Topic 4

Temperature, Atmospheric Circulation and Climate

- Temperature Controls
- Global Temp. Patterns
- Atmospheric Circulation
- Primary High and Low Pressure Areas
- Global Circulation Model
- Local Winds
- Ocean Currents
- Weather and Climate
- Climate Classification
- Climographs

KEY LEARNING CONCEPTS

Chapters 5, 6, & 10

Temperature Concepts and Measurement

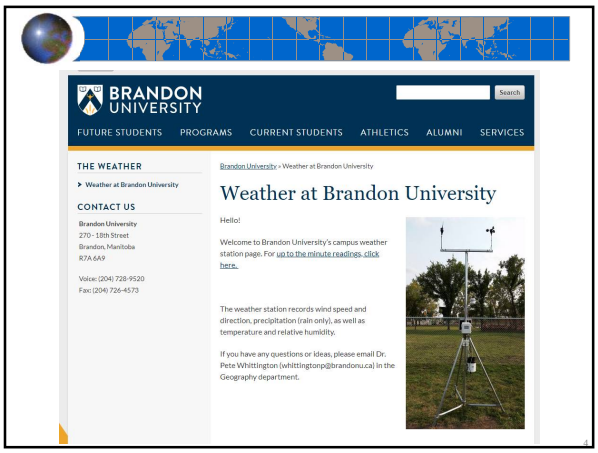
- Temp. is a measure of kinetic energy
  - Avg. energy of motion of molecules
- Heat is the transfer/flow of energy
- Three standard scales of measurement

Thermometer and Instrument Shelter

(a)

(b)

FIGURE 5.3 Instrument shelter. (a) This standard thermistor shelter is white (for high albedo) and louvered (for ventilation). (b) The Stephenson Screen, a louvered wooden box that houses a minimum and maximum thermometer or a wet bulb thermometer apparatus, provides protection from direct insolation. [(a) Bobbé Christopherson. (b) Dick Hemingway.]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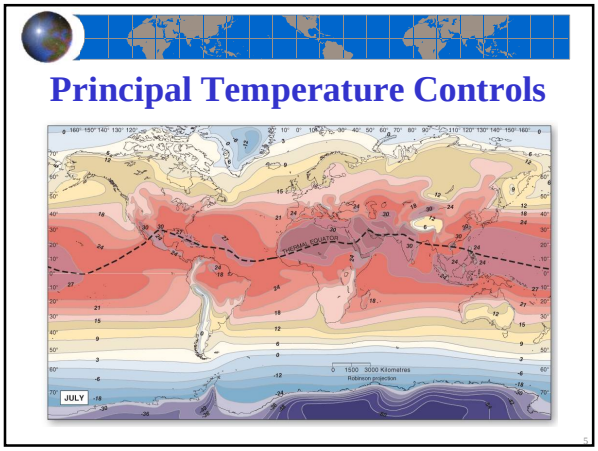
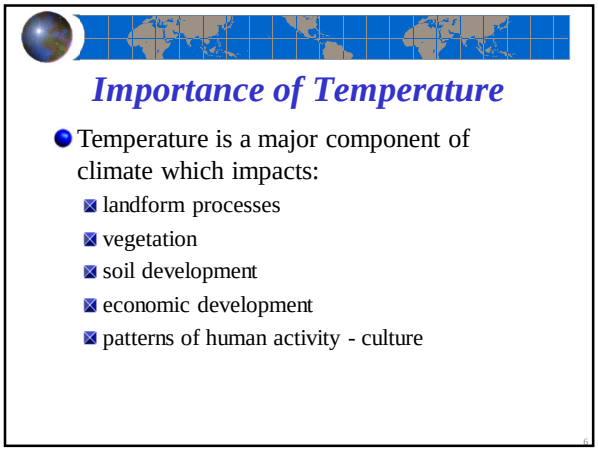
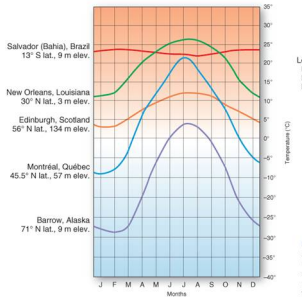
Hello!
Welcome to Brandon University's campus weather station page. For up to the minute readings, click here.
The weather station records wind speed and direction, precipitation (rain only), as well as temperature and relative humidity.
If you have any questions or ideas, please email Dr. Pete Whittington (whittingtonp@brandonu.ca) in the Geography department.


Principal Temperature Controls
JULY
0 1500 3000 Kilometres
Robinson projection


Importance of Temperature
Temperature is a major component of climate which impacts:
landform processes
vegetation
soil development
economic development
patterns of human activity - culture

Latitude



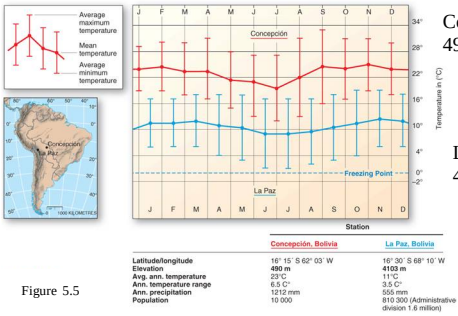
Located on maps in: Figure 1.14
Figure 4.17 – net radiation
Figure 4.19 – latent heat
Figure 4.20 – sensible heat

Determines intensity and duration of insolation.

Most important factor influencing mean annual and mean monthly temperature.

FIGURE 5.4 Latitude affects temperatures. A comparison of five cities from near the equator to north of the Arctic Circle demonstrates changing seasonality and increasing differences between average minimum and maximum temperatures as one moves to higher latitudes.

Altitude/Elevation



Concepcion
490 m

La Paz
4103 m

	Concepción, Bolivia	La Paz, Bolivia
Latitude/longitude	16° 15′ S 62° 03′ W	16° 30′ S 68° 10′ W
Elevation	490 m	4103 m
Avg. ann. temperature	23°C	11°C
Ann. temperature range	6.5 C°	3.5 C°
Ann. precipitation	1212 mm	555 mm
Population	10 000	810 300 (Administrative division 1.6 million)

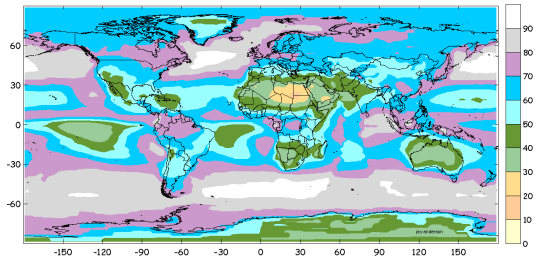
Figure 5.5

As elevation ↑, density of atm. ↓ and reduces ability to absorb or reradiate heat

Cloud Cover

Less insolation = lower daytime temp

Increased counter radiation = higher nighttime temps



Mean Annual Cloud Cover (%)
(data: ISCCP)

Land-Water Heating Differences

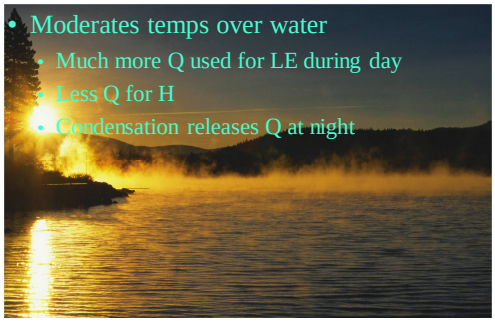
- Result of four (not five) major differences between physical properties of land and water:

1. evaporation
2. transparency
3. specific heat
4. circulation

- Note: in the book circulation is divided into movement and ocean currents & sea surface temperatures

