CHAPTER 6 THE ATMOSPHERE AND THE OCEANS

Key Concepts

Major Concept (I) *The intensity of solar radiation per unit area reaching the surface of Earth varies as a function of latitude.*

Related or supporting concepts:

- Figure 6.1 illustrates how the sun's rays reach the surface at different angles with increasing latitude. Where the sun's rays are more nearly perpendicular to the surface, the intensity of the radiation per unit area will be greater.
- Because Earth is tilted on its axis by 23½° with respect to its orbital plane around the sun, the sun's rays will be perpendicular to the surface somewhere between 23½°N (called the Tropic of Cancer) and 23½°S (called the Tropic of Capricorn). It is in this band of latitude centered on the equator that the maximum incoming solar radiation reaches the planet's surface.
- There are actually two reasons why the intensity of solar radiation at the surface decreases with latitude:
    a. the angle of the sun's rays as measured from a perpendicular to the surface increases, and
    b. the amount of atmosphere the radiation must penetrate increases as the angle increases.
- There is also obviously a daily change in incoming radiation from a maximum at noon when the sun is highest in the sky to a minimum in the middle of the night.
- The seasonal change in incoming radiation is due to the tilt of Earth's rotational axis. The Northern Hemisphere sees a maximum in radiation in the summer and a minimum in winter months while the Southern Hemisphere is just the opposite.
- The length of daylight in a given day is also a factor in the amount of radiation which reaches the surface at any given location. Long periods of daylight at the North Pole in the summer and the South Pole in the winter result in high daily levels of solar radiation. The South Pole levels are slightly higher than at the North Pole because Earth's orbit is elliptical and Earth is closest to the sun in the winter.

Major Concept (II) *Earth maintains a fairly constant temperature because it loses as much heat as it gains from the sun. The accounting of heat gain and loss is called the heat budget of the planet.*

Related or supporting concepts:

- The long term mean temperature of the Earth is about 16ºC. In order to maintain this average temperature the Earth's heat budget must be balanced.

- The heat budget can best be understood if we make the simple assumption that the total incoming solar radiation available to Earth is measured as being equal to 100 units of heat (whatever those units may be). We can then follow the heat budget by looking at figure 6.2.
- Of these incoming 100 units of heat:
  - a. the atmosphere will
    - i. reflect 31 units, and
    - ii. absorb 17½ units,
  - b. the planet's surface will
    - i. reflect 4 units, and
    - ii. absorb 47½ units.
- A total of 65 units (17½ + 47½) are absorbed and contribute to heating the planet. To balance the heat budget, 65 units of heat must be lost to space.
- The 65 units of heat that are lost come from:
  - a. 59½ lost by the atmosphere, and
  - b. 5½ lost by the surface.
- Note that the surface and the atmosphere do not each have balanced heat budgets. In particular:
  - a. the surface gained 47½ and lost 5½ for a net gain of 42 units, and
  - b. the atmosphere gained 17½ and lost 59½ for a net loss of 42 units.
- Even though the surface and the atmosphere do not independently have balanced heat budgets, the planet as a whole does because the surface transfers 42 units of heat to the atmosphere through:
  - a. 29½ units due to evaporation, and
  - b. 12½ units due to conduction and convection.
- Evaporation cools the surface and heats the air when the water vapor later condenses.
- Incoming solar radiation has short wavelengths that allow it to pass through the air without significantly heating it. The re-radiated energy from the planet's surface is longer wavelength energy that is absorbed by the atmosphere. For this reason, the atmosphere is heated from below, not from above as we might expect. This makes convection and movement in the air much more efficient.
- In general, regions below 45°N and S gain more heat than they lose, and above these latitudes the surface loses more heat than it gains (see fig. 6.3). This imbalance is moderated by the transfer of heat from low latitudes to high latitudes by moving air and surface currents in the oceans.

