Topic 4

Temperature, Atmospheric Circulation and Climate

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

KEY LEARNING CONCEPTS

Chapters 5, 6, & 10

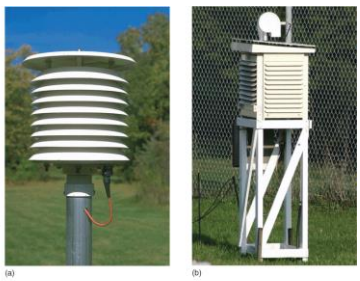
1

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

2

Thermometer and Instrument Shelter

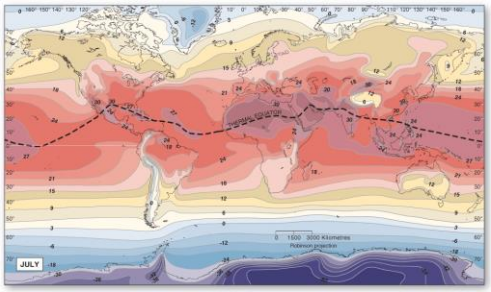


(a) (b)

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) Robbé Christopherson. (b) Dick Hemingway.]

3

Principal Temperature Controls



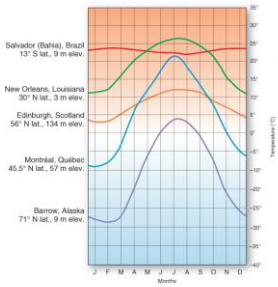
4

Importance of Temperature

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

5

Latitude



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

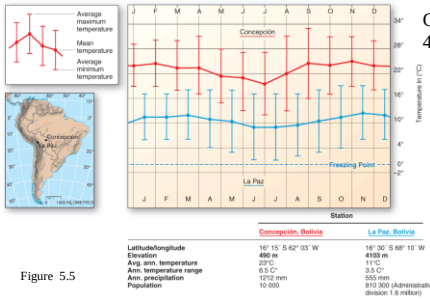
Determines intensity and duration of insolation.

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.

6

Altitude/Elevation



Concepcion
490 m

La Paz
4103 m

Figure 5.5

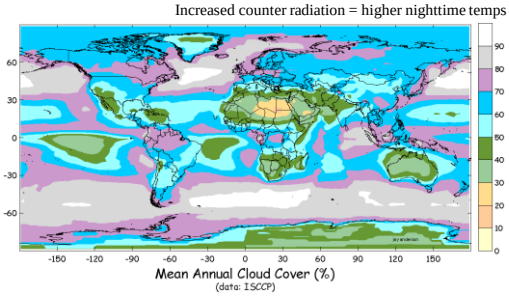
As elevation ↑, density of atm. ↓ and reduces ability to absorb or reradiate heat

7

Cloud Cover

Less insolation = lower daytime temp

Increased counter radiation = higher nighttime temps



8

Land-Water Heating Differences

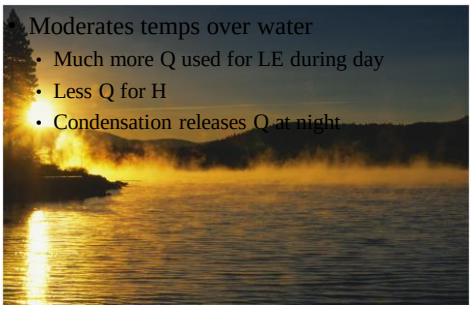
- Result of four (not five) major differences between physical properties of land and water:

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

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

9

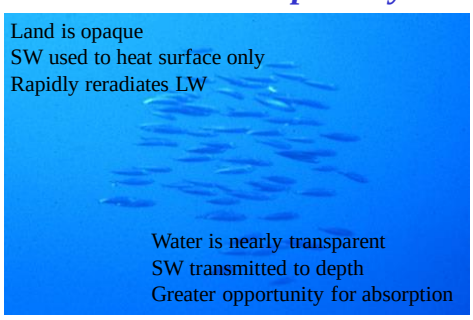
L vs. W: Evaporation



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

10

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

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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

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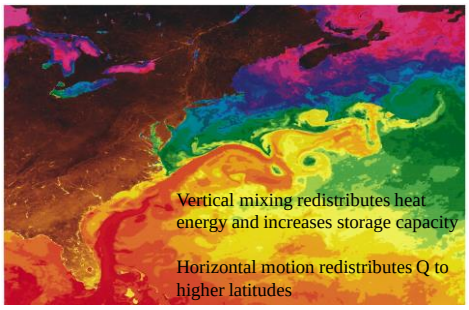
L vs. W: Circulation