L vs. W: Evaporation

- Moderates temps over water
  - Much more Q used for LE during day
  - Less Q for H
  - Condensation releases Q at night



L vs. W: Transparency

Land is opaque
SW used to heat surface only
Rapidly reradiates LW

Water is nearly transparent
SW transmitted to depth
Greater opportunity for absorption

L vs. W: Specific Heat

Specific heat of water 4x greater than land

Water heats slower, and losses it's heat energy slower

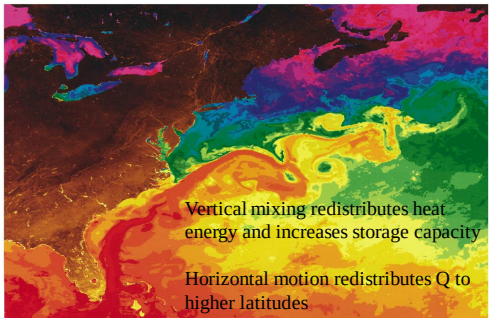
Stores a much greater quantity of heat energy

Material	Specific Heat
Lead	0.031
Mercury	0.033
Brass	0.094
Copper	0.095
Iron or Steel	0.113
Glass	0.195
Alcohol	0.547
Aluminum	0.712
Water	1.000

Table 2: Specific heat capacity of building materials

Material	J/(g·k)
Asphalt	0.920
Brick	0.840
Concrete	0.880
Glass	0.840
Granite	0.790
Gypsum	1.090
Marble	0.880
Sand	0.836
Wood	1.7
Water at 25°C	4.18

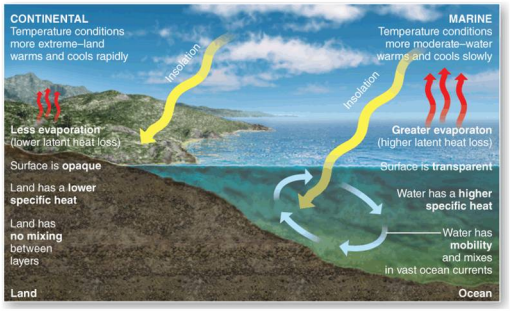
L vs. W: Circulation

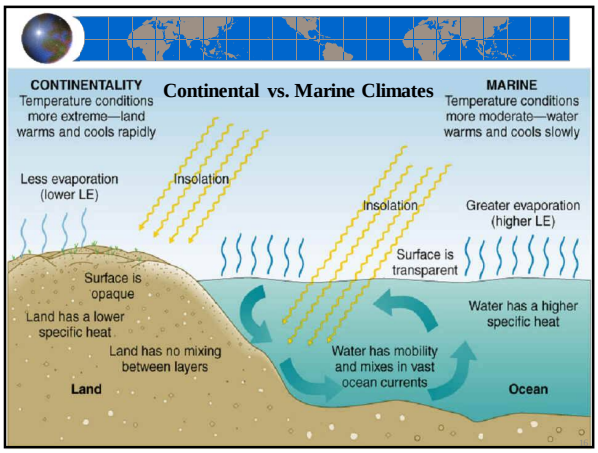


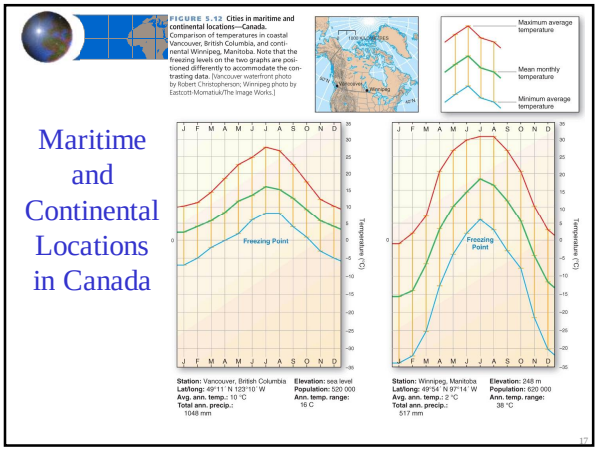
Vertical mixing redistributes heat energy and increases storage capacity

Horizontal motion redistributes Q to higher latitudes

Land-Water Heating Differences







Global Temperature Patterns

To summarize: temperature patterns can be explained by primary temperatures controls:

1. Latitude
2. Elevation
3. Cloud Cover
4. Proximity to Water (L vs. W differences)

Global Mean Temperatures: January

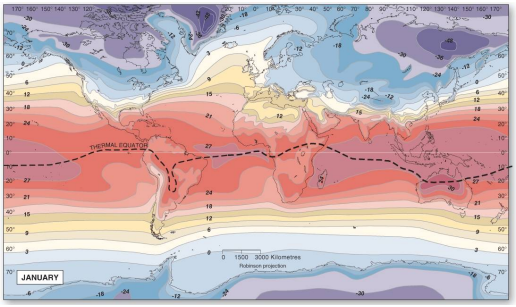


Figure 5.13

Bending of Continental Isotherms

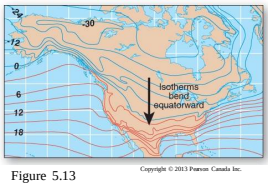
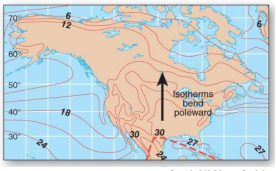


Figure 5.13

January: equatorward



July: poleward

Figure 5.16

Global Mean Temperatures: July

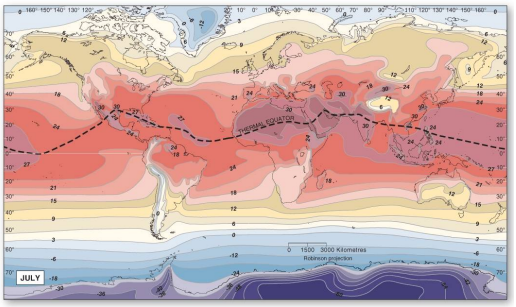


Figure 5.16

Annual Temperature Range

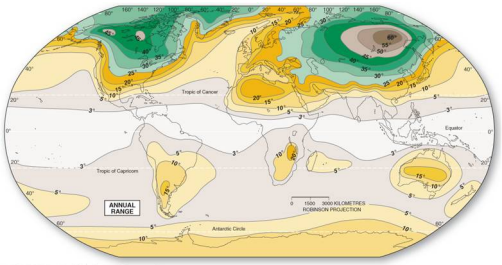
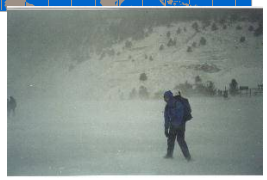


FIGURE 5.18 Global annual temperature ranges.
The annual range of global temperatures in Celsius degrees, C°. The mapped data show the difference between average January and July temperature maps.

Apparent Temperature



- Wind Chill
  - Increased cold due to wind speed
    - More discomfort with high wind and high humidity
- Humidex
  - Increased heat due to higher humidity
    - More discomfort with high humidity and low wind

Wind Chill Temperature Index

FIGURE 5.1.1
Wind Chill Temperature Index for various temperatures and wind speeds.
[© Environment Canada, 2012.]

