Name ______________________________

Storm Systems

Purpose

By examining photographs of Earth, Mars, Venus, and Jupiter, you will recognize wind circulation patterns and the influence of **rotation** and the **Coriolis effect** on planetary atmospheres.

Materials

World map.

Introduction

Our lives are affected every day by the weather—on some days more than others! Being able to predict the weather is a convenience, but being able to predict severe weather is important to public safety. Furthermore, understanding the Earth's weather patterns is critical to agriculture, transportation, and the military. To gain insight into Earth's weather and circulation patterns, it is useful to examine the atmospheres of other planets, comparing them to each other and to Earth.

Atmospheric circulation is caused by differences in heating, primarily between the poles and equator. On an ideal non-rotating planet (Figure 8.1), warm air would rise over the equatorial regions, lowering the air pressure there. Air in each hemisphere would then circulate to the cool polar regions where it would sink, increasing air pressure there. To complete the cycle, the cold high-pressure air would travel at ground level back toward the equator. This simplified pattern of circulation is called a Hadley cell, named after the British scientist who first proposed the model. On a real planet, the pattern of atmospheric circulation is complicated by rotation, which breaks the circulation into several cells from pole to equator and results in an ever-changing pattern of turbulent swirling clouds, called **eddies.** Also, if a planet is tilted with respect to its orbit around the Sun, the latitude of maximum solar heating changes as the planet goes through its yearly cycle of seasons.

Air moves from regions of high pressure to regions of low pressure. The pressure difference, or gradient, is the driving force for atmospheric circulation. However, other effects prevent the direct motion of a given air mass from high to low pressure. Friction between the ground and the atmosphere modifies air motion, as does the presence of mountains or other topography. Furthermore, the Coriolis effect deflects air masses as they move. On a planet that rotates in the normal sense (toward the east), a parcel of air is deflected to the right of its direction of motion in the northern hemisphere and to the left in the southern hemisphere. Figure 8.2 shows this effect.

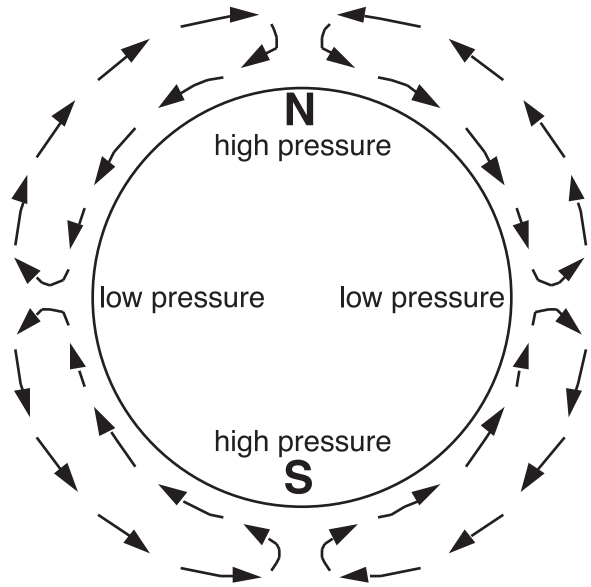

Figure 8.1. The idealized Hadley cell model of atmospheric circulation. Although unrealistically simplified, this pattern of airflow would develop on a planet if it were spinning very slowly and if the axis were at right angles to the orbital plane (that is, if there were no seasons). The Sun would always heat the planet most strongly at the equator. Air would rise along the equator and lower the pressure locally. Colder, dense air would sink at the poles, raising the air pressure there. This air would return toward the equator along the ground. Rapid planetary rotation breaks up this circulation pattern into several cells and produces turbulent eddies.

Cyclonic storms are the fundamental mechanism

EG-1998-03-109-HQ Activities in Planetary Geology for the Physical and Earth Sciences

for turbulent, inclement weather on Earth. These are huge, well-organized centers of low pressure which develop along the boundaries between air masses. As a cyclone intensifies, so does weather activity along the boundary, or **front.** In addition to its clouds, a storm front commonly brings with it precipitation, wind, and cooler temperatures.

