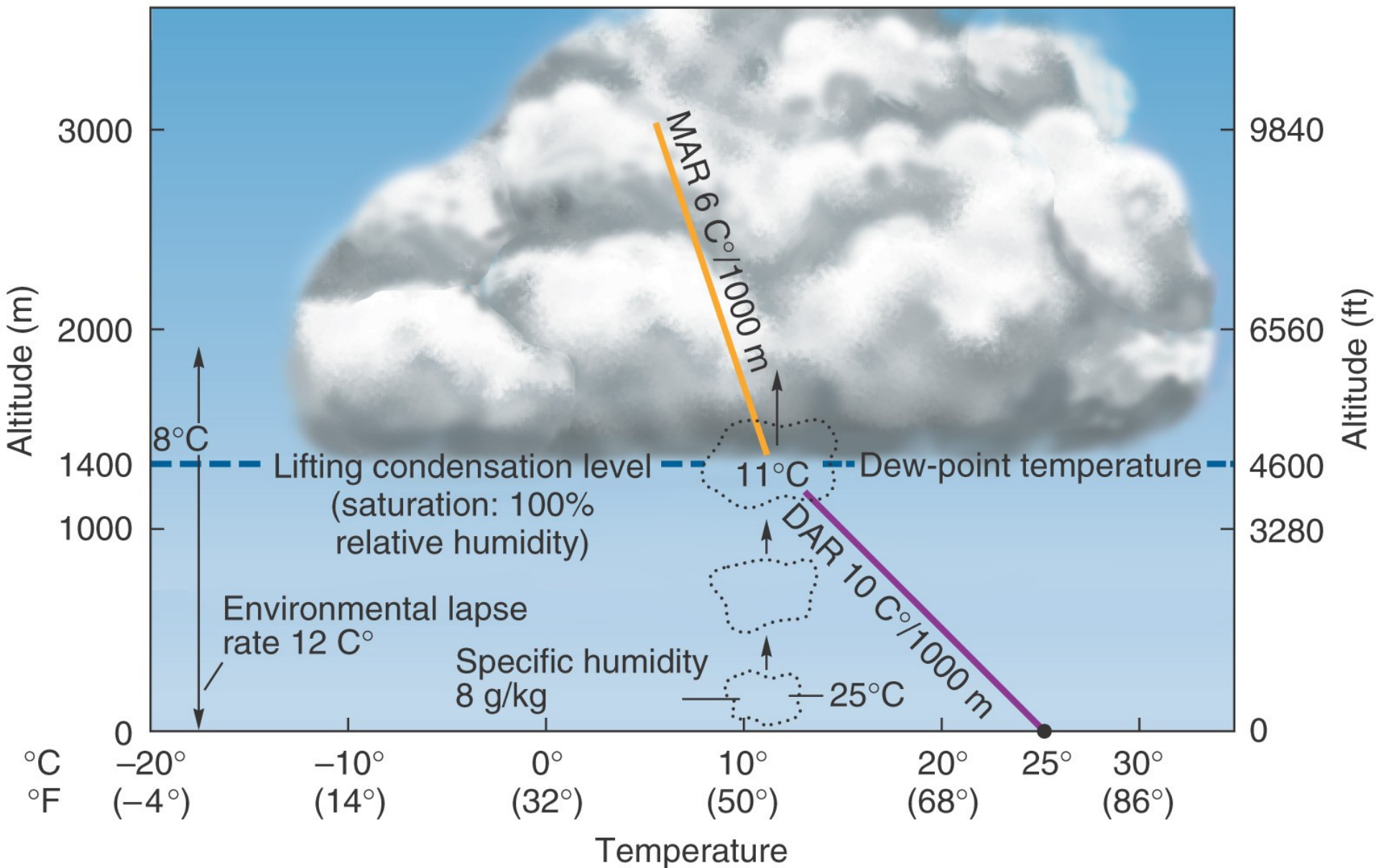
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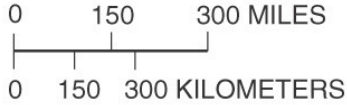
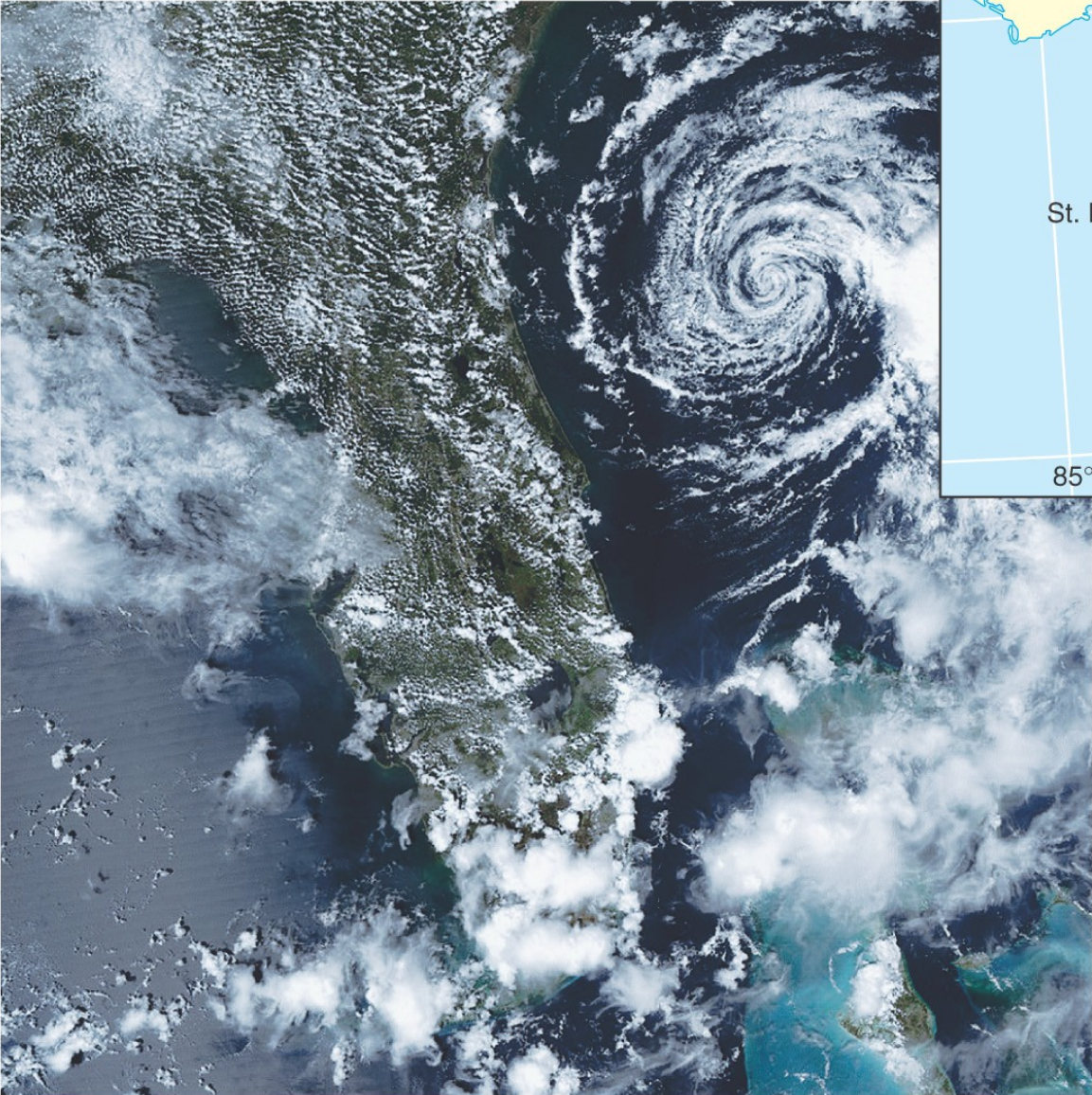
(d) Frontal (e.g. cold front)

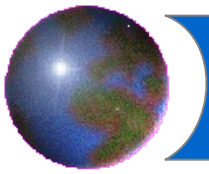
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Local Heating and Convection