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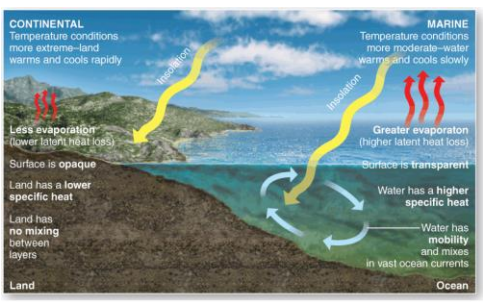
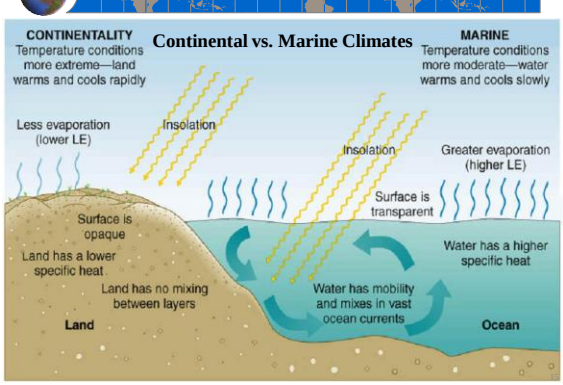
Land-Water Heating Differences



14



Maritime and Continental Locations in Canada

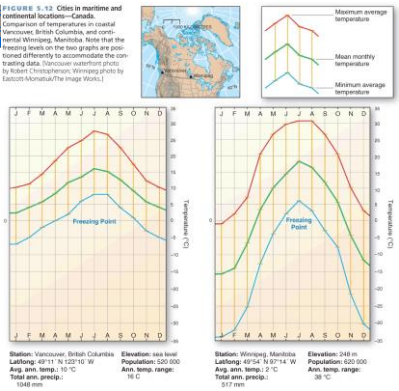


FIGURE 5.12 Cities in maritime and continental locations—Canada. Comparison of temperatures in coastal Vancouver, British Columbia, and continental Winnipeg, Manitoba. Note that the freezing levels on the two graphs are positioned differently to accommodate the contrasting data. (Vancouver waterfront photo by Robert Christopherson; Winnipeg photo by Eastcott-Momatiuk/The Image Works.)

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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)

17

Global Mean Temperatures: January

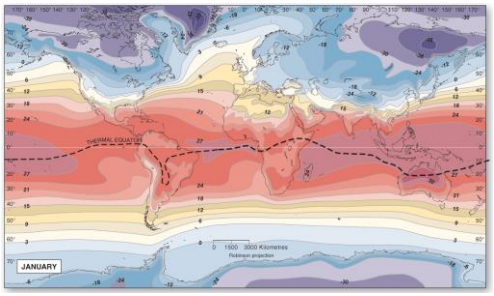

Figure 5.13

18

Bending of Continental Isotherms

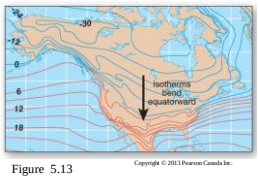

Figure 5.13

January: equatorward

July: poleward

Figure 5.16

19

Global Mean Temperatures: July

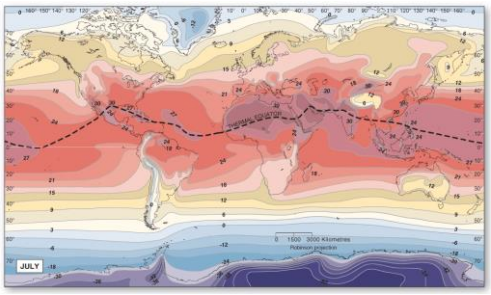

Figure 5.16

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Annual Temperature Range

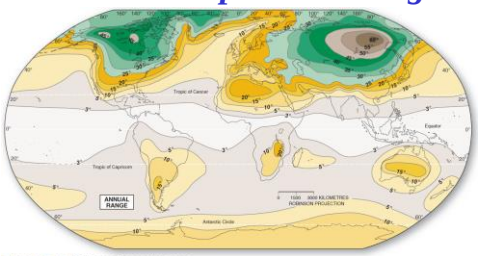

FIGURE 5.18 Global annual temperature ranges.
The annual range of global temperatures in Celsius degrees, C°. The mapped data show the difference between average January and July temperature maps.

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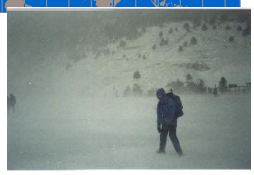
Apparent Temperature



- 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

22

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).

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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.