The motion of air parcels on Earth generates such low pressure centers. Air parcels can approach low pressure cells from all directions. Because of the Coriolis deflection, a circulation of winds is set up around the low pressure centers (Figure 8.3). The result is a counterclockwise spiral of air into a low center in the northern hemisphere, and a clockwise spiral in the southern hemisphere.

Procedure and Questions

Examine Figure 8.4, using the world map to help identify the land masses that are visible.

1. Notice the well-defined spiral pattern of clouds southwest of the Baja peninsula, Mexico.

   a. Which way is this cloud pattern spiraling, clockwise or counterclockwise?

   b. Why?

2. Now examine the two cloud spirals over the southern Pacific Ocean.

   a. Which way are these clouds spiraling, clockwise or counterclockwise?

   b. Why?

3. Notice the long line of clouds stretching over the southern Pacific Ocean. What is this feature and what kind of weather is likely associated with it?

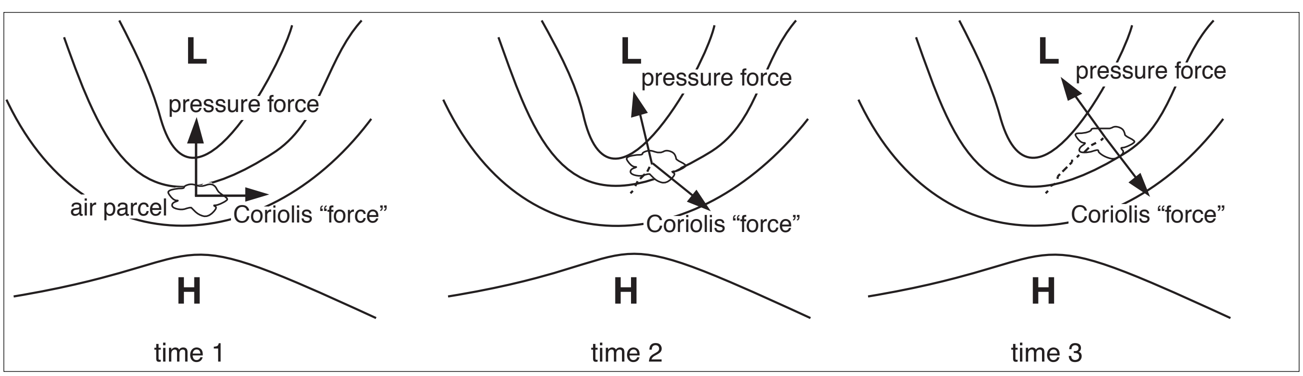

Figure 8.2. *As a small mass of air, called an air parcel, moves under the influence of a pressure gradient, its path is not a direct one from high to low pressure. The curved lines around the low pressure centers (L) are contours of equal pressure, or isobars. The low pressure center can be considered a "well" or sink for air, and the high pressure center (H) can be considered a "ridge" or source of air. If you were riding along an air parcel in the northern hemisphere, you would be deflected to the right of your direction of motion as the air parcel drifts from high pressure toward lower pressure. Thus, the final motion is nearly parallel to the isobars, rather than across them. In the southern hemisphere, the mirror image of the diagram is observed, with the Coriolis "force" causing air parcels to deflect toward their left.*