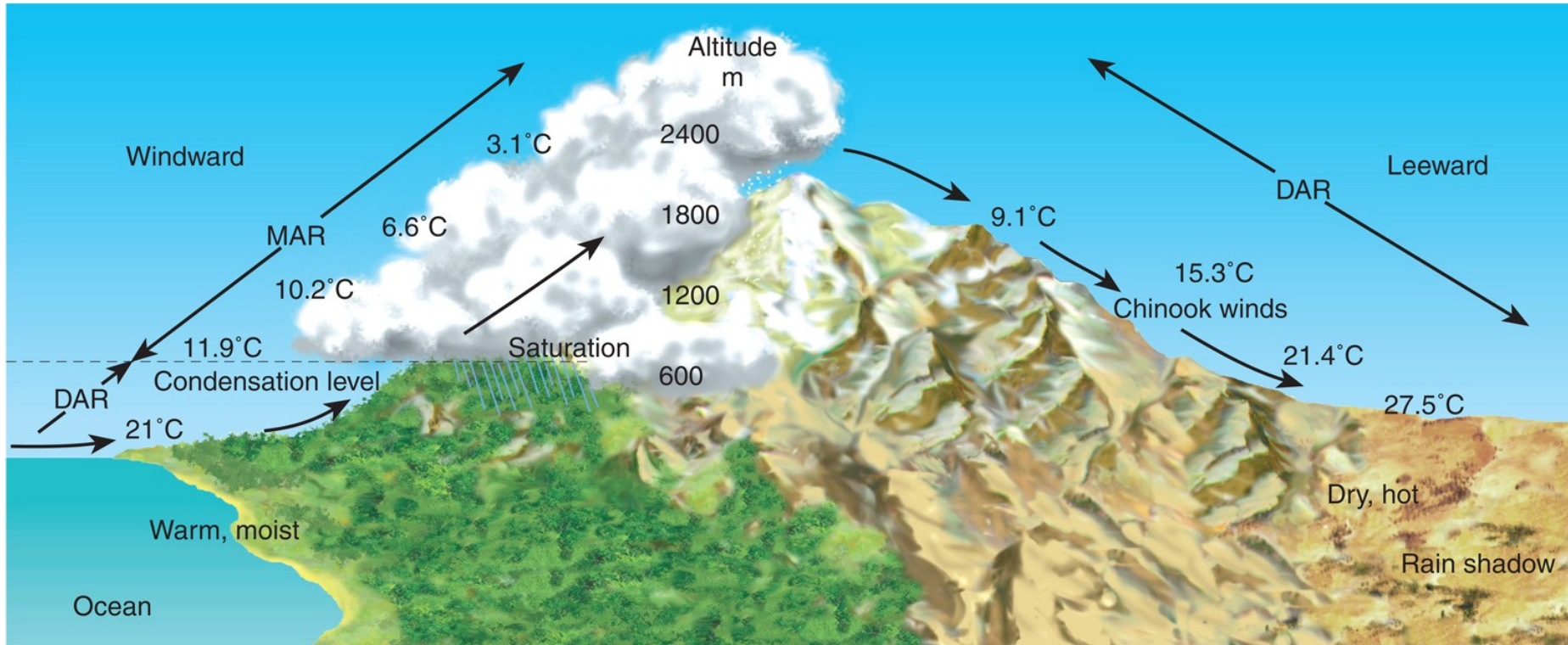


Convection over Florida





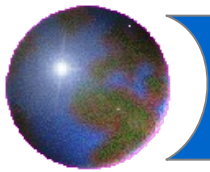
Orographic Precipitation



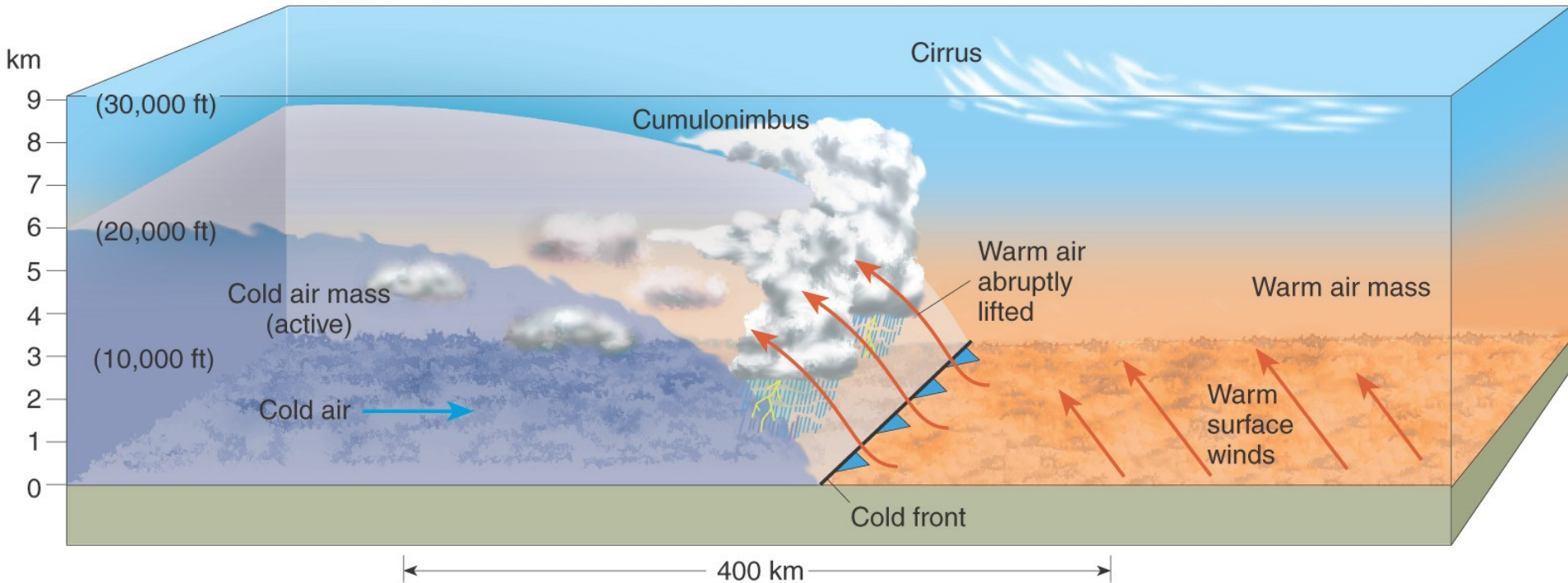
(a)