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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

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Wind Essentials

Wind defined by:

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

26

Driving Forces

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

27

Gravity

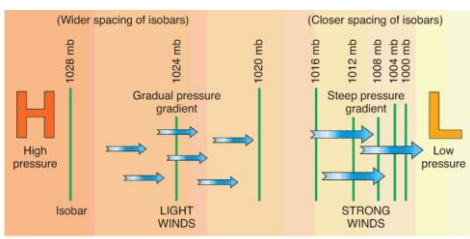
- Force of gravity produces atm. pressure
- Without gravity there would be:
  - no atmospheric pressure
  - so no variations in atmospheric pressure
  - no atmospheric motion

  and oh . . .,

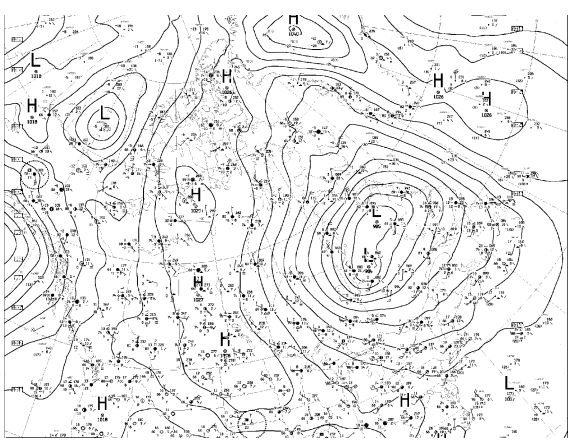
  by the way,

  no atmosphere

Pressure Gradient Force



(a)



Primary High- & Low-Pressure Areas

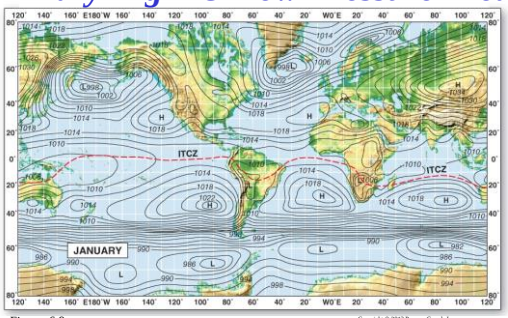


Figure 6.9a

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Primary High- & Low-Pressure Areas

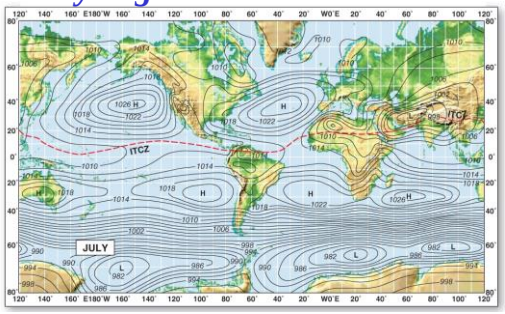
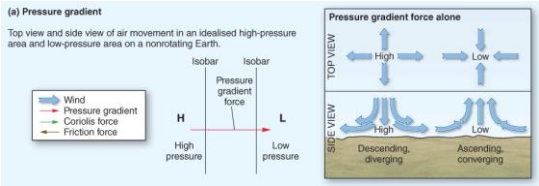


Figure 6.9b

32

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)

33

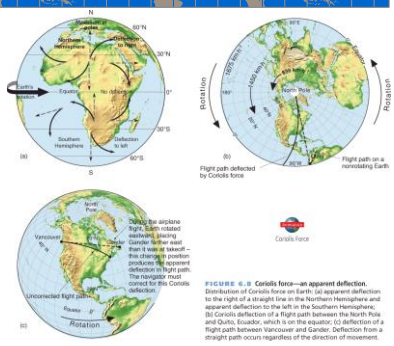
Pressure Gradient Force

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

Something must be affecting their path?

34

Coriolis Force



The current edition finally has it (almost) right!

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.

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Coriolis Force

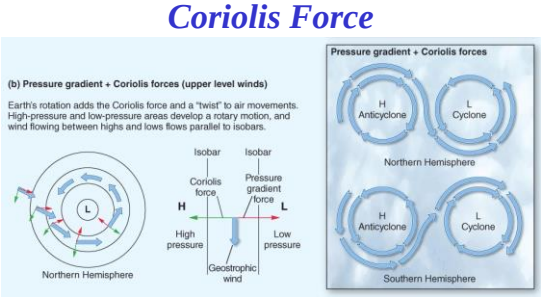


Figure 6.7b

36

Friction Force

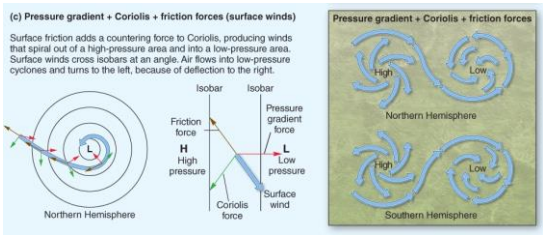
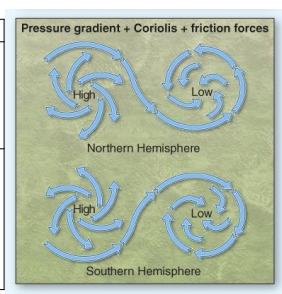