Major Concept (III) *Sea surface temperatures show the variation with latitude that we would expect, higher temperatures in tropical regions and lower temperatures with increasing latitude. The high heat capacity of water results in much lower variations in temperature with daily and seasonal changes than are found on land at comparable latitudes.*

Related or supporting concepts:

- Land has a much lower heat capacity than water. Consequently, the land will gain and lose heat more rapidly than the oceans will.
- In figure 6.4 you can see the latitudinal dependence of average sea surface temperature in the summer. These temperatures will change seasonally but the change will not be as drastic as it is on the continents (see fig. 6.5).
- Seasonal variations in sea surface temperature are only a few degrees in equatorial and polar regions because of the stability of the climate.
- Maximum temperature variations occur at mid-latitudes, especially in the Northern Hemisphere where these changes are as large as 8 - 9°C, near 40°N and S where seasonal changes in climate are most pronounced.
- Large amounts of heat are transferred from the sea surface to the atmosphere around 20 - 30°N and S where a warm, relatively dry climate evaporates water from the surface. The evaporation cools the oceans and the subsequent condensation of this water vapor in the air heats the atmosphere.
- Surface currents and winds transfer heat from lower latitudes to higher latitudes and help to maintain a relatively uniform global temperature.

Major Concept (IV) *At high latitudes cold temperatures can create sea ice. This process produces a variety of different forms of ice and has a significant effect on the salinity of the near surface water.*

Related or supporting concepts:

- The first sign of the formation of sea ice is the presence of a layer of slush at the surface as temperatures fall.
- Newly formed sea ice is thin and can be easily broken into pieces called pancakes by wind and waves.
- Continued formation of ice causes pancakes to join to create larger masses called floes.
- Continuous, or nearly continuous sea ice is also called pack ice.
- Floes move with respect to one another. When they collide they can crumple and override one another to form ridges and hummocks.
- Floes may also separate and create narrow segments of open water called leads.
- The maximum thickness of ice formed in a season is usually about 2 m.
- The ice, along with any snow that may cover it, acts as an insulator for the underlying water preventing it from losing heat too rapidly. This is why it is difficult to form very thick ice even with prolonged periods of low temperatures.
- The crystalline structure of ice excludes large salt ions. Some salt water may be trapped in the ice if it forms quickly but with time it will drain out. Sea ice is mostly fresh water.
- Salts will be concentrated in the shallow surface water as ice forms. This water will

therefore be both very cold and fairly saline, leading to a high density.

- Sea ice is permanent around Antarctica and the high Arctic. It is seasonal at high northern latitudes near continental margins.
- If one season's ice is not entirely melted over the summer it will add to the thickness of the next season's formation. In some areas this results in ice thickness as great as 3½ - 5 m.
- As glaciers move toward coastlines, segments may break off and create castle icebergs that drift at sea (see fig. 6.8). These are irregular-shaped masses with roughly 12 percent of their volume above water and 88 percent below. Castle icebergs are watched closely to see if they pose a threat to shipping lanes.
- The greatest danger to navigation from icebergs is in the North Atlantic. Antarctic icebergs are usually trapped in the Antarctic Circumpolar current and icebergs from Alaska commonly remain in narrow bays.
- Seasonal variations in sea ice cover at high latitudes are illustrated in figure 6.7.

Major Concept (V) *The atmosphere has a layered structure and is a mixture of a number of different gases. It has pressure variations that produce regions of low and high pressure with ascending and descending air.*

Related or supporting concepts:

- The atmosphere has a layered structure (see fig. 6.9).

Layer	Elevation (km)
troposphere	0 - 10
tropopause (transition layer)	10 - 20
stratosphere	20 - 50
stratopause (transition layer)	50 - 60
mesosphere	60 - 80
mesopause (transition layer)	80 - 90
thermosphere	above 90 km

- The density of the atmosphere increases rapidly close to the surface. Roughly 99 percent of atmospheric gases are found below an elevation of 30 km and 90 percent are below an elevation of about 15 km.
- Precipitation, evaporation, wind systems, and clouds are all restricted to the troposphere.
- Temperature reversals occur in the different layers of the atmosphere.
    a. The troposphere is heated from below by re-radiation, conduction, and condensation of water vapor. Consequently, temperature decreases with elevation.
    b. Ozone is the stratosphere absorbs ultraviolet radiation causing temperature to increase with altitude.
    c. Temperature decreases again with altitude in the mesosphere.
    d. Temperature increases with altitude in the thermosphere.

e. Temperature remains constant throughout the transition layers.