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Figure 5.30



Cold Front

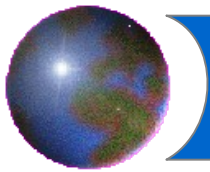


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Figure 5.31a

*Cold Front
and
Squall Line*





Warm Front

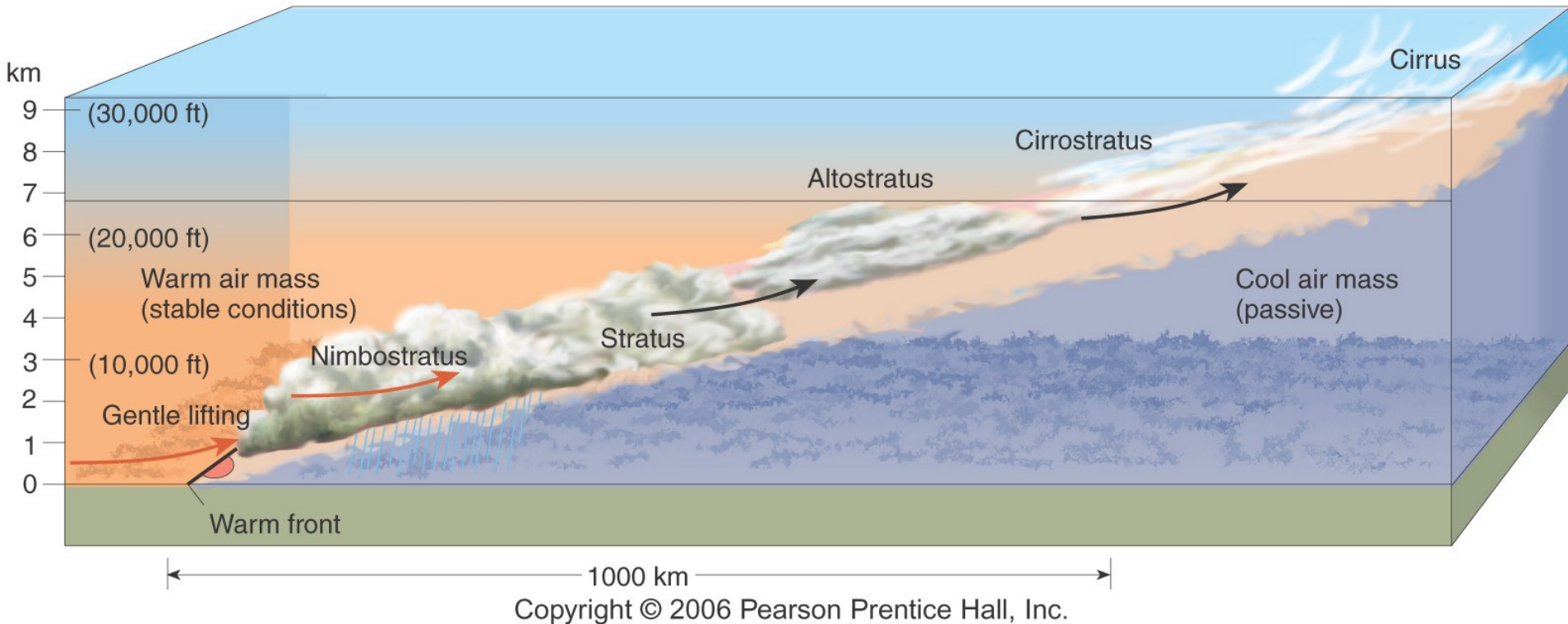
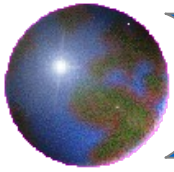


Figure 5.32

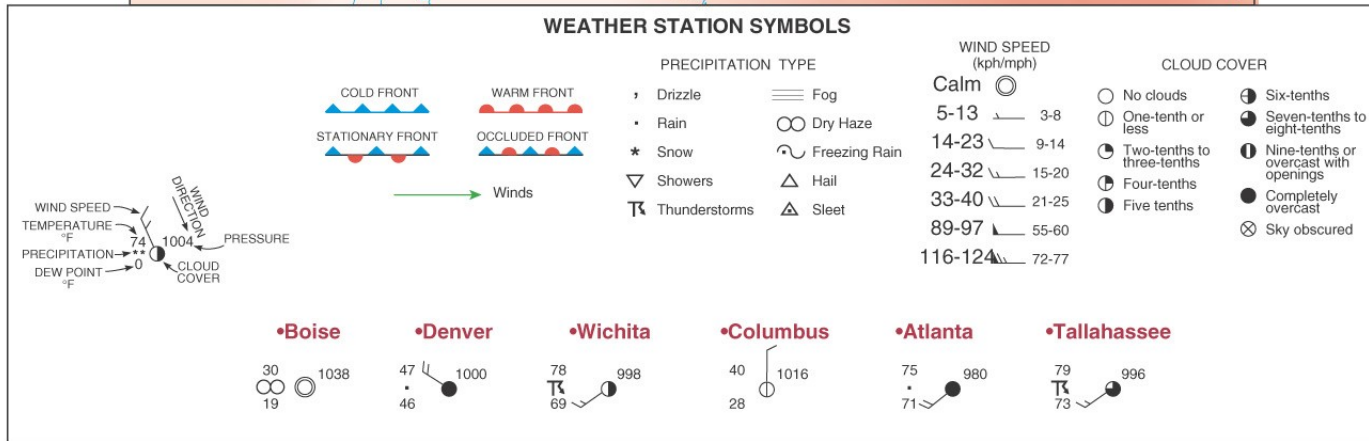
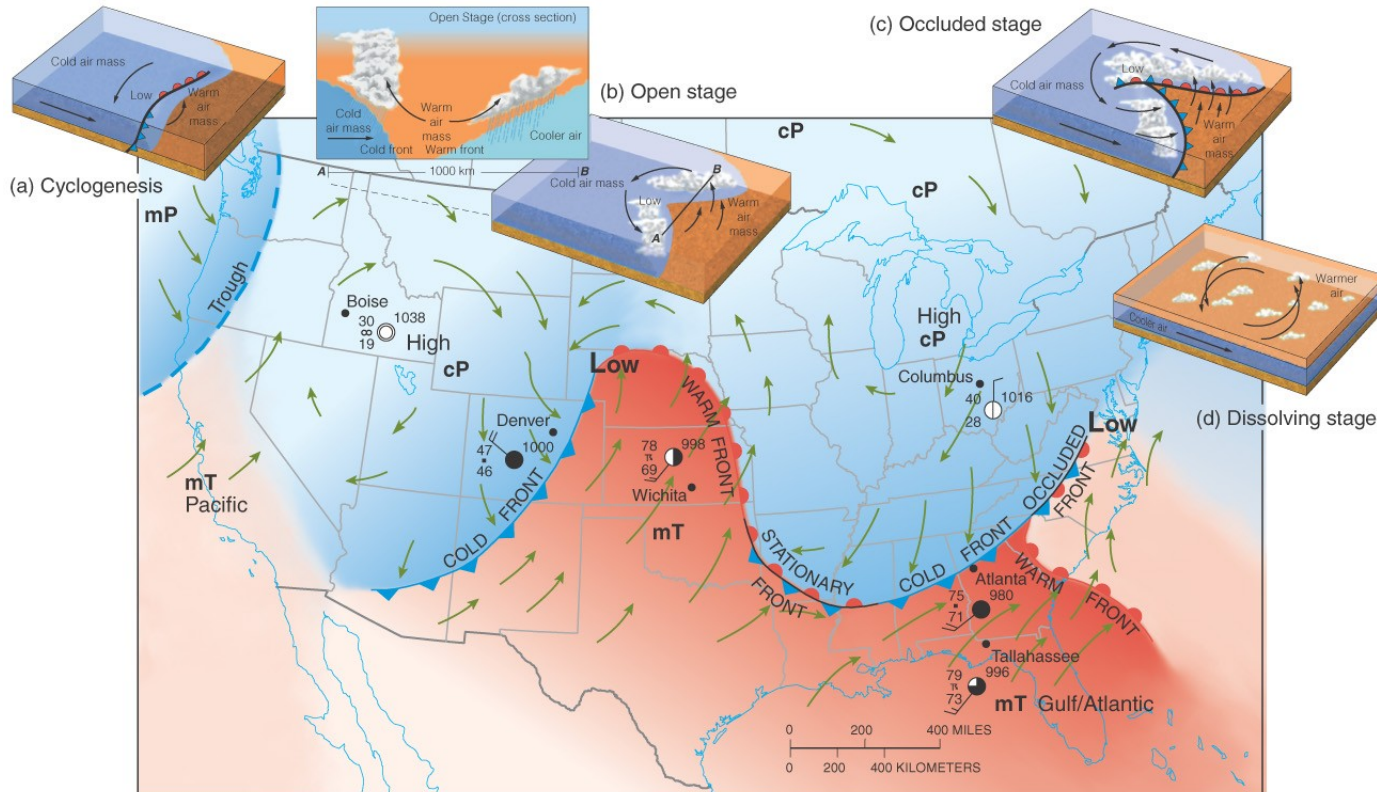