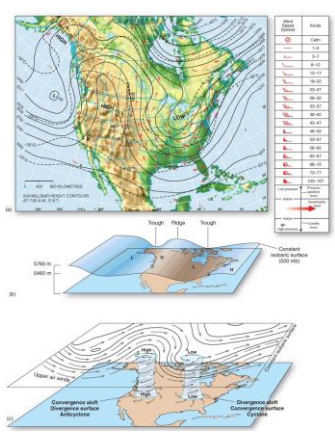
Figure 6.7c

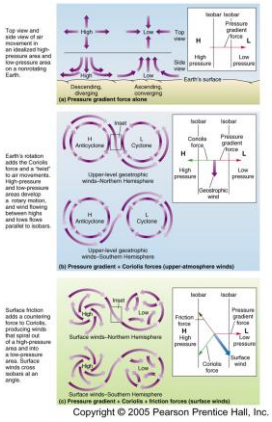
Cyclones and Anticyclones

	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





40

Primary High- & Low-Pressure Areas

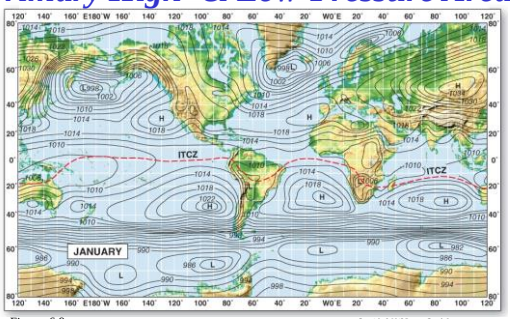


Figure 6.9a

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Primary High- & Low-Pressure Areas

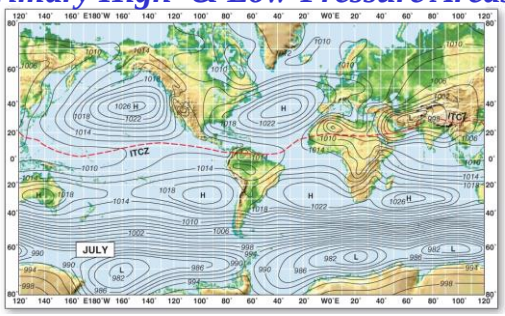


Figure 6.9b

43

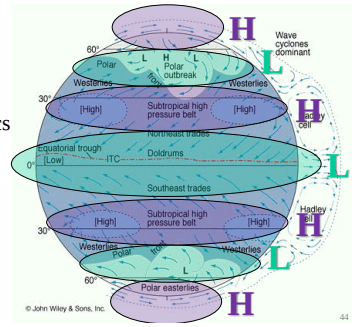
Primary High- & Low-Pressure Areas

Result of:

differential heating & moisture characteristics

OR

dynamic forces



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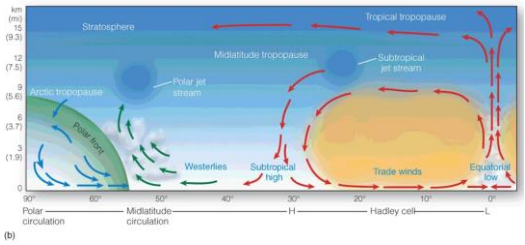
Generalized Circulation Model



Cross-section of One Hemisphere

45

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

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Equatorial Low (ITCZ)

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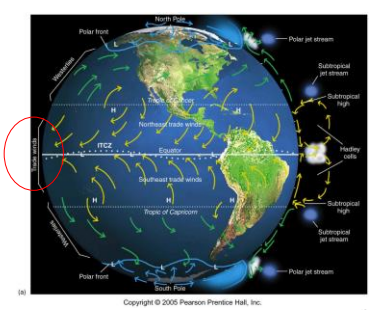
Trade Winds

- 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



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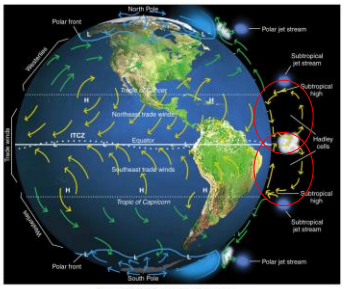
Subtropical High-Pressure