Actual Air Temperature in (°C)

Wind speed, km·h⁻¹	Calm	0°	−5°	−10°	−15°	−20°	−25°	−30°	−35°	−40°	−45°	−50°
8		−2°	−7°	−13°	−19°	−24°	−30°	−36°	−41°	−47°	−53°	−58°
10		−3°	−9°	−15°	−21°	−27°	−33°	−39°	−45°	−51°	−57°	−63°
15		−4°	−11°	−17°	−23°	−29°	−35°	−41°	−48°	−54°	−60°	−66°
20		−5°	−12°	−18°	−24°	−30°	−37°	−43°	−49°	−56°	−62°	−68°
25		−6°	−12°	−19°	−25°	−32°	−38°	−44°	−51°	−57°	−64°	−70°
30		−6°	−13°	−20°	−26°	−33°	−39°	−46°	−52°	−59°	−65°	−72°
35		−7°	−14°	−20°	−27°	−33°	−40°	−47°	−53°	−60°	−66°	−73°
40		−7°	−14°	−21°	−27°	−34°	−41°	−48°	−54°	−61°	−68°	−74°
45		−8°	−15°	−21°	−28°	−35°	−42°	−48°	−55°	−62°	−69°	−75°
50		−8°	−15°	−22°	−29°	−35°	−42°	−49°	−56°	−63°	−69°	−76°
55		−8°	−15°	−22°	−29°	−36°	−43°	−50°	−57°	−63°	−70°	−77°
60		−9°	−16°	−23°	−30°	−36°	−43°	−50°	−57°	−64°	−71°	−78°
65		−9°	−16°	−23°	−30°	−37°	−44°	−51°	−58°	−65°	−72°	−79°
70		−9°	−16°	−23°	−30°	−37°	−44°	−51°	−58°	−65°	−72°	−80°
75		−10°	−17°	−24°	−31°	−38°	−45°	−52°	−59°	−66°	−73°	−80°
80		−10°	−17°	−24°	−31°	−38°	−45°	−52°	−60°	−67°	−74°	−81°

Frostbite times: Low risk of frostbite | 30 min. | 5–10 min. | 2–5 min. | 2 min.

'The traditional value for "normal" body temperature, 37°C , was set in 1868 using old methods of measurement. According to Dr. Philip Mackowiak of the University of Maryland School of Medicine, a more accurate modern assessment places normal at 36.8°C with a range of 2.7 C°, for the human population (*Journal of the American Medical Association*, September 23–30, 1992).

Humidex

TABLE 5.1.2 Comfort Levels and Suggested Activities for Ranges of Humidex

Range of Humidex (°C)	Degree of Comfort
Less than 29	No discomfort
30 to 39	Some discomfort; tone down or modify strenuous outdoor activity
40 to 45	Great discomfort; avoid exertion, curtail activity
Above 45	Dangerous
Above 54	Heat stroke is imminent

Source: The Meteorological Service of Canada. Reproduced with the permission of Environment Canada, http://www.qc.ec.gc.ca/meteo/documentation/humidex_e.html.

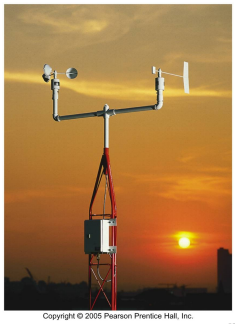
Atmospheric Circulation *(chapter 6)*

- Basic element of atmospheric circulation is wind
  - Primary Circulation = global
  - Secondary Circulation = regional
  - Tertiary Circulation = local
- Redistributes heat energy
- Causes oceanic circulation

Wind Essentials

Wind defined by:

- Speed, as measured with an anemometer
- Direction of origin, as indicated by wind vane



Driving Forces

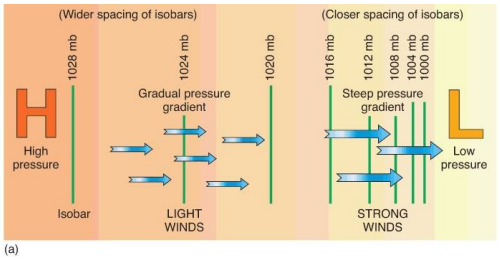
- Force of Gravity
- Pressure Gradient Force
- Coriolis Force
- Friction Force

Gravity

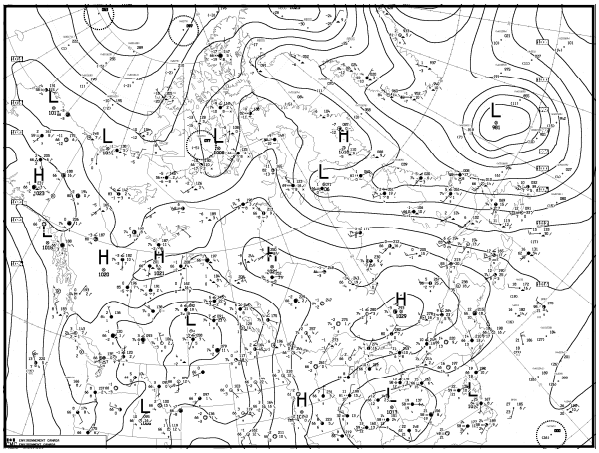
- Force of gravity produces atm. pressure
- Without gravity there would be:
  - no atmospheric pressure
  - so no variations in atmospheric pressure
  - no atmospheric motion

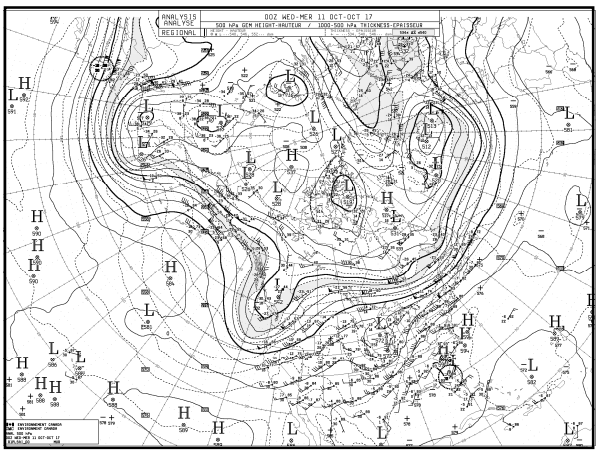
and oh . . .,
by the way,
no atmosphere

Pressure Gradient Force



(a)





Primary High- & Low-Pressure Areas

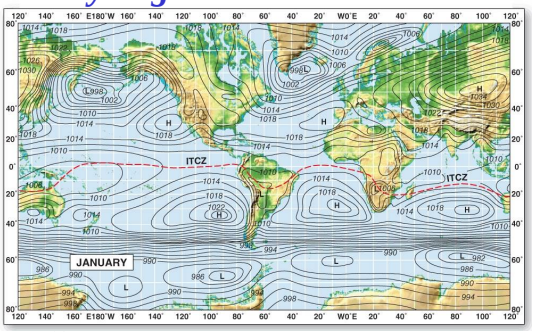


Figure 6.9a

Primary High- & Low-Pressure Areas

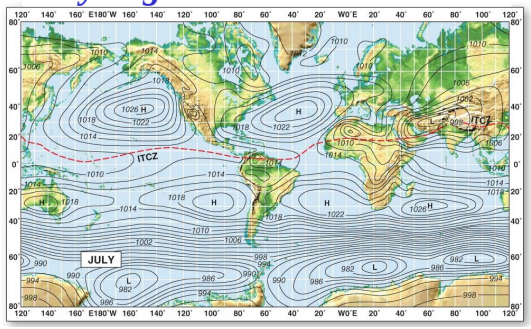
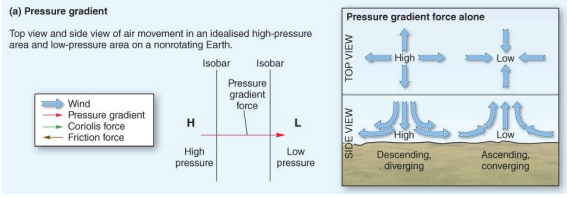


Figure 6.9b

Descending and Ascending Air



Areas of high pressure: air descends (hence, higher pressure) and diverges at Earth's surface

Areas of low pressure: air ascends (so lower surface pressure) and is replaced by converging flow (inflow)

Pressure Gradient Force

But the red arrows on this map are not moving directly from high to low.