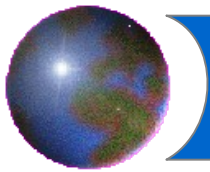
Midlatitude Cyclonic Systems

● Life Cycle of a Midlatitude Cyclone

- ❑ Storm tracks
- ❑ Open stage
- ❑ Occluded stage

Midlatitude Cyclone



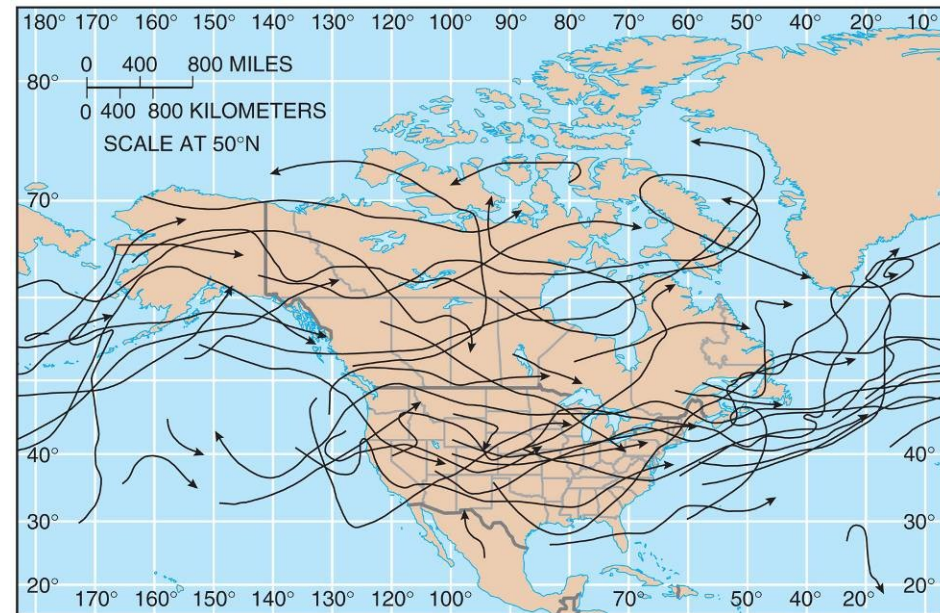


Average and Actual Storm Tracks



(a) Average storm tracks

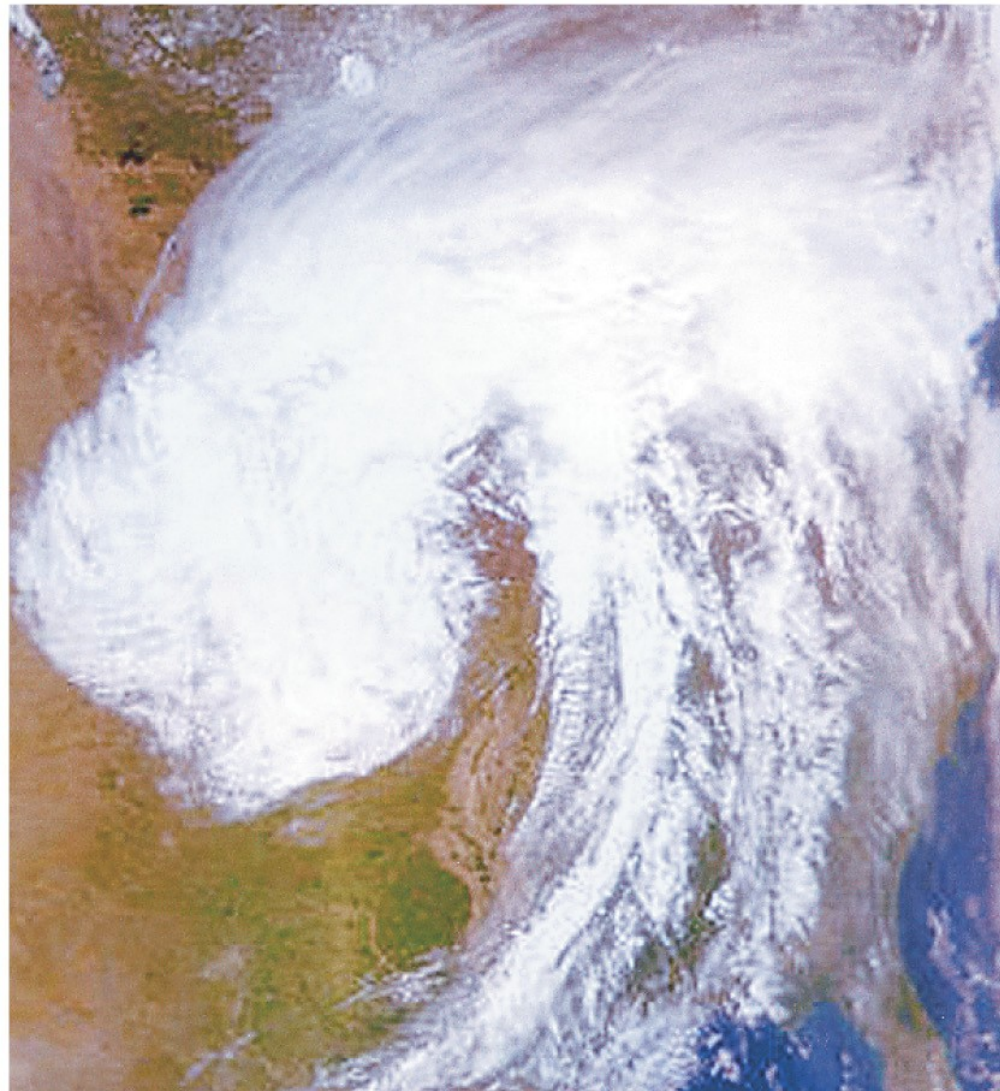
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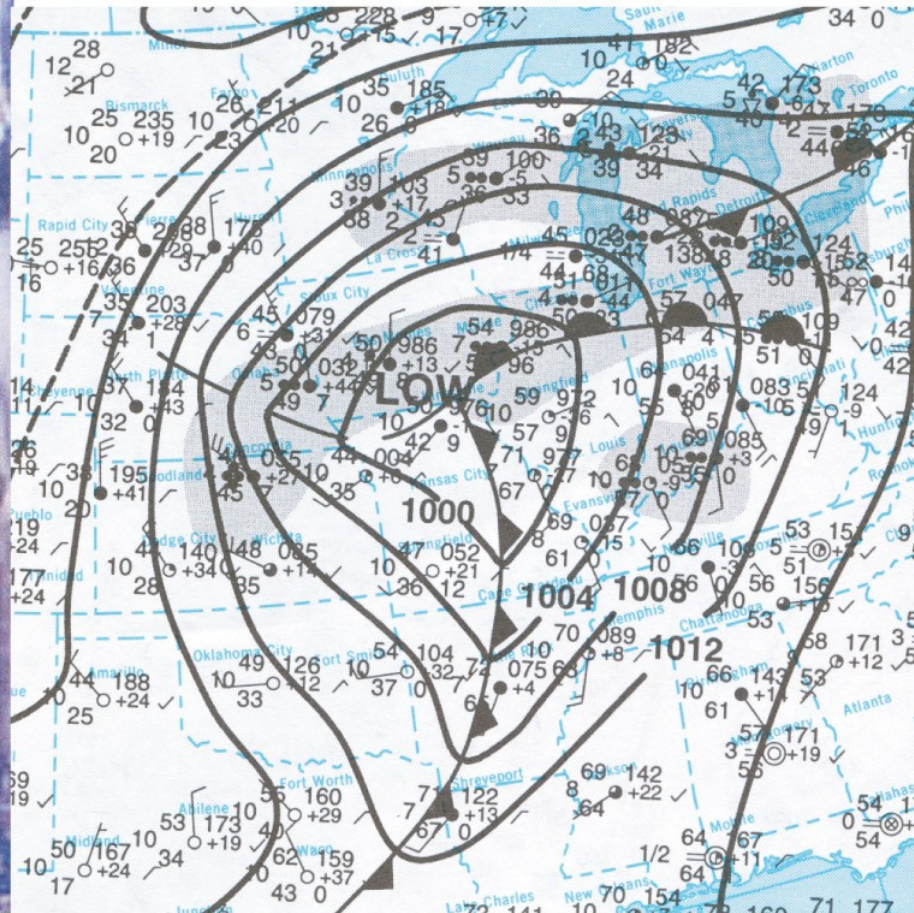
(b) Actual storm tracks in March 1991