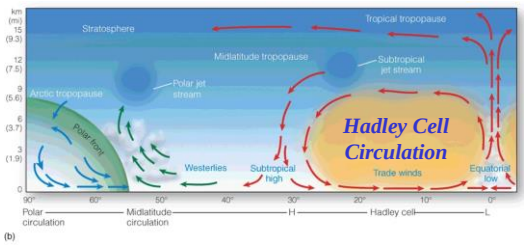
- Divergence aloft over ITCZ results in upper atm. flow toward subtropics
- Cool air is <u>forced</u> to descend and warms adiabatically (due to increase in pressure)
- High pressure results from descending, diverging air
  - mid-latitude deserts



(a)

49

Generalized Circulation Model



(b)

50

Atlantic Sub-Tropical High

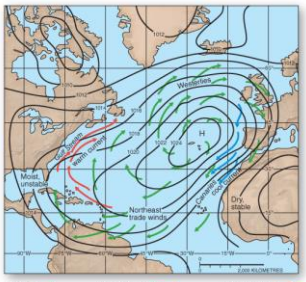


FIGURE 6.12 Subtropical high-pressure system in the Atlantic.
Characteristic circulation in the Northern Hemisphere. Note deserts extend to the shores of Africa, which has offshore cool currents, whereas the southeastern United States is moist and humid, with offshore warm currents.

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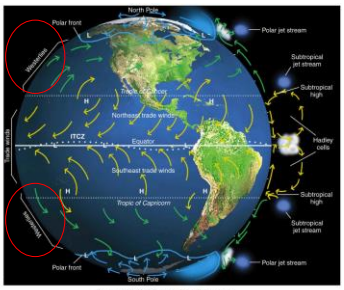
Westerlies

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

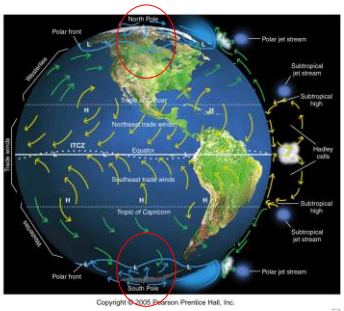


(a)

52

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

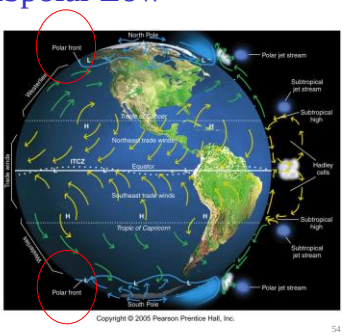


(a)

53

Subpolar Low

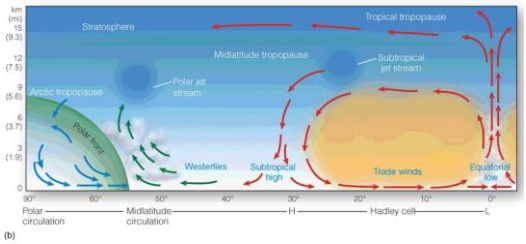
- Result of uplift along polar front
- Conflict between cold dry air and warm, moist air
- Mechanical lifting at frontal boundary
- Results in cool, moist air



(a)

54

Generalized Circulation Model



Polar Front
Development of Mid-latitude Cyclones

55

General Atmospheric Circulation Model

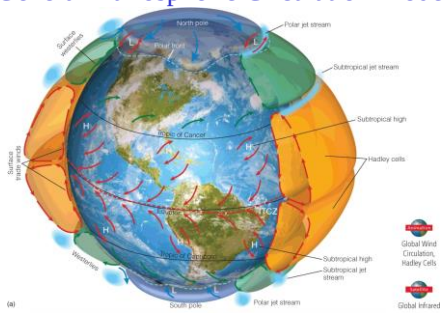
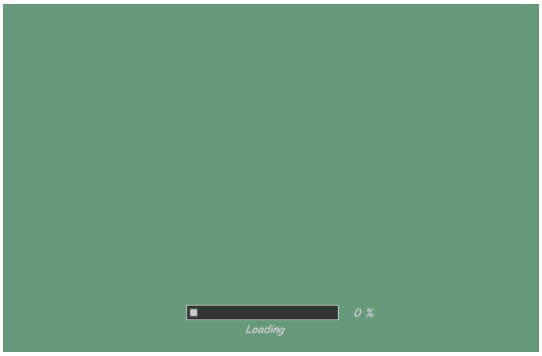
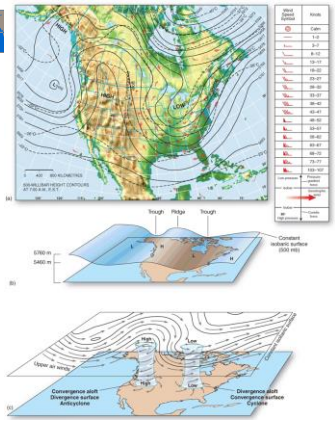


Figure 6.11a

56



Upper Atm. Circulation



58

Rossby Waves

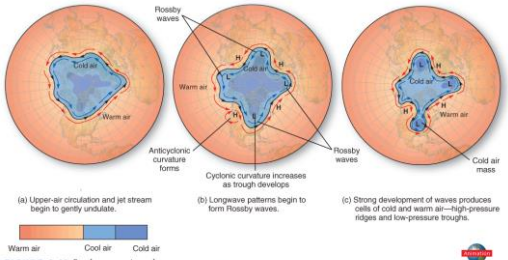


FIGURE 6.15 Rossby upper-atmosphere waves.
Development of waves in the upper-air circulation. Note undulations in Rossby waves, labeled "L" for troughs and "H" for ridges.