- You can see from table 6.1 that while there are a number of different gases in the atmosphere, nitrogen and oxygen account for roughly 99 percent of the gas (nitrogen 78 percent, oxygen 21 percent). Interestingly, there is very little hydrogen. Remember when we talked about the hydrologic cycle and water reservoirs, we learned that there is relatively little water stored in the atmosphere, given its enormous size.
- The atmosphere is composed of a mixture of gases, suspended microscopic particles, and water droplets.
- Atmospheric gases are typically categorized as being permanent or variable. Permanent gases are present in a constant relative percentage of the atmosphere's total volume. The concentration of variable gases changes both in time and location.
- Motion in the atmosphere is the result of density differences from one location to another.
- The density of air will increase with:
  a. decreasing temperature,
  b. increasing pressure or altitude, and
  c. decreasing water vapor content.
- The density of air will decrease with:
  a. increasing temperature,
  b. decreasing pressure or altitude, and
  c. increasing water vapor content.
- The overlying air presses down on the surface of the planet. The weight of a column of air at the surface pushes down with a force called the atmospheric pressure.
- Atmospheric pressure can be measured using different units. The average atmospheric pressure at sea level is:
  a. 1013.25 millibars, or
  b. 14.7 lbs/in^2.
- High pressure zones have pressures greater than average and low pressure zones have pressures below this average value.

Major Concept (VI) *As the planet has aged the composition of the atmosphere has changed naturally. There is clear evidence now, however, that human activities have produced marked changes in atmospheric chemistry over a very short period of time.*

Related or supporting concepts:

- There are three active reservoirs for CO_2: the atmosphere, the oceans, and the terrestrial system. Of these reservoirs, the oceans store the largest amount of CO_2 and the atmosphere stores the least (see fig. 6.10).
- It is estimated that roughly 7 billion tons of CO_2 are being added to the atmosphere annually as a result of human activity.

- Short wavelength incoming radiation is not blocked by CO_2, but re-radiated long wavelength energy is and this warms the atmosphere causing the greenhouse effect.
- Changing atmospheric chemistry can be monitored over past years by analyzing bubbles trapped in polar ice. It can be demonstrated that following the Industrial Revolution, the concentration of CO_2 has risen dramatically and continues to rise at an increasing rate (see fig. 6.12).
- There is a clear seasonal variation in CO_2 related to increasing uptake by plants for photosynthesis in the spring and summer, and increasing release through decay in the fall and winter.
- Scientists have estimated that the greenhouse effect may produce a global warming of 2 - 4°C over the next few decades. This could melt high latitude ice and raise sea level by as much as 1 m (3.3 ft).
- Natural mechanisms have been identified that may decrease the greenhouse effect. These include:
  a. the release of sulfur into the atmosphere from the oceans, and
  b. large volcanic eruptions.
- Sulfur is released by small marine plant-like organisms that produce dimethyl sulfide gas. Sulfur can act to reduce temperatures by:
  a. increasing the density and reflective properties of marine clouds, and
  b. blocking incoming short wavelength solar radiation.
- Large volcanic eruptions propel huge amounts of ash and dust high into the atmosphere. This material can block incoming solar radiation.
- Significant reductions in the concentration of ozone in the stratosphere have been detected over Antarctica since the late 1970s. It is estimated that the average global loss of ozone since 1978 is about 3 percent. At polar latitudes the loss is estimated at about 8 percent per decade.
- A decrease in ozone concentration allows more ultraviolet radiation to reach the earth's surface.
- Increased levels of ultraviolet radiation have decreased the production of plant-like organisms in Antarctic surface water by about 2 to 4 percent since 1990. These organisms are at the base of the food chains that support Antarctic marine life.
- The decrease in ozone is thought to be due to the release of chlorine into the atmosphere. Chlorine is a component of chlorofluorocarbons used in refrigeration, air-conditioning, solvents, and the production of some foam insulation.

Major Concept (VII) *The great envelope of air that surrounds our planet is constantly in motion as a result of density differences that create pressure variations.*

Related or supporting concepts:

- Less dense air (low pressure regions) rises while higher density air (high pressure regions) will descend toward the surface.
- When the descending air in a high pressure system encounters the surface it will flow

horizontally toward areas where the air is rising in a low pressure region.