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Midlatitude Cyclone



3:00 P.M. EST



7:00 A.M. EST

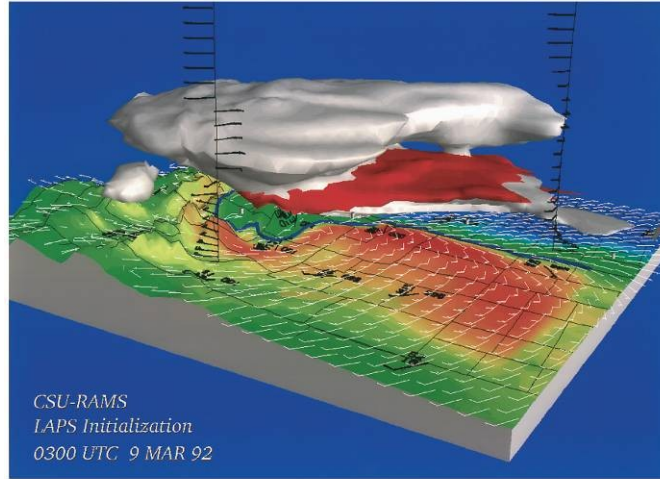
(a)

(b)

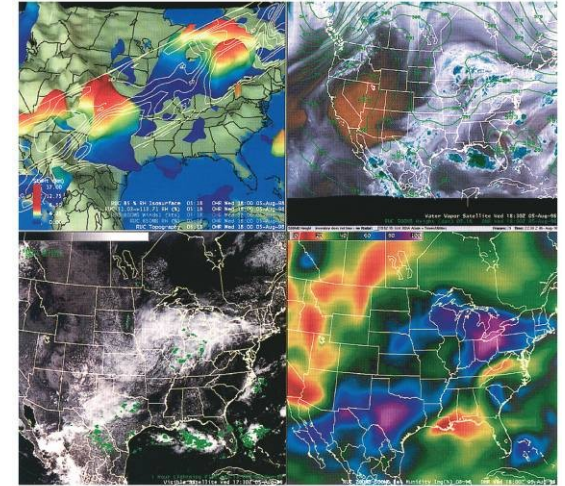
Weather Forecasting



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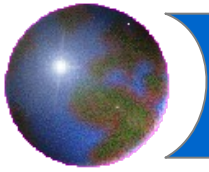


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Figure 5.3.2



Violent Weather

● Thunderstorms

- ❑ Atmospheric turbulence
- ❑ Lightning and thunder
- ❑ Hail

● Derechos

● Tornadoes

- ❑ Tornado measurement and science

● Tropical Cyclones

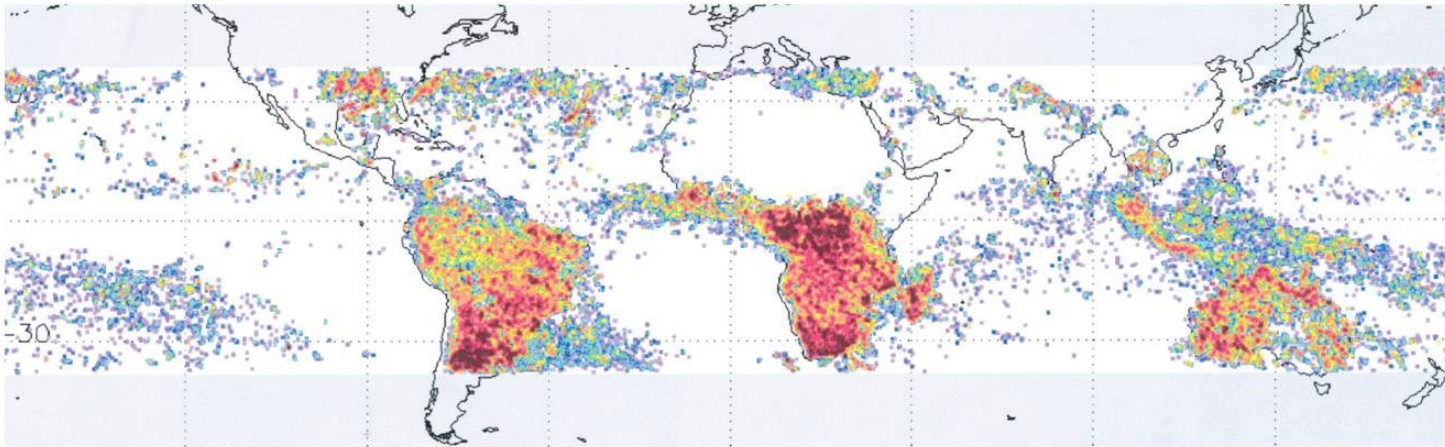
- ❑ Hurricanes and typhoons
- ❑ Physical structure
- ❑ A final word

Thunderstorms



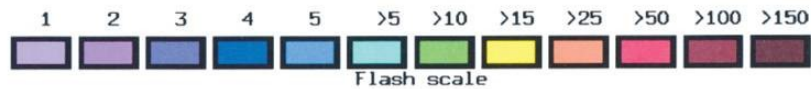
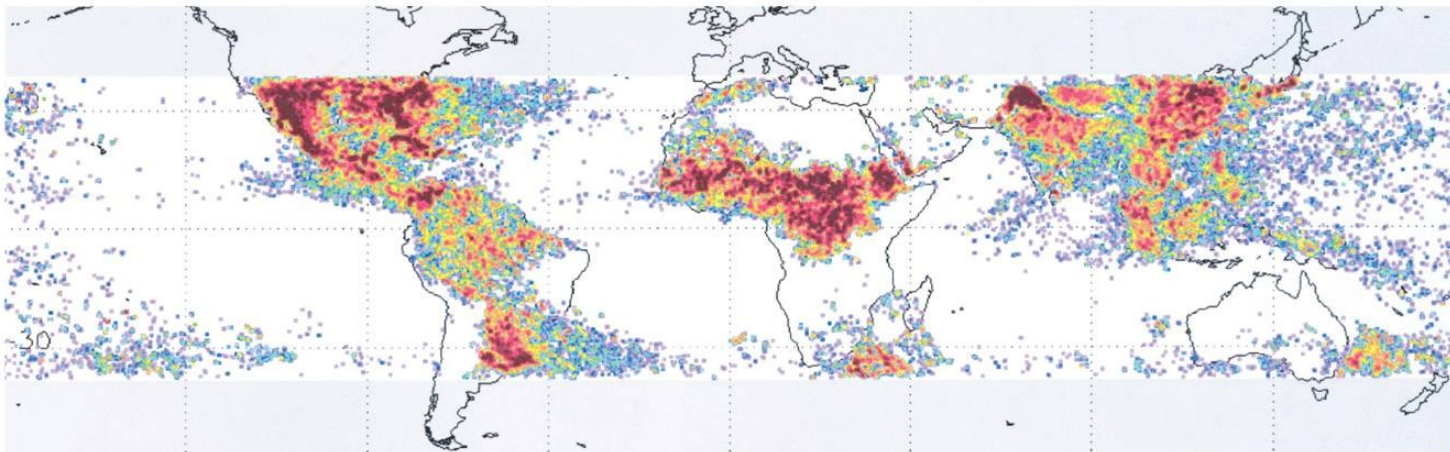
Figure 5.36

Thunderstorms



(b)

Winter (Dec. 1999, Jan. and Feb. 2000)



(c)

Summer (June, July, August 2000)

Figure 5.37

Clouds overshoot top of thunderstorm

Anvil

Mesocyclone
(3 to 10 km
diameter)