Jet Stream, Rossby Waves

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Jet Streams

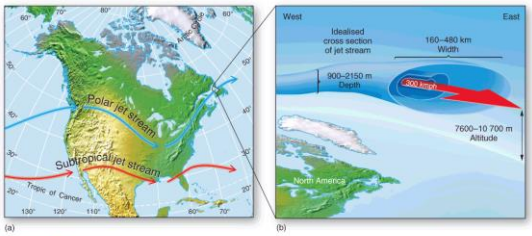


FIGURE 6.16 Jet streams.
(a) Average locations of the two jet streams over North America. (b) Stylised portrait of a polar jet stream.

60

Local Winds

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

61

Land and Sea Breezes

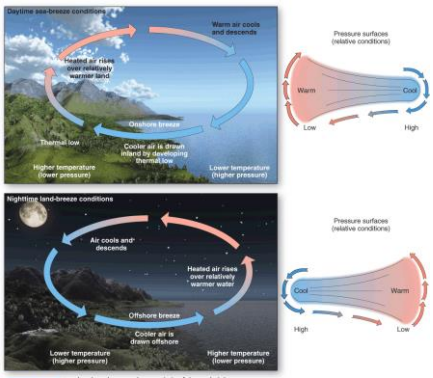


FIGURE 6.17 Land and sea breezes characteristic of day and night.

62

Mountain Valley Breezes

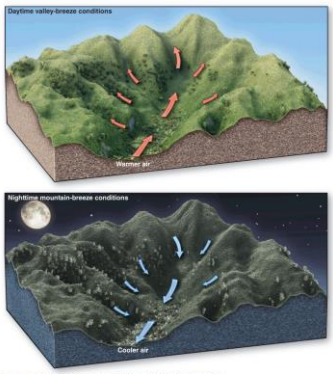


FIGURE 6.18 Pattern of valley and mountain breezes day and night.

63

Monsoonal Winds

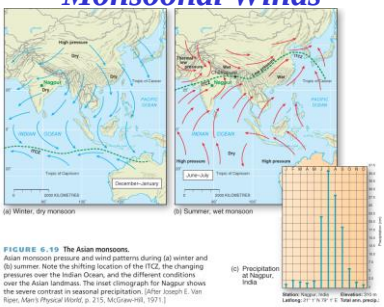


FIGURE 6.19 The Asian monsoons. Asian monsoon pressure and wind patterns during (a) winter and (b) summer. Note the shifting location of the ITCZ, the changing pressures over the Indian Ocean, and the different conditions over the Asian landmass. The inset climograph for Nagpur shows the severe contrast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

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

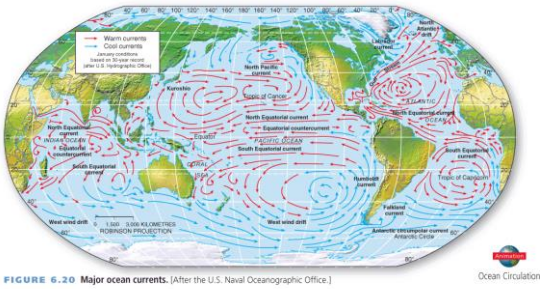


FIGURE 6.20 Major ocean currents. [After the U.S. Naval Oceanographic Office.]

Ocean Circulation

Thermohaline Circulation – The Deep Currents

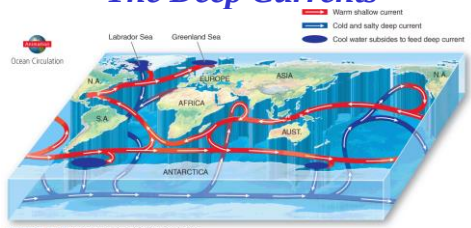


FIGURE 6.22 Deep-ocean thermohaline circulation.
This global circulation is a vast conveyor belt of water, drawing heat energy from warm shallow currents and transporting it for release in the depths of the ocean basins in cold, deep, salty currents. Four blue areas at high latitudes are where surface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