Something must be affecting their path?

Coriolis Force

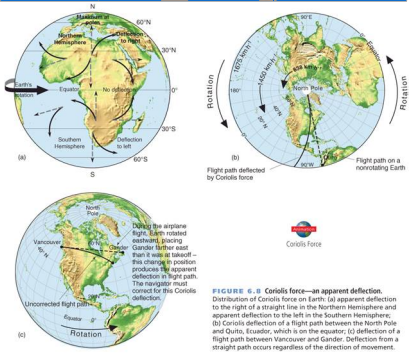
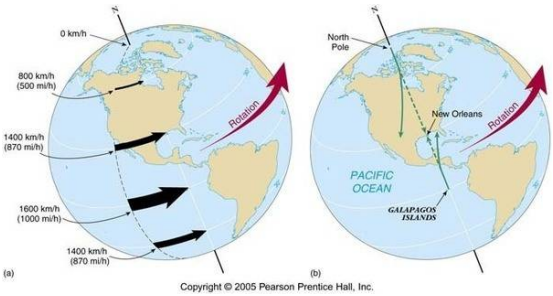


FIGURE 6.8 Coriolis force—an apparent deflection. Distribution of Coriolis force on Earth: (a) apparent deflection to the right of a straight line in the Northern Hemisphere and apparent deflection to the left in the Southern Hemisphere; (b) Coriolis deflection of a flight path between the North Pole and Quito, Ecuador, which is on the equator; (c) deflection of a flight path between Vancouver and Gander. Deflection from a straight path occurs regardless of the direction of movement.



Coriolis Force

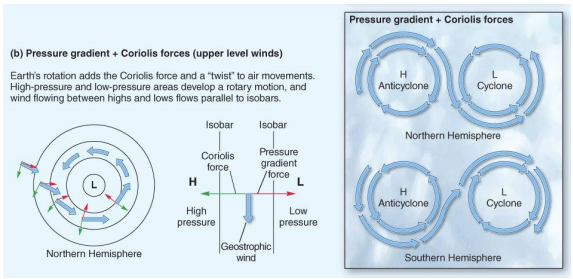


Figure 6.7b

Friction Force

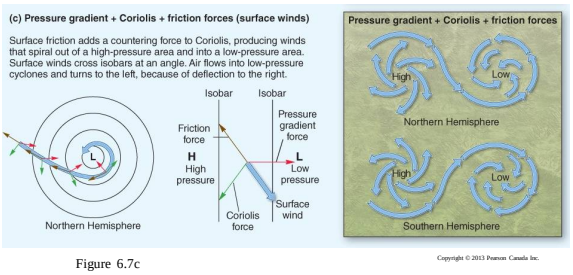
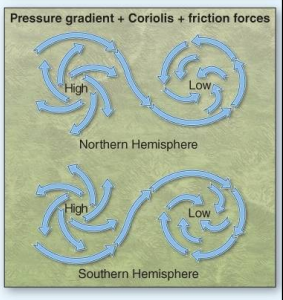


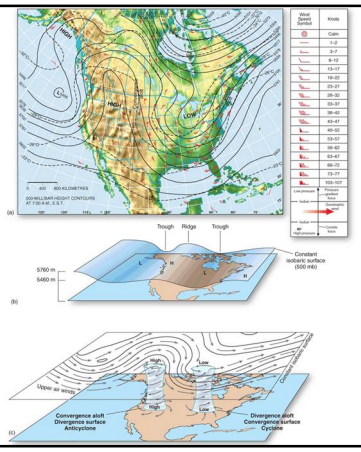
Figure 6.7c

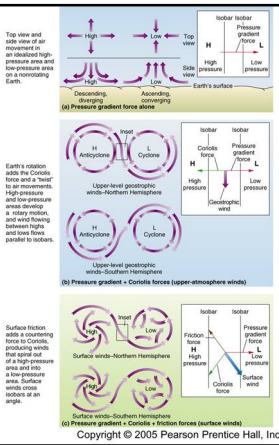
Cyclones and Anticyclones

	High Pressure	Low Pressure
Northern Hemisphere	**Anticyclone** spiral outward clockwise direction	**Cyclone** spiral inward counterclockwise direction
Southern Hemisphere	**Anticyclone** spiral outward counter-clockwise direction	**Cyclone** spiral inward clockwise direction

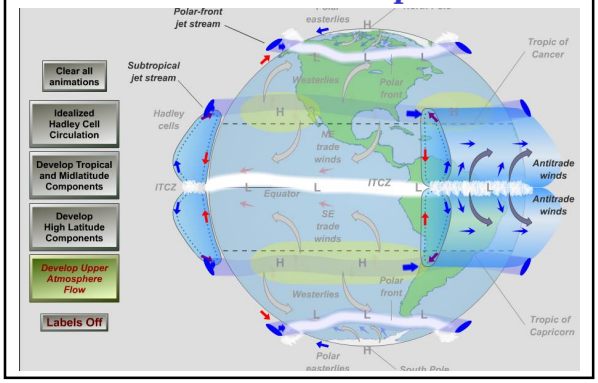


Upper Atm. Circulation





Wind Pattern Development



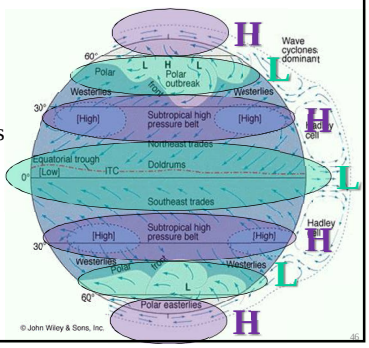
Primary High- & Low-Pressure Areas

Result of:

differential heating & moisture characteristics

OR

dynamic forces



Primary High- & Low-Pressure Areas

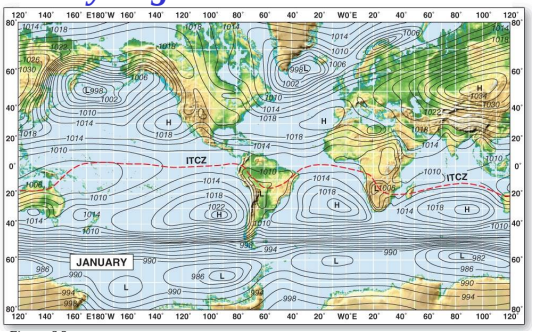


Figure 6.9a

Primary High- & Low-Pressure Areas

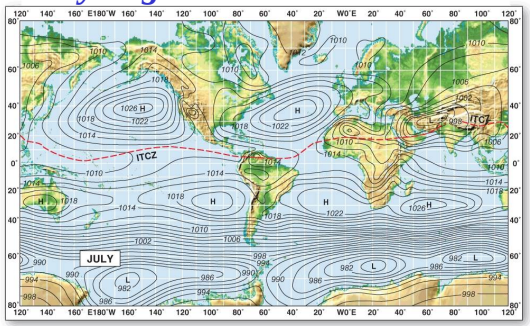
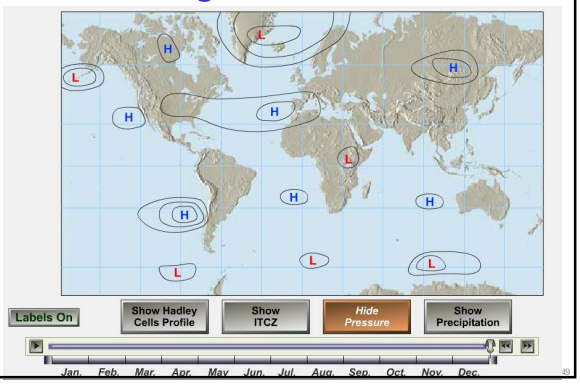
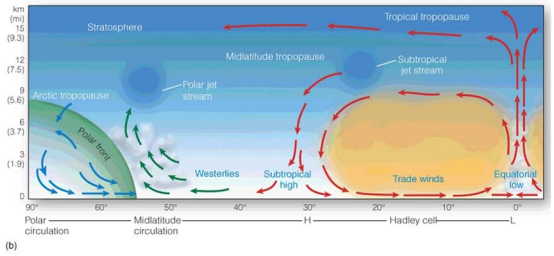