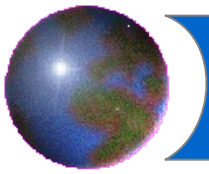
Tornado

Air inflows

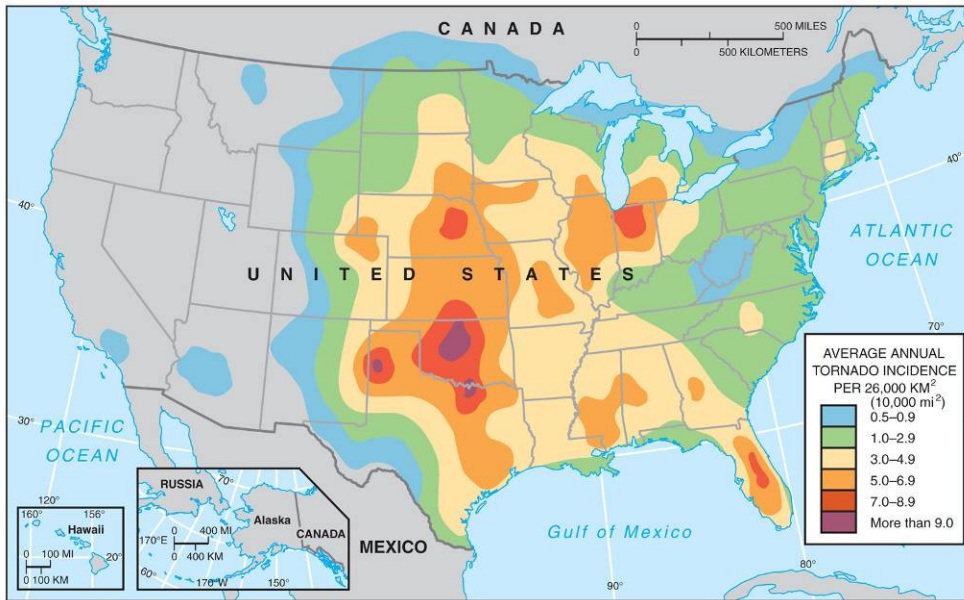
Twister!



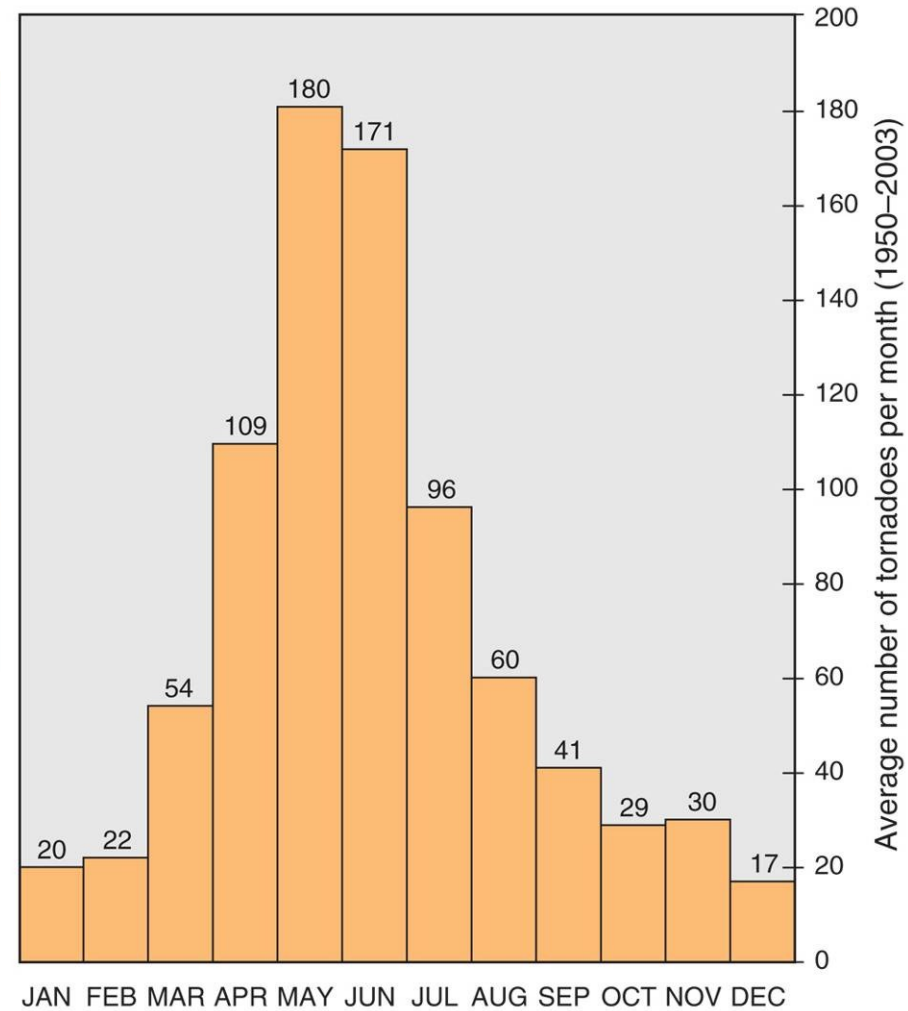
Figure 5.38



Tornadoes



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Figure 5.39

(b)

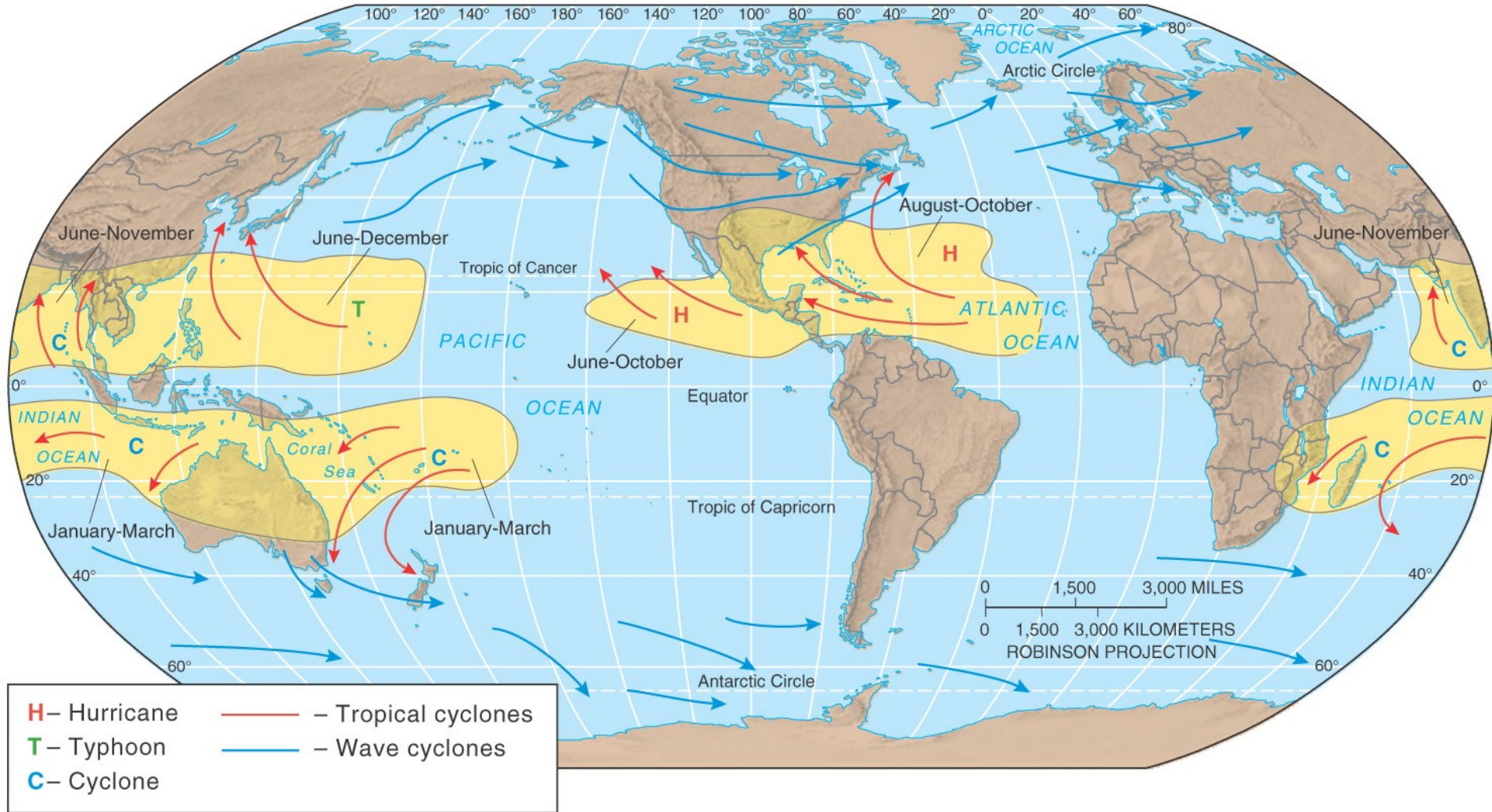
Table 5.1 Tropical Cyclone Classification