67

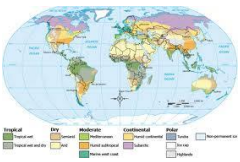
Weather and Climate (chapter 10)

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

68

Weather and Climate (chapter 10)

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



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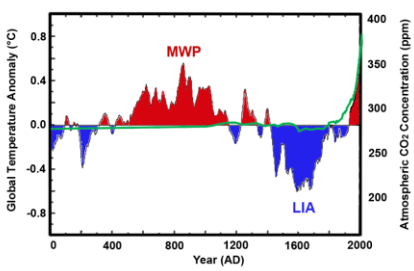
Components of Climate

- 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

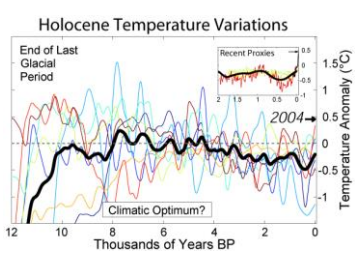
70

Climate Variability



71

Climate Variability



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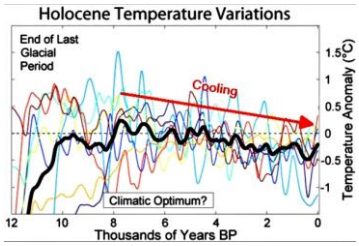
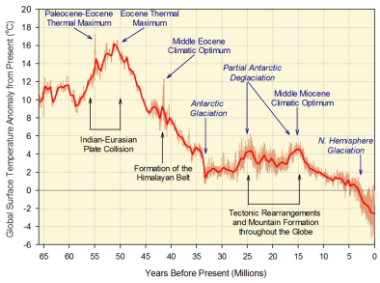
Climate Variability



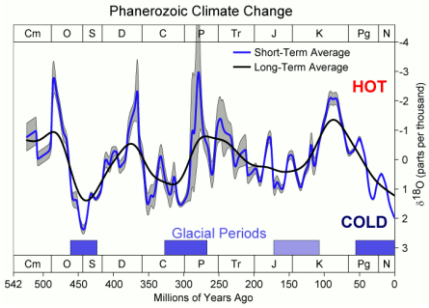
73

Climate Variability



74

Climate Variability



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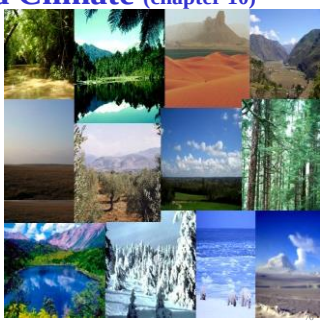
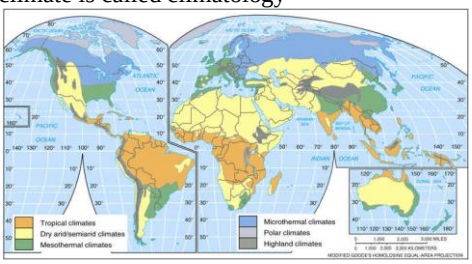
Weather and Climate (chapter 10)

- 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



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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

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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

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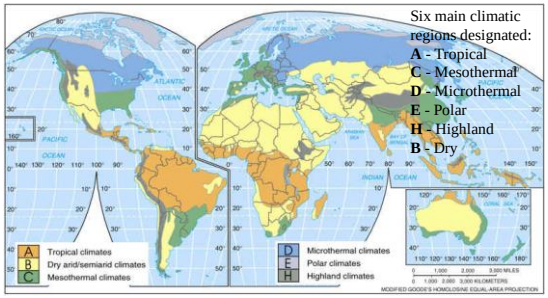
General Classification Categories



80

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

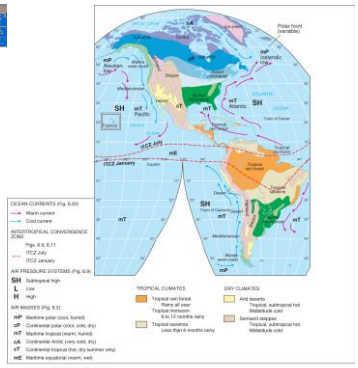


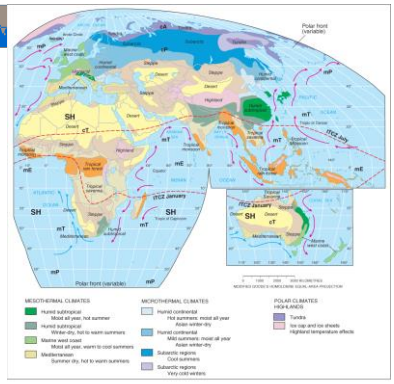
FIGURE 10.4 **World climate classification.** Annotated on this map are selected air masses, near-shore ocean currents, pressure systems, and the January and July locations of the ITCZ. Use the colours in the legend to locate various climate types; some labels of the climate names appear in italics on the map to guide you.