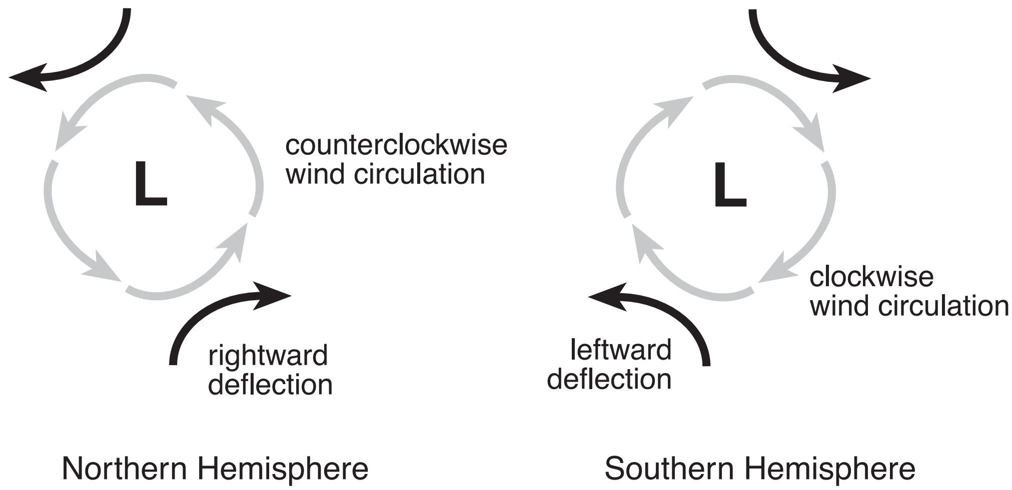

Figure 8.3. *A simplified illustration of how low pressure cells (cyclones) develop. Air parcels heading toward lows are deflected by the Coriolis effect to set up a counterclockwise circulation pattern in the northern hemisphere, and a clockwise pattern in the southern hemisphere.*

4. As Earth rotates from west to east, frictional drag pulls the atmosphere along more slowly in the same direction. Assuming that the storm system off of southern Chile will reach the coast by tomorrow, and noting that this photo was taken in September, determine a likely weather forecast (temperature, clouds, and precipitation) for the next 24 hours in each of the following locations:

   a. Indianapolis (40°N, 86°W)

   b. El Paso (32°N, 106°W)

   c. The Galápagos Islands (0°N, 91°W)

   d. Tierra del Fuego (54°S, 68°W)

   e. Buenos Aires (34°S, 58°W)

5. Will the air pressure become higher or lower in Bermuda during the next 24 hours? Explain.

6. Look at Figure 8.5, taken by a spacecraft in orbit over Mars. Like Earth, Mars rotates west to east.

   a. What do you think this cloud feature is?

   b. In what hemisphere is the feature? How do you know?

7. Examine the atmosphere of Venus as seen in Figure 8.6.

   a. Can you identify any obvious spiraling clouds that might be due to the Coriolis Effect?

   b. Compare the photos of Venus and Earth, and recall the simple Hadley cell circulation model of Figure 8.1. Does Venus appear to have a more simple or more complex pattern of atmospheric circulation than Earth?

   c. How does the circulation pattern support the proposition that Venus rotates slowly?

Jupiter is a gaseous planet, having no solid surface (but likely possessing a solid core). Although the planet is composed mostly of hydrogen and some helium, its visible clouds probably consist of ammonia (NH_4), ammonium hydrosulfide (NH_4HS), and water (H_2O). The Great Red Spot (GRS) is a great storm in the clouds of Jupiter.

8. Base your answers to the following questions on the Voyager photos of Jupiter shown in Figures 8.7 and 8.8.

   a. Does Jupiter rotate quickly or slowly? Justify your answer.

   b. Does the GRS lie in the northern or southern hemisphere of Jupiter?

   c. In which direction do winds around the GRS rotate?

   d. Is the GRS a Coriolis-induced storm? Support your answer.

9. The winds of Jupiter commonly blow in opposite directions in neighboring bands. That is, winds blow to the east in one band and to the west in the neighboring band. These opposing winds can act to create swirling eddies and storms. Draw a sketch of the GRS. Indicate with arrows the directions that winds along its northern and southern edges are blowing.