Figure 6.9b

Resulting Weather Patterns



Generalized Circulation Model



Cross-section of One Hemisphere

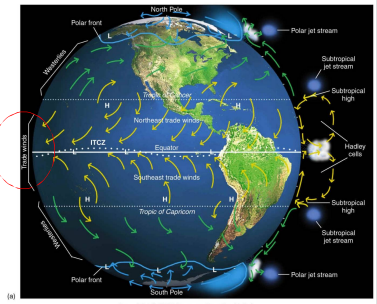
Equatorial Low (ITCZ)

- Result of differential heating
  - high sun angle
  - constant daylength
- Warm, moist air, less dense, so rises
  - Converging, ascending air
- Migrates seasonally with thermal equator
- Locally calm winds

Equatorial Low (ITCZ)

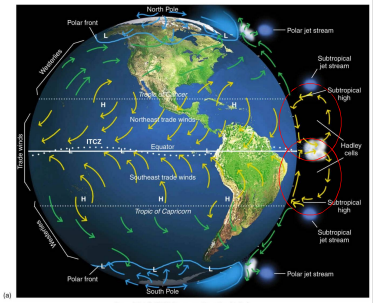
Trade Winds

- Surface flow toward ITCZ results in Trades winds
- Deflection produces Northeast trade winds and southeast trade winds
- Trade winds are warm and increasingly moist lots of latent heat storage

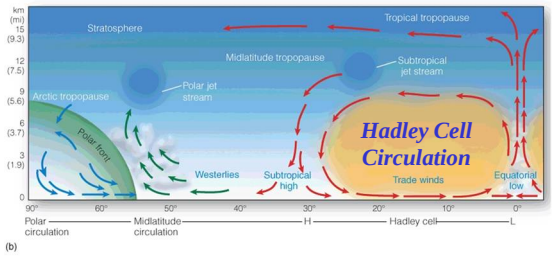


Subtropical High-Pressure

- Divergence aloft over ITCZ results in upper atm. flow toward subtropics
- Cool air is <u>forced</u> to descend and warms adiabatically (due to increase in pressure)
- High pressure results from descending, diverging air
  - mid-latitude deserts



Generalized Circulation Model



Atlantic Sub-Tropical High

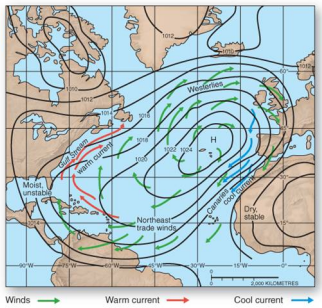
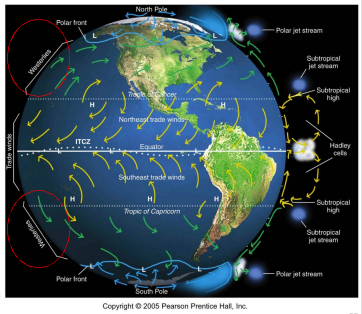


FIGURE 6.12 Subtropical high-pressure system in the Atlantic.
Characteristic circulation in the Northern Hemisphere. Note deserts extend to the shores of Africa, which has offshore cool currents, whereas the southeastern United States is moist and humid, with offshore warm currents.

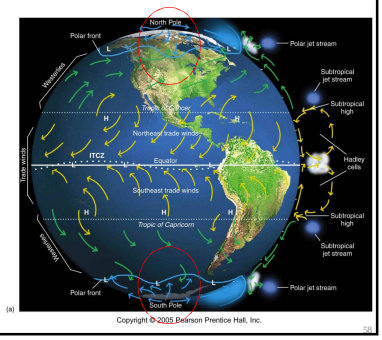
Westerlies

- Result of surface flow from subtropical high toward mid-latitudes
- Deflection produces prevailing westerly circulation



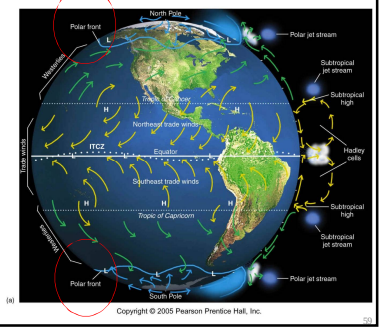
Polar High and Easterlies

- Result of cold dry air over poles
- Descending and diverging air
- Results in a dome of high pressure
- Deflection produces polar easterlies

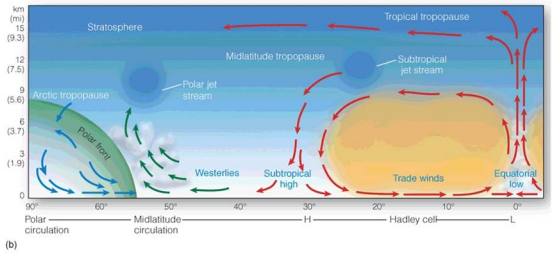


Subpolar Low

- Result of uplift along polar front
- Conflict between cold dry air and warm, moist air
- Mechanical lifting at frontal boundary
- Results in cool, moist air



Generalized Circulation Model



Polar Front
Development of Mid-latitude Cyclones

General Atmospheric Circulation Model

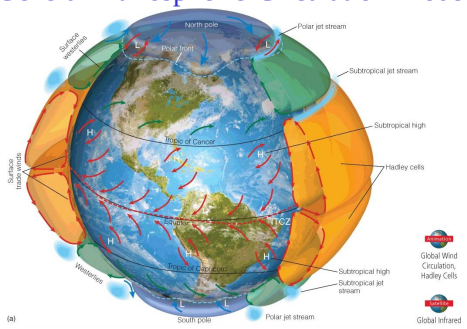
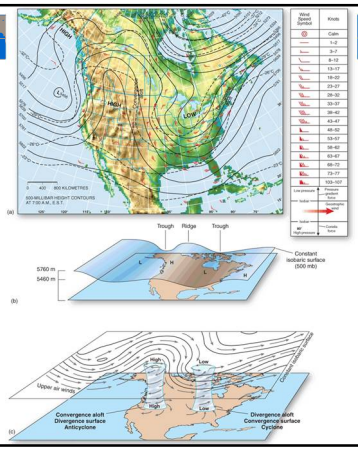


Figure 6.11a

Upper Atm. Circulation



Rossby Waves

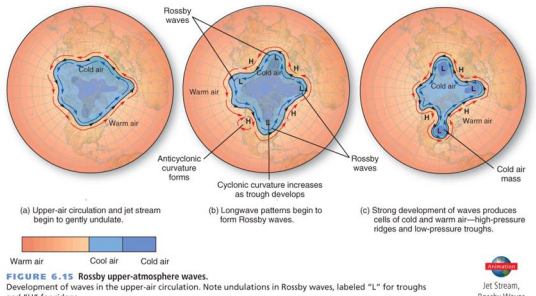


FIGURE 6.15 Rossby upper-atmosphere waves.
Development of waves in the upper-air circulation. Note undulations in Rossby waves, labeled "L" for troughs and "H" for ridges.