81

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



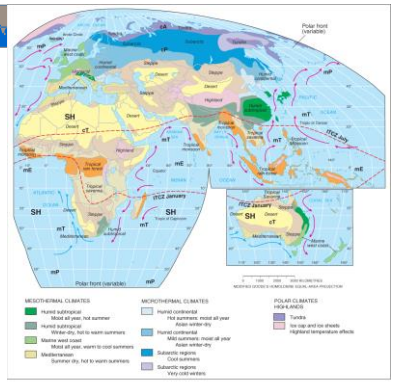
82

Classification Subgroups

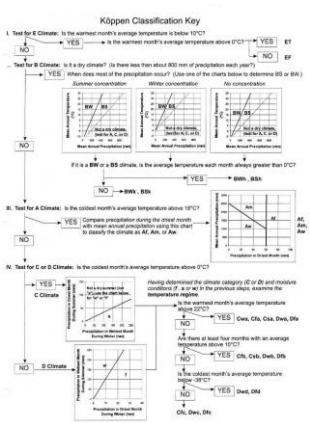
Exceptions to the above are:

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

H climates, which are not further subdivided



83



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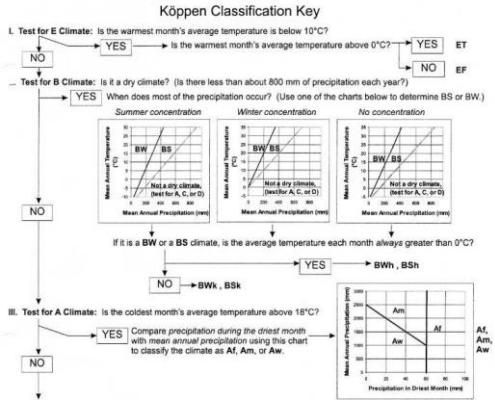
Brandon, MB, Canada
Climate Normals 1971-2000

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

85



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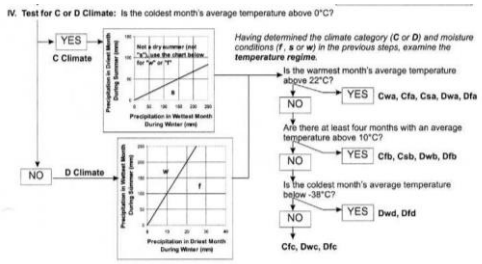

87

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	1980/22	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

1971 to 2000 Canadian Climate Normals station data

88

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	D
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	D
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	D
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	D
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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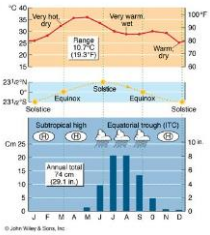
Climographs

- 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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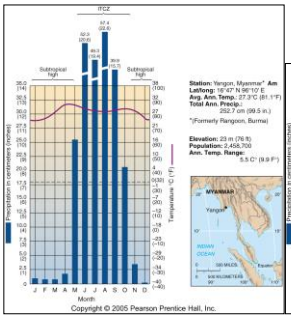
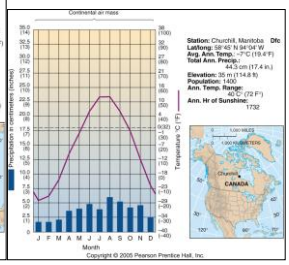

ITCZ
Subtropical high
Subtropical high
Precipitation in centimeters (inches)
Temperature °C (°F)
Month
J F M A M J J A S O N D
Station: Yangon, Myanmar* Am
Lat/long: 16°47' N 96°10' E
Avg. Ann. Temp.: 27.3°C (81.1°F)
Total Ann. Precip.:
252.7 cm (99.5 in.)
*(Formerly Rangoon, Burma)
Elevation: 23 m (76 ft)
Population: 2,458,700
Ann. Temp. Range:
5.5 C° (9.9 F°)
MYANMAR
Yangon
INDIAN OCEAN
Copyright © 2005 Pearson Prentice Hall, Inc.


Continental air mass
Precipitation in centimeters (inches)
Temperature °C (°F)
Month
J F M A M J J A S O N D
Station: Churchill, Manitoba Dfc
Lat/long: 58°45' N 94°04' W
Avg. Ann. Temp.: -7°C (19.4°F)
Total Ann. Precip.:
44.3 cm (17.4 in.)
Elevation: 35 m (114.8 ft)
Population: 1400
Ann. Temp. Range:
40 C° (72 F°)
Ann. Hr of Sunshine:
1732
Churchill
CANADA
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