- High in the atmosphere the rising air will move outward away from the low pressure center toward areas where it can descend once again in high pressure regions.
- The air that moves horizontally from high pressure regions to low pressure regions at the surface and from the top of low pressure regions to the top of high pressure regions at altitude is called the wind.
- Large circulation cells cycle air from the surface aloft and back again. The direction of the wind aloft is opposite the direction of the wind at the surface.
- A simple model of circulation in the atmosphere can be imagined if we assume first that Earth does not rotate and is uniformly covered with water (no continents):
    a. the maximum incoming solar radiation would be in equatorial regions,
    b. the minimum incoming solar radiation would be in polar regions, and
    c. most evaporation would be near the equator.
- This model would predict warm, moist air near the equator that would have low density and would rise. As the air rose it would cool, the water vapor would condense, and precipitation would form.
- The air aloft would move toward the poles where it would eventually sink because it would be cold and dry and therefore have a high density. Air at the surface would be moving from the poles toward the equator to replace the rising air.
- Atmospheric circulation in this simple model planet would consist of two massive circulation cells, one in each hemisphere, with air moving to higher latitudes at altitude carrying heat with it, and toward low latitudes along the surface to pick up moisture and be warmed again near the equator (fig. 6.14). The poles would be characterized by high pressure and the equator by low pressure.
- Winds are always named for the direction from which they are coming. Thus, the Northern Hemisphere surface winds would be north winds while the Southern Hemisphere surface winds would be south winds.

Major Concept (VIII) *The rotation of the planet introduces a complication called the Coriolis effect. The Coriolis effect is due to the fact that as we observe motions in the atmosphere and the oceans, our stable platform, or reference frame, Earth is rotating. This causes an apparent curvature to the path of moving objects that are not rigidly attached to the surface.*

Related or supporting concepts:

- Imagine that you are tracking the progress of an airplane flying from Seattle to San Diego. You have two tracking stations from which to observe the flight; one of them is on the surface of the planet and the other is in a stationary space station.
- During the flight of the plane, the globe continues to rotate on its axis. It rotates toward the east.
- From the space station we would observe the plane flying in a straight line away from Seattle to lower latitudes while Earth rotated beneath it to the east. If there were lines

of longitude drawn on the planet we would see them moving toward the east under the plane.

- From the station on the surface of Earth we would be unaware of our eastward rotation. Instead it would look as if the plane was following a curved path to the southwest. This would be equivalent to being deflected to the right of its intended path.
- This apparent deflection is called the Coriolis effect, named after Gaspard Gustave de Coriolis (1792-1843).
- The Coriolis effect has the following properties (see fig. 6.15):
  - a. deflection is to the right in the Northern Hemisphere,
  - b. deflection is to the left in the Southern Hemisphere,
  - c. the magnitude of the effect increases with increasing latitude,
  - d. the magnitude of the effect is zero at the equator,
  - e. the magnitude of the effect increases with increasing speed of the object, and
  - f. the effect can be seen in moving air in the atmosphere and in moving water masses in the oceans.

Major Concept (IX) *Because of the rotation of Earth, the large scale circulation in the atmosphere actually produces three circulation cells in each hemisphere. These cells define bands of latitude with prevailing winds at the surface and aloft (see fig. 6.16).*

Related or supporting concepts:

- The Coriolis effect causes the prevailing winds to be deflected from straight north-south paths.
- Between the equator and 30°N and S are surface winds called the trade winds.
- The trade winds blow from the northeast in the Northern Hemisphere and the southeast in the Southern Hemisphere.
- Between 30° and 60° are prevailing winds called the westerlies, or prevailing westerlies. They blow out of the southwest in the Northern Hemisphere and out of the northwest in the Southern Hemisphere.
- Between 60° and 90° are winds called the polar easterlies that blow from the northeast in the Northern Hemisphere and the southeast in the Southern Hemisphere.
- Take a look at figure 6.16 to see the pattern of prevailing surface winds and atmospheric circulation cells.
- Regions where the motion of the air is primarily vertical between major circulation cells are areas where there are very light and unsteady winds. These areas are called:
  - a. the doldrums, or intertropical convergence, at the equator, and
  - b. the horse latitudes at ±30°.
- High pressure systems with clear skies and little precipitation are found where there is descending air at ±30° and ±90°.
- Low pressure systems with cloudy skies and high precipitation are found where there is ascending air near the equator and ±60°.