Designation	Winds	Features
Tropical disturbance	Variable, low	Definite area of surface low pressure; patches of clouds
Tropical depression	Up to 34 knots (63 kmph, 39 mph)	Gale force, organizing circulation; light to moderate rain
Tropical storm	35–63 knots (63–118 kmph, 39–73 mph)	Closed isobars; definite circular organization; heavy rain; assigned a name
Hurricane (Atlantic and E. Pacific)	Greater than 65 knots	Circular, closed isobars; heavy rain, storm surges;
Typhoon (W. Pacific)	(119 kmph, 74 mph)	tornadoes in right-front quadrant
Cyclone (Indian Ocean, Australia)		

Saffir-Simpson Hurricane Damage Potential Scale

Category	Wind Speed	Notable Atlantic Examples
1	65–82 knots (74–95 mph)	—
2	83–95 knots (96–110 mph)	—
3	96–113 knots (111–130 mph)	1985 Elena; 1991 Bob; 1995 Roxanne, Marilyn; 1998 Bonnie
4	114–135 knots (131–155 mph)	1979 Frederic; 1985 Gloria; 1995 Felix, Luis, Opal; 2004 Charley 1998 Georges
5	>135 knots (>155 mph)	1935 No. 2; 1938 No. 4; 1960 Donna; 1961 Carla; 1969 Camille; 1979 David; 1988 Gilbert; 1989 Hugo; 1992 Andrew; 1998 Mitch

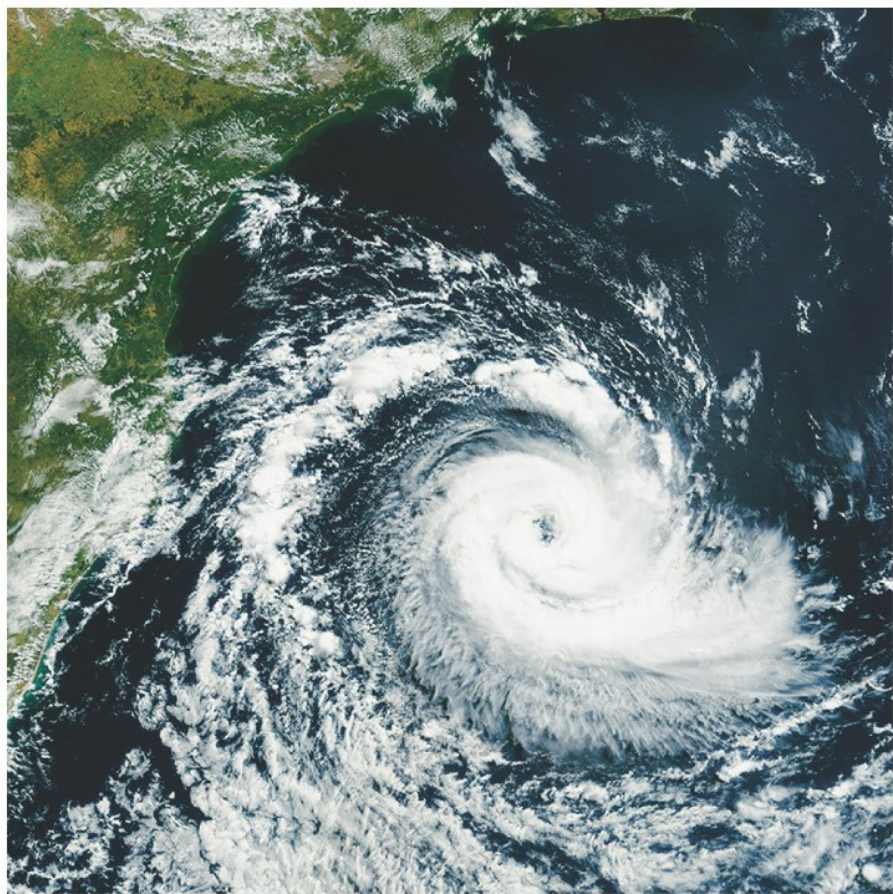
Tropical Cyclones



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Figure 5.40

Brazilian Hurricane



(b)



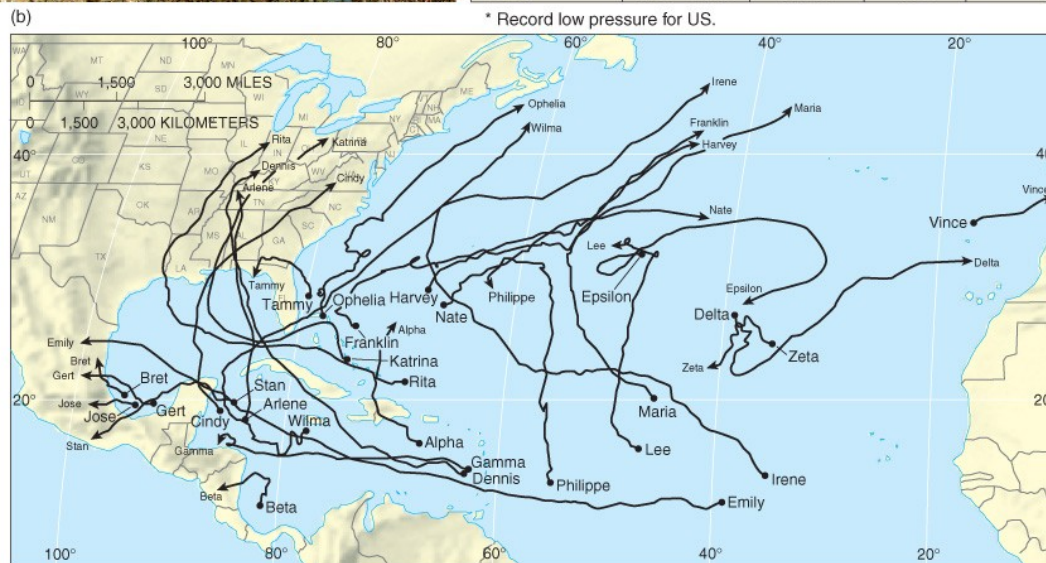
Figure 5.40

2005 Hurricane Season



T-Tropical Storm, or H (cat. no.)-Hurricane (affected US)	2005 Dates (inclusive)	Top average wind speed (mph/kmph)	Lowest Central Pressure (mb)	Days as: H or T	T
T-Arlene (US)	6/8 - 6/12	70/113	989	—	3
T-Bret	6/28 - 6/30	40/64	1004	—	1
T-Cindy (US)	7/03 - 7/06	70/113	997	—	2
H4-Dennis (US)	7/05 - 7/11	150/241	930	4	3
H4-Emily	7/11 - 7/21	155/249	930	7	4
T-Franklin	7/21 - 7/29	70/113	997	—	8
T-Gert	7/23 - 7/25	45/72	1005	—	2
T-Harvey	8/02 - 8/08	65/105	994	—	6
H2-Irene	8/04 - 8/18	100/161	975	3	8
T-Jose	8/22 - 8/23	50/80	1001	—	1
H5-Katrina (US)	8/23 - 8/30	175/282	902	4	3
T-Lee	8/28 - 9/02	40/64	1007	—	1
H3-Maria	9/01 - 9/10	115/185	960	5	3
H1-Nate	9/05 - 9/10	90/145	979	3	4
H1-Ophelia (US)	9/06 - 9/18	85/137	976	7	9
H1-Philippe	9/17 - 9/24	80/129	985	2	5
H5-Rita (US)	9/18 - 9/25	175/282	987	5	4
H1-Stan	10/01 - 10/05	80/129	979	1	3
T-Tammy (US)	10/05 - 10/06	50/80	1001	—	2
H1-Vince	10/09 - 10/11	75/121	987	2	2
H5-Wilma (US)	10/15 - 10/25	175/282	882*	7	2
T-Alpha	10/22 - 10/24	50/80	998	—	2
H3-Beta	10/27 - 10/31	115/185	960	2	4
T-Gamma	11/14 - 11/21	45/72	1004	—	3
T-Delta	11/23 - 11/28	70/113	980	—	6
H1-Epsilon	11/29 - 12/08	80/129	987	3	7
T-Zeta	12/30 - 01/05	65/105	992	—	7