Jet Stream, Rossby Waves

Jet Streams

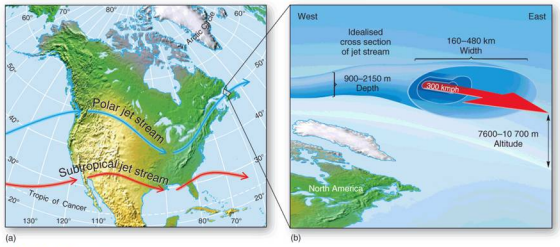


FIGURE 6.16 Jet streams.
(a) Average locations of the two jet streams over North America. (b) Stylised portrait of a polar jet stream.

Regional Winds - Monsoonal Winds

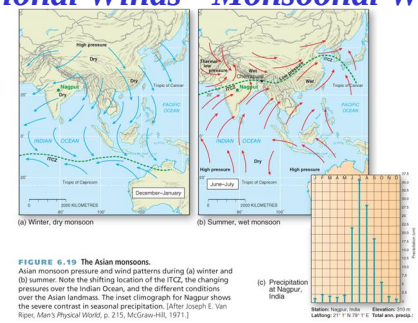


FIGURE 6.19 The Asian monsoons.
Asian monsoon pressure and wind patterns during (a) winter and (b) summer. Note the shifting location of the ITCZ, the changing pressures over the Indian Ocean, and the different conditions over the Asian landmass. The inset climograph for Nagpur shows the severe contrast in seasonal precipitation. [After Joseph E. Van Riper, *Man's Physical World*, p. 215, McGraw-Hill, 1971.]

Local Winds

- Land-sea breezes
- Mountain-valley breezes
- Katabatic winds
- Chinooks

Land and Sea Breezes

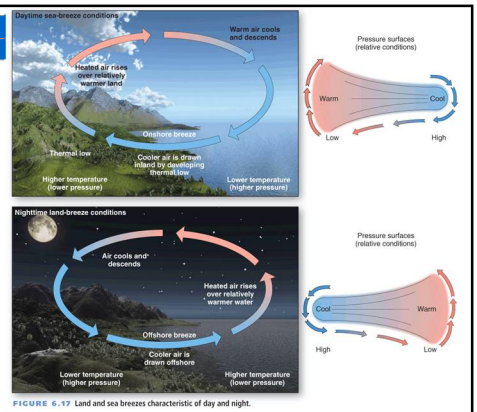


FIGURE 6.17 Land and sea breezes characteristic of day and night.

Mountain Valley Breezes

Katabatic Winds

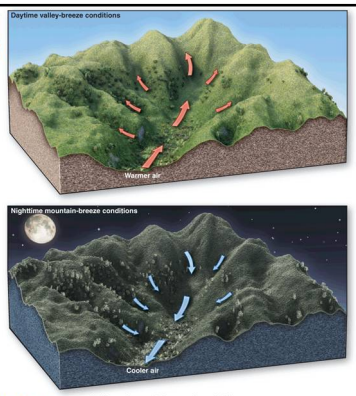


FIGURE 6.18 Pattern of valley and mountain breezes day and night.

Chinook Winds

- Occur when strong prevailing winds cross a mountain range
- Air is warmed and dried descending the leeward side
- Warm, dry, windy weather with variable cloudiness

Oceanic Currents

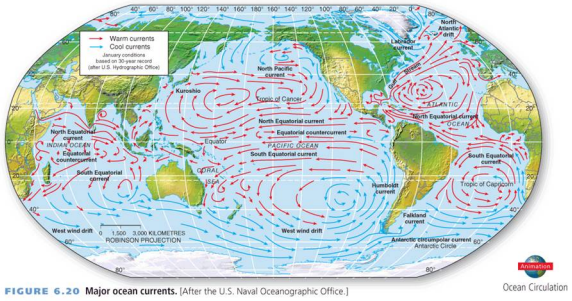


FIGURE 6.20 **Major ocean currents.** [After the U.S. Naval Oceanographic Office.]

Thermohaline Circulation– The Deep Currents

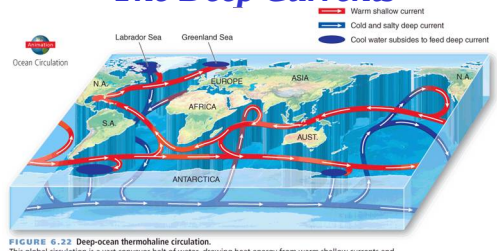
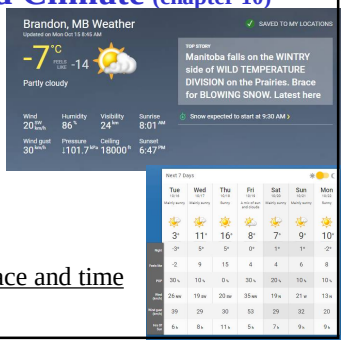


FIGURE 6.22 **Deep-ocean thermohaline circulation.**
This global circulation is a vast conveyor belt of water, drawing heat energy from warm shallow currents and transporting it for release in the depths of the ocean basins in cold, deep, salty currents. Four blue areas at high latitudes are where surface water cools, sinks, and feeds the deep circulation.

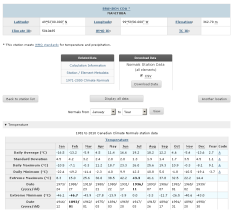
Weather and Climate (chapter 10)

- Weather is:
  - temperature
  - precipitation
  - pressure
  - humidity
  - and wind
- at a particular place and time



Weather and Climate (chapter 10)

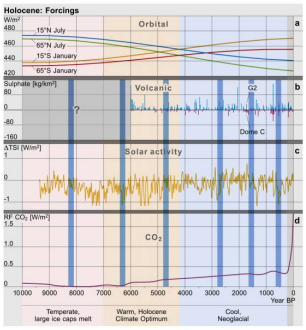
- Climate: variability of daily and seasonal weather characteristics averaged over a long period of time



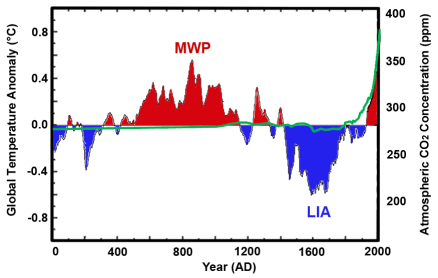
Components of Climate

- Insolation
  - – determined by duration & intensity
- Temperature
  - - Latitude - Altitude - Cloud Cover
  - - Land-Water Heating Differences:
    - - Evaporation (LE) - Transparency
    - - Specific Heat - Circulation
- Atm. Circulation
  - - Primary/Secondary Winds - Ocean Currents
  - - Semi-Permanent High and Low Pressure Areas
- Precipitation
  - – the W&C course