Major Concept (X) *Weather patterns at the surface are strongly influenced by upper air currents. One of the best examples of this is the polar jet stream high in the atmosphere between the polar easterlies and the westerlies.*

Related or supporting concepts:

- The jet stream blows at velocities of 300 km/hr (188 mi/hr) or more from west to east around the globe.
- The path the jet stream takes can be highly sinuous. It may curve drastically and move as much as 2000 km (1250 mi) north and south in response to the location and motion of low and high pressure systems.
- Alternating low and high pressure systems around the Northern Hemisphere will cause the jet stream to oscillate north and south (see fig. 6.17).
- These high and low pressure systems move slowly eastward, along with the wave form of the jet stream, as the westerlies drive them.
- The velocity and deflection of the jet stream is greatest in the winter.
- Subtropical jet streams are high in the atmosphere between the trade winds and the westerlies.
- The region of convergence of the northeast and southeast trade winds near the surface in equatorial regions is called the intertropical convergence zone. Rising moist air creates storms and clouds that move to the west in this region.

Major Concept (XI) *The presence of continents and the difference in heat capacity of land and water result in seasonal changes in wind patterns.*

Related or supporting concepts:

- Land has a lower heat capacity than water so it gains and loses heat more readily.
- In equatorial and polar regions there is little change in wind patterns with the seasons because there is little change in the climate at these latitudes.
- In mid-latitudes the land is warmer than the water during the summer and colder than the water in the winter.
- In the summer as the land heats up it will also heat the overlying atmosphere creating a region of low pressure. The air over the water will be cooler and denser creating high pressure. The low pressure zones over the continents join with the low pressure bands at 60°N and the equator to break the high pressure belt at 30°N into discrete high pressure cells.
- In the winter the rapidly cooling land will cool the overlying air also, creating high pressure cells over the continents with lower pressure over the warmer seawater. The high pressure region at the pole will combine over the continents with the high pressure belt at 30°N to break the low pressure region at 60°N into distinct cells.
- In the Northern Hemisphere winds blow clockwise around high pressure cells and

counterclockwise around low pressure cells. In the Southern Hemisphere the motion reverses.

- The speed of the wind depends on how fast the pressure changes over a fixed distance; this is the pressure gradient. Increasing the pressure gradient increases the speed and strength of the wind.
- On the west coast of the United States the summer high pressure system over the water creates northerly winds that cool the land. In the winter the low pressure system over the ocean produces southerly winds that warm the land.
- On the east coast of the United States the high pressure system over the Atlantic in the summer brings southerly winds carrying warm, moist air. In the winter the low pressure system over the water creates northerly winds that bring cold air to the coast.
- In the Southern Hemisphere where there is a great deal more water than land, these seasonal changes are minor.

Major Concept (XI) *The difference in heat capacity between land and water leads to special wind conditions along coastlines that vary in scale from very large to local and vary in time from seasonal to daily.*

Related or supporting concepts:

- Seasonal prevailing wind patterns over India and Asia caused by differential heating of land and water are called monsoons (see fig. 6.21).
- The winter, or dry, monsoon is caused by high pressure and sinking air over the cold continent that flows off the land and out over the Indian Ocean.
- The summer, or wet monsoon, is caused by low pressure and rising air over the land. To replace this air, winds blow warm, moist air from over the Indian Ocean. As this moist air rises over the continent, the water vapor condenses and produces abundant rainfall.
- Daily changes in temperature from night to day can cause a reversal of wind direction along coasts.
- As the land is heated during the day the air will rise over it and a breeze will blow from the water onto the land. This is called an onshore breeze. It generally has a cooling effect on the coast. This breeze is strongest in the afternoon.
- During the evening when the land cools the air will sink over the land and flow out over the water in an offshore breeze. The offshore breeze reaches its peak in the late night or early morning hours.
- An additional atmospheric phenomena that is seen is the production of rain by the forced lifting of air flowing over the water when it encounters an island or other landmass. As the air rises over the land it will cool with increasing height and the water vapor will condense, producing rainfall. On the opposite, or leeward, side of the island there will be a region of very little rainfall called a rain shadow.