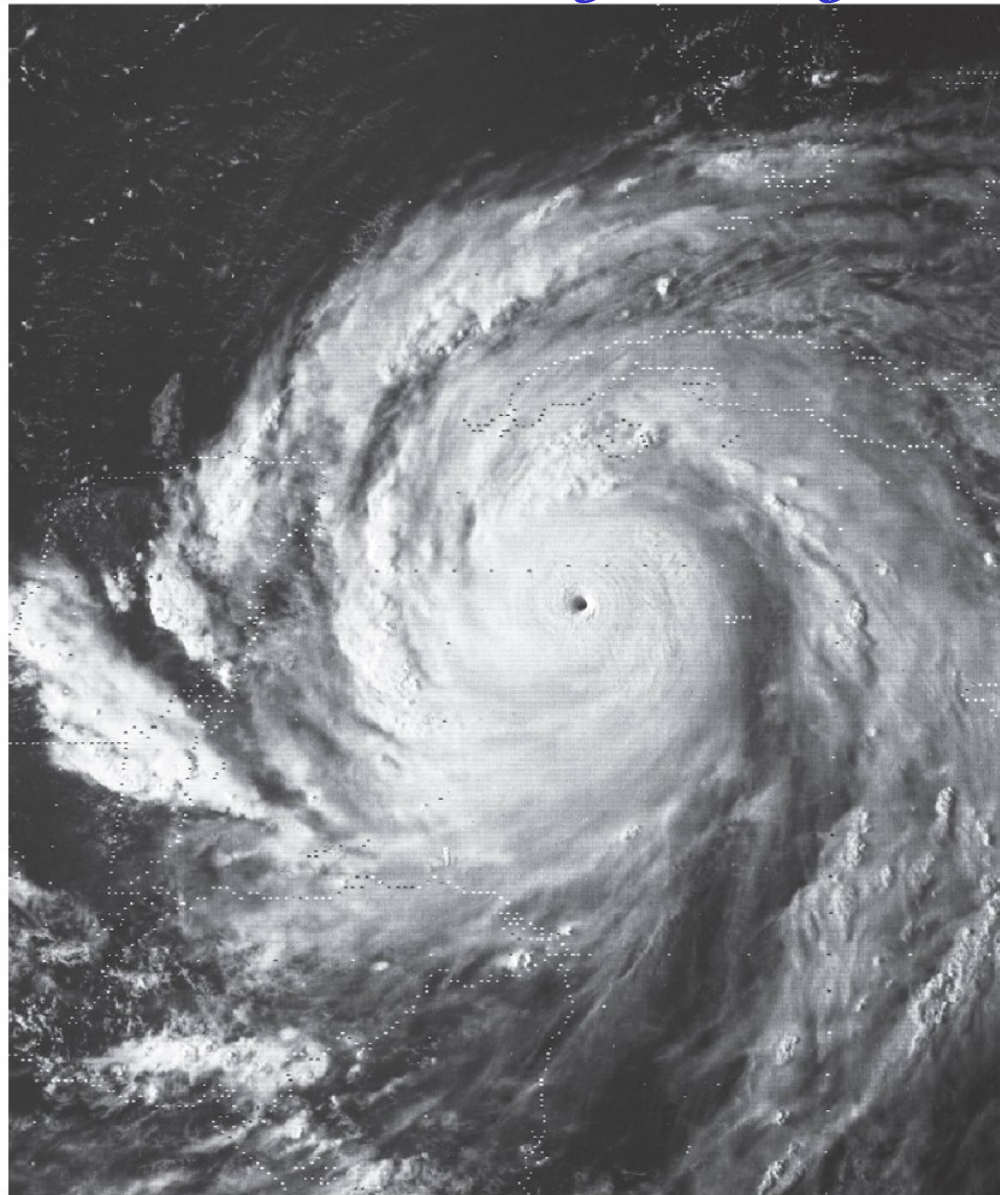
* Record low pressure for US.



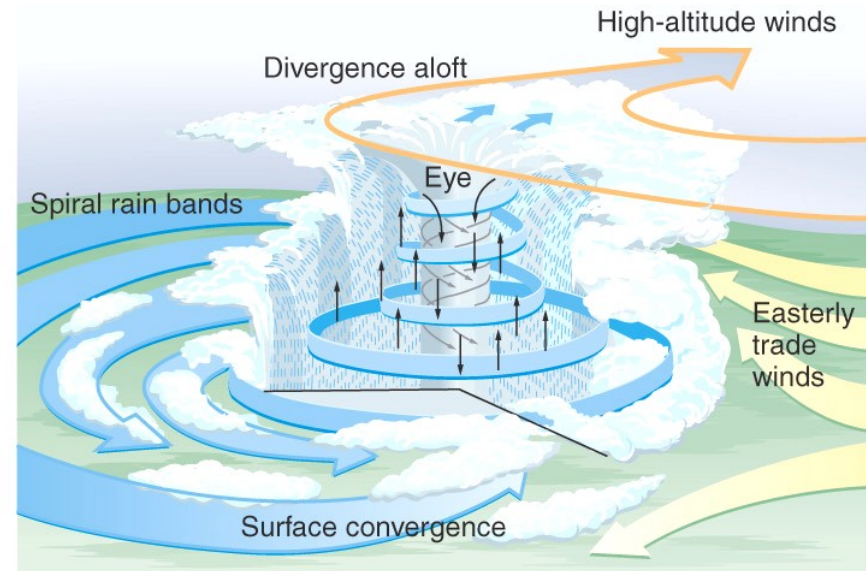
(a)

Figure 5.41

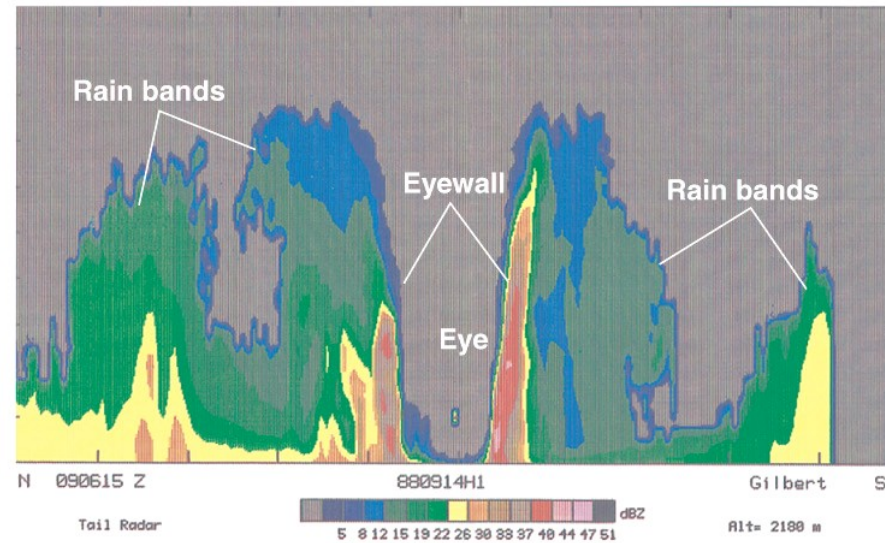
Profile of a Hurricane



(a)



(b)



(c)



End of Chapter 5

Elemental Geosystems 5e

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