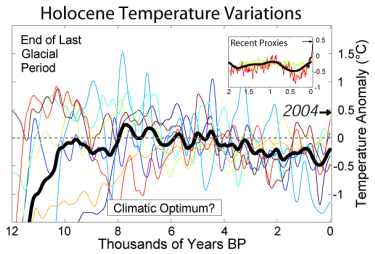
Climate Variability



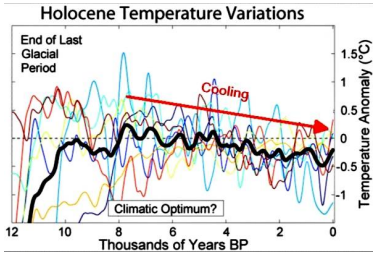
Climate Variability



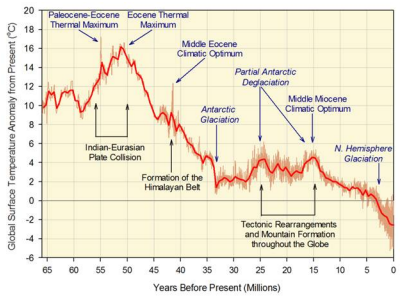
Climate Variability



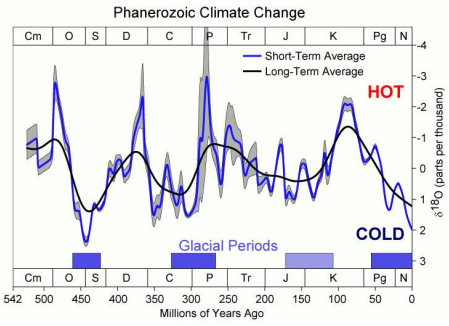
Climate Variability



Climate Variability

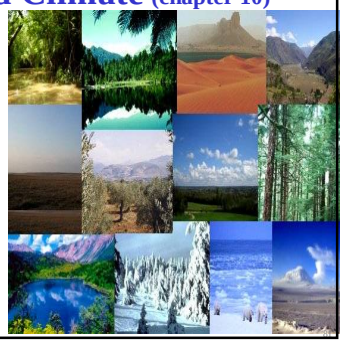


Climate Variability



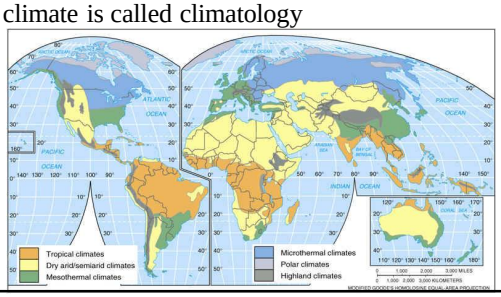
Weather and Climate (chapter 10)

- Climate influences the physical and biotic environment
  - Landforms/landscapes
  - Soil conditions/fertility
  - Natural vegetation
  - Wildlife
- and in turn is influenced by the physical and biotic environment



Global Climate Systems

Study of the spatial and temporal patterns of climate is called climatology



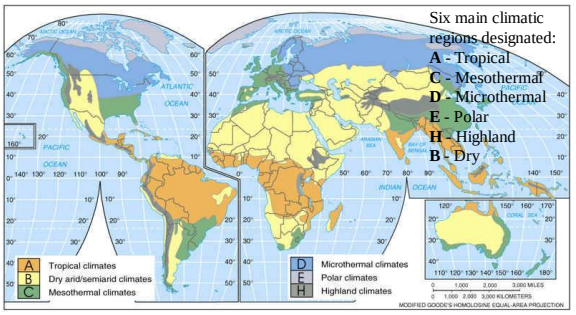
Classification of Climatic Regions

- Genetic classification
  - Based on knowledge of causes of climate
- Empirical classification
  - Based on grouping areas with similar climate data or calculated normals

Koppen-Geiger Classification

- Criteria include measures of:
  - mean monthly temperature
  - mean monthly precipitation
  - and mean annual precipitation
- Does not consider:
  - winds, temperature extremes, precipitation intensity, amount of sunshine, cloud cover, or net radiation

General Classification Categories

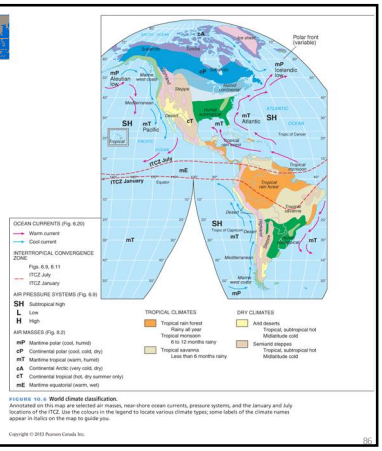


Six main climatic regions designated:
A - Tropical
C - Mesothermal
D - Microthermal
E - Polar
H - Highland
B - Dry

Classification Subgroups

Subgroups identified by second letter indicating seasonal precipitation patterns

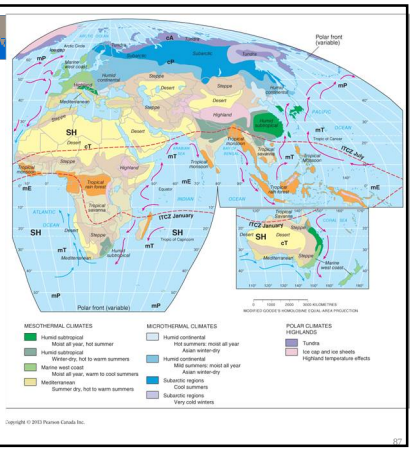
f - no dry season
m - monsoonal
w - winter dry
s - summer dry
W - arid **B** climates
K - semiarid **B** climates



Classification Subgroups

Third letter indicates temperature characteristics of subgroups

a hot summers
b warm summers
c cool summers
d very cold winters
h hot **B** climates
k cold **B** climates

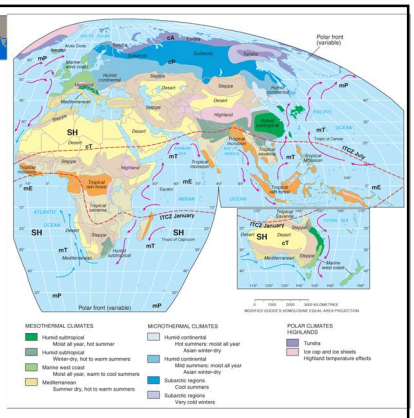


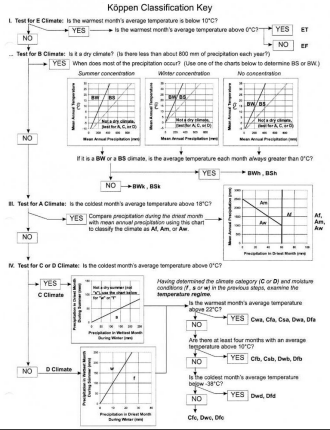
Classification Subgroups

Exceptions to the above are:

E climates:
ET polar tundra
EF polar frost
EM polar marine

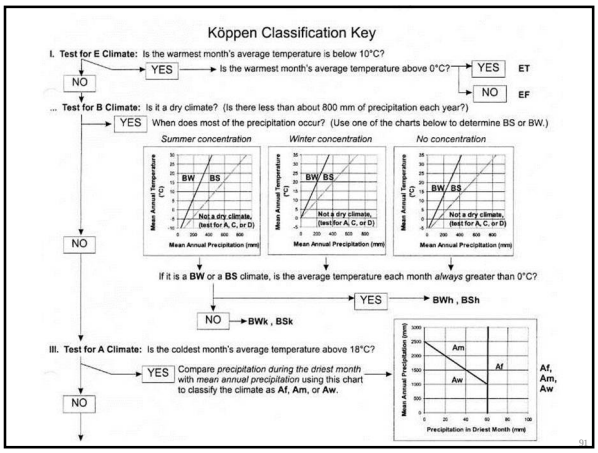
H climates, which are not further subdivided