Major Concept (XII) *The condensation of water vapor close to the surface produces fog. There are three different types of fog.*

Related or supporting concepts:

- The three types of fog are:
  - a. advective fog,
  - b. sea smoke, and
  - c. radiative fog.
- Advective fog forms when warm, moist air either flows from the land out over colder seawater or when it flows from the sea onto colder land. In either case, the air is cooled from below and the water vapor condenses to form fog.
- Sea smoke generally forms during the winter when cold, dry air flows from the land or across sea ice over warmer water. The water warms the air and the dry air picks up moisture from the water. As the air warms it rises and the water vapor condenses forming streamers of fog moving upward from the sea surface.
- Radiative fog is produced when there are warm days followed by much colder nights. During the day the warm air is able to hold a lot of water vapor without being saturated. The cold night causes the water vapor to condense and form fog. With the next day's heating the fog disappears.

Major Concept (XIII) *Occasionally the pattern of prevailing winds called the trade winds will be disrupted, causing them to either break down or strengthen. Because these winds play a critical role in driving surface currents in the oceans, the result can have dramatic effects on the movement of water from east to west in equatorial regions. In addition, it can have a major impact on marine organisms and on global weather patterns.*

Related or supporting concepts:

- El Niño begins with atmospheric changes that break down the high-pressure system over Easter Island, and the low-pressure system over Indonesia that drive the trade winds.
- The trade winds drive surface currents from east to west along the equator.
- Normal surface circulation in the oceans is for cold water to move toward the equator on the eastern sides of ocean basins and for warm water to move away from the equator on the western sides of ocean basins.
- An El Niño event first begins with a strengthening of the trade winds, thus increasing the volume of warm water in the western Pacific. This is followed by a weakening of the trade winds.
- When the trade winds break down, the warm water driven westward will flow back toward the eastern side of the basin thereby raising the temperature of the water in that region (see fig. 6.25). This condition is called El Niño or the El Niño Southern Ocean Oscillation (EN/SO).

- The surge of warm water to the east also brings its overlying low-pressure storm systems with it.
- The increase in temperature causes the death of cold-water marine organisms and radically upsets the food chain.
- Precipitation patterns are also reversed with the normally dry west coast of South America receiving heavy rainfall and the normally wet region of Indonesia becoming dry.
- El Niño seems to occur on a four to seven year cycle and surface temperatures can remain elevated for more than a year. It often occurs near Christmas, which is why it was named after the Christ Child.
- The strongest El Niño on record occurred in 1997-98. Surface water temperatures in the eastern tropical Pacific rose as much as 8ºC above normal. Normally dry regions of Ecuador and Peru had as much as 350 cm (138 in or 11.5 ft) of rainfall. Severe drought conditions occurred in areas of the west Pacific in the Philippines, Indonesia, and Australia. Coastal California experienced strong storms with severe coastal erosion, flooding, and landslides.
- When the trade winds are strengthened the eastern Pacific waters become unusually cold and the western Pacific waters are warmer than normal. This condition is called La Niña (the girl), or El Viejo (the old one). This produces unusually wet conditions in India, Burma, and Thailand along with drier than normal conditions along the west coast of South America.
- La Niña can also disrupt global weather patterns, causing droughts and severe storms.
- Our ability to forecast these events is improving with the use of satellite measurements of sea surface temperatures.

Major Concept (XIV) *Large amounts of energy are transferred from the ocean to the atmosphere in the formation of severe storms that form in the tropics and move to higher latitudes.*

Related or supporting concepts:

- Severe storms generated in tropical regions go by a variety of names including:
  a. tropical storm,
  b. cyclone,
  c. hurricane, and
  d. typhoon.
- Warm, humid air rises quickly causing condensation and the release of heat into the atmosphere.
- The heat that is released contributes to the velocity of the winds in these storms.
- Heavy precipitation commonly accompanies the high winds.
- These storms usually move to the west and away from the equator along curved paths due to the Coriolis effect (see fig. 6.26). The paths curve to the right in the Northern Hemisphere and to the left in the Southern Hemisphere.

- At the center of the storm the rapidly rising air creates very low pressure. With very low pressure on the sea surface, the water will rise up in a large regional bulge under the storm's center.
- When these storms reach land the high winds can drive this bulge of water onshore causing severe flooding. This is called storm surge or a storm tide (see fig. 6.27).