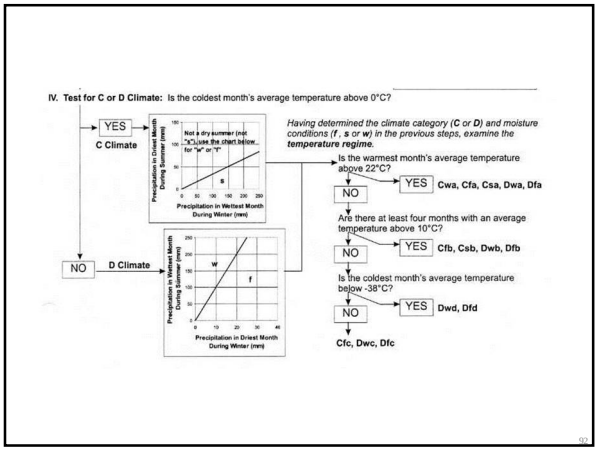


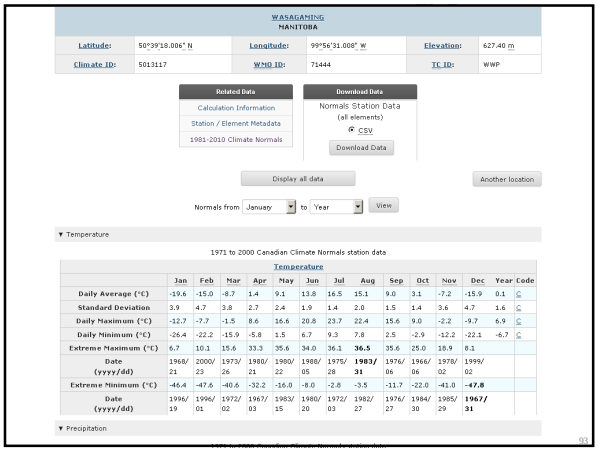


Brandon, MB, Canada
Climate Normals 1971-2000

Latitude: 49.55N **Longitude:** 099.57W **Altitude**: 409m												
Temperature (C)	J	F	M	A	M	J	J	A	S	O	N	D
Mean 3.3 C	-17	-14	-7	3	11	16	19	18	11	5	-5	-14
Precipitation (mm)	J	F	M	A	M	J	J	A	S	O	N	D
Total 453 mm/yr	18	16	21	35	48	67	72	69	51	22	15	19







WASAGAMING
MANITOBA

Latitude:	50°39'18.006" N	Longitude:	99°56'31.008" W	Elevation:	627.40 m
Climate ID:	5013117	WMO ID:	71444	TC ID:	WWP

Related Data
Calculation Information
Station / Element Metadata
1981-2010 Climate Normals

Download Data
Normals Station Data (all elements)
CSV
Download Data

Display all data
Another location
Normals from January to Year View

▼ Temperature

1971 to 2000 Canadian Climate Normals station data

Temperature

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	Code
Daily Average (°C)	-19.6	-15.0	-8.7	1.4	9.1	13.8	16.5	15.1	9.0	3.1	-7.2	-15.9	0.1	C
Standard Deviation	3.9	4.7	3.8	2.7	2.4	1.9	1.4	2.0	1.5	1.4	3.6	4.7	1.6	C
Daily Maximum (°C)	-12.7	-7.7	-1.5	8.6	16.6	20.8	23.7	22.4	15.6	9.0	-2.2	-9.7	6.9	C
Daily Minimum (°C)	-26.4	-22.2	-15.9	-5.8	1.5	6.7	9.3	7.8	2.5	-2.9	-12.2	-22.1	-6.7	C
Extreme Maximum (°C)	6.7	10.1	15.6	33.3	35.6	34.0	36.1	**36.5**	35.6	25.0	18.9	8.1		
Date (yyyy/dd)	1968/21	2000/23	1973/26	1980/21	1900/22	1988/05	1975/28	**1983/31**	1976/06	1966/06	1978/02	1999/02		
Extreme Minimum (°C)	-46.4	-47.6	-40.6	-32.2	-16.0	-8.0	-2.8	-3.5	-11.7	-22.0	-41.0	**-47.8**		
Date (yyyy/dd)	1996/19	1996/01	1972/02	1967/03	1983/15	1980/20	1972/03	1982/27	1976/27	1984/30	1985/29	**1967/31**		

▼ Precipitation

WASAGAMING
MANITOBA

Latitude:	50°39'18.006" N	Longitude:	99°56'31.008" W	Elevation:	627.40 m
Climate ID:	5013117	WMO ID:	71444	TC ID:	WWP

Related Data
Calculation Information
Station / Element Metadata
1971-2000 Climate Normals

Download Data
Normals Station Data (all elements)
CSV
Download Data

Display all data
Another location

Normals from January to Year View

▼ Temperature

1981 to 2010 Canadian Climate Normals station data

Temperature

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	Code
Daily Average (°C)	-17.5	-14.1	-8.1	1.9	8.5	13.6	17.0	15.6	9.6	2.7	-6.9	-14.2	0.7	[]
Standard Deviation	4.1	4.6	3.3	2.6	2.1	2.1	1.1	1.9	1.5	1.7	4.0	4.8	1.4	[]
Daily Maximum (°C)	-10.9	-7.1	-1.3	8.9	15.6	20.2	23.9	22.7	16.1	8.4	-1.8	-8.2	7.2	[]
Daily Minimum (°C)	-24.1	-21.0	-14.9	-5.2	1.3	6.9	10.0	8.5	3.0	-3.1	-12.0	-20.1	-5.9	[]
Extreme Maximum (°C)	6.7	10.1	15.6	33.3	35.6	34.0	36.1	**36.5**	35.6	25.6	18.9	8.1		
Date (yyyy/dd)	1968/ 21	2000/ 23	1973/ 26	1980/ 21	1980/ 22	1988/ 05	1975/ 28	**1983/ 31**	1976/ 06	2003/ 09	1978/ 02	1999/ 02		
Extreme Minimum (°C)	-46.4	-47.6	-41.7	-32.2	-16.0	-8.0	-2.8	-3.5	-11.7	-22.0	-41.0	**-47.8**		
Date (yyyy/dd)	1996/ 19	1996/ 01	2003/ 08	1967/ 03	1983/ 15	1980/ 20	1972/ 03	1982/ 27	1976/ 27	1984/ 30	1985/ 29	**1967/ 31**		

▼ Precipitation

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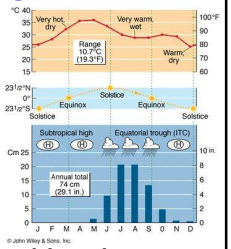
Climographs

- Typically depict:
  - mean monthly precip (vertical bar)
  - mean monthly temp (line)
- May also include:
  - location
  - mean annual temp
  - mean annual precip
  - elevation
  - population
- Provide a graphic illustration of the variability and seasonality of temp and precip characteristics



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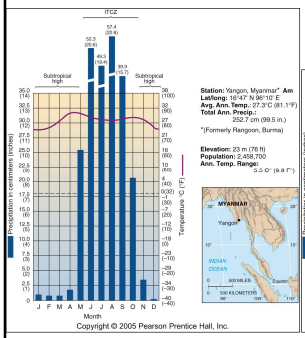

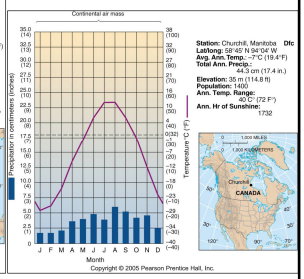

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