Key Terms and Related Major Concepts

At the back of the chapter in your book there are a number of key terms. You should be able to find the following terms referenced in the major concept indicated in parentheses.

heat budget(II)	trade winds(IX)	offshore(XI)
sea ice(IV)	westerlies(IX)	rain shadow(XI)
pack ice(IV)	polar easterlies(IX)	advective fog(XII)
iceberg(IV)	doldrums(IX)	sea smoke(XII)
atmospheric pressure(V)	horse latitudes(IX)	radiative fog(XII)
high pressure zone(V)	jet stream(X)	El Niño(XIII)
low pressure zone(V)	monsoon(XI)	La Niña(XIII)
greenhouse effect(VI)	onshore(XI)	storm tide/storm surge(XIV)
Coriolis effect(VIII)		

Test Your Understanding With The Following Questions:

FILL IN THE BLANK

1. Abnormally warm surface water temperatures occur in the eastern tropical Pacific during ______ ____________.
2. The highest northern latitude at which the sun will be directly overhead in the sky is called the Tropic of __________________.
3. The atmosphere is fairly transparent to radiation that has _______________ wavelengths.
4. A dome of water beneath a strong low pressure system that is driven onto land is called a ________________ _______________.
5. Sheets of new sea ice can be broken into ________________________ by the wind.
6. Air moves from regions of _________ pressure to regions of _________ pressure.
7. The areas of high pressure at 30°N and S are called the _______________ latitudes.
8. A region of low precipitation on the protected side of islands is called a ____________ __________________.
9. The most abundant gas in the atmosphere is ________________________.

10. The accounting of where energy is gained and lost by the planet is called the planet's

____________ __________________.

TRUE - FALSE

1. The greenhouse effect is caused by an increase in the amount of ozone in the atmosphere.
2. Some predictions are that the greenhouse effect could raise sea level by as much as 1 m.
3. The Coriolis effect causes a deflection to the left in the Southern Hemisphere.
4. Land has a lower heat capacity than water.
5. The onshore breeze is strongest at night.
6. There are six major atmospheric circulation cells.
7. The prevailing surface winds between the equator and 30° blow from west to east.
8. Moist air is denser than dry air.
9. The warming of the planet by the greenhouse effect is thought to be countered slightly by the release of sulfur into the air from plants in the oceans.
10. Carbon dioxide concentrations in the atmosphere vary naturally with the seasons.

MULTIPLE CHOICE

1. The maximum seasonal change in sea surface temperature is about __________ °C.
    a. 1 to 2
    b. 8 to 9
    c. 3 to 5
    d. 15 to 20
    e. 12 to 14
2. The density of air increases with:
    a. increasing pressure
    b. decreasing temperature
    c. increasing water vapor content
    d. all of the above
    e. a and b above
3. The Coriolis effect:
    a. is maximum at the equator
    b. is zero at the poles
    c. causes all objects in motion to be deflected to the right
    d. all of the above
    e. none of the above
4. The region of rising air at the equator is called the:
    a. horse latitudes
    b. equatorial high pressure belt
    c. doldrums
    d. monsoon
    e. prevailing westerlies
5. A strong wind at high latitudes that influences weather patterns is called:

a. the jet stream
b. the easterlies
c. the upper air monsoon
d. a typhoon
e. none of the above

6. Streamers of fog that rise from the sea surface on cold winter days are called:
   a. sea gas
   b. sea smoke
   c. sea mist
   d. sea ghosts
   e. sea vapor
7. El Niño seems to occur on a ______________ year cycle.
   a. 1 - 2
   b. 10 - 12
   c. 5 - 10
   d. 4 - 7
   e. 20 - 30
8. La Niña is associated with the following:
   a. unusually cold surface water in the eastern tropical Pacific
   b. unusually strong trade winds
   c. dry conditions over western South America
   d. wet conditions in the western Pacific basin
   e. all of the above
9. The jet stream can blow at speeds as great as _________ km/hr.
   a. 20
   b. 1000
   c. 300
   d. 50
   e. 100
10. Icebergs float with only about ______ percent of their mass above water.
   a. 12
   b. 5
   c. 25
   d. 18
   e. 30

Answer Key for 'Key Terms' and 'Test Your Understanding'

FILL IN THE BLANK

1. El Niño
2. Cancer
3. short
4. storm surge
5. pancakes
6. high, low
7. horse
8. rain shadow
9. nitrogen
10. heat budget

TRUE - FALSE
1.F 2.T 3.T 4.T 5.F 6.T 7.F 8.F 9.T 10.T

MULTIPLE CHOICE
1.b 2.d 3.e 4.c 5.a 6.b 7.d 8.e 9.c 10.a