Sketch area

Figure 8.4. *Earth as seen from the Geostationary Operational Environmental Satellite, GOES-7. The picture was taken at 6 p.m. Greenwich Mean Time on September 25, 1994, soon after the start of northern hemisphere autumn. The north pole is toward the top.*

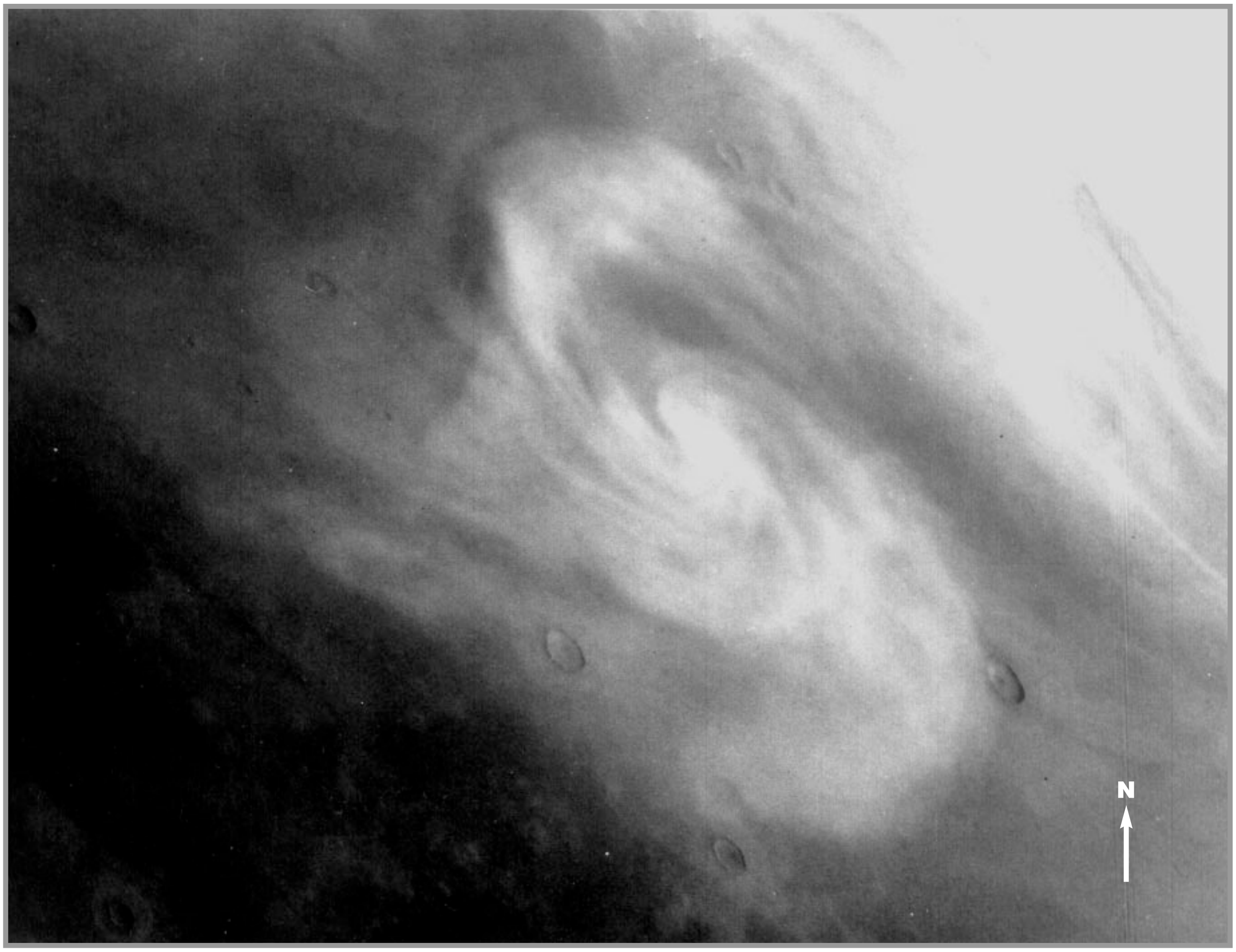

Figure 8.5. *Viking Orbiter image 78A42, showing a water frost cloud pattern over the surface of Mars. North is toward the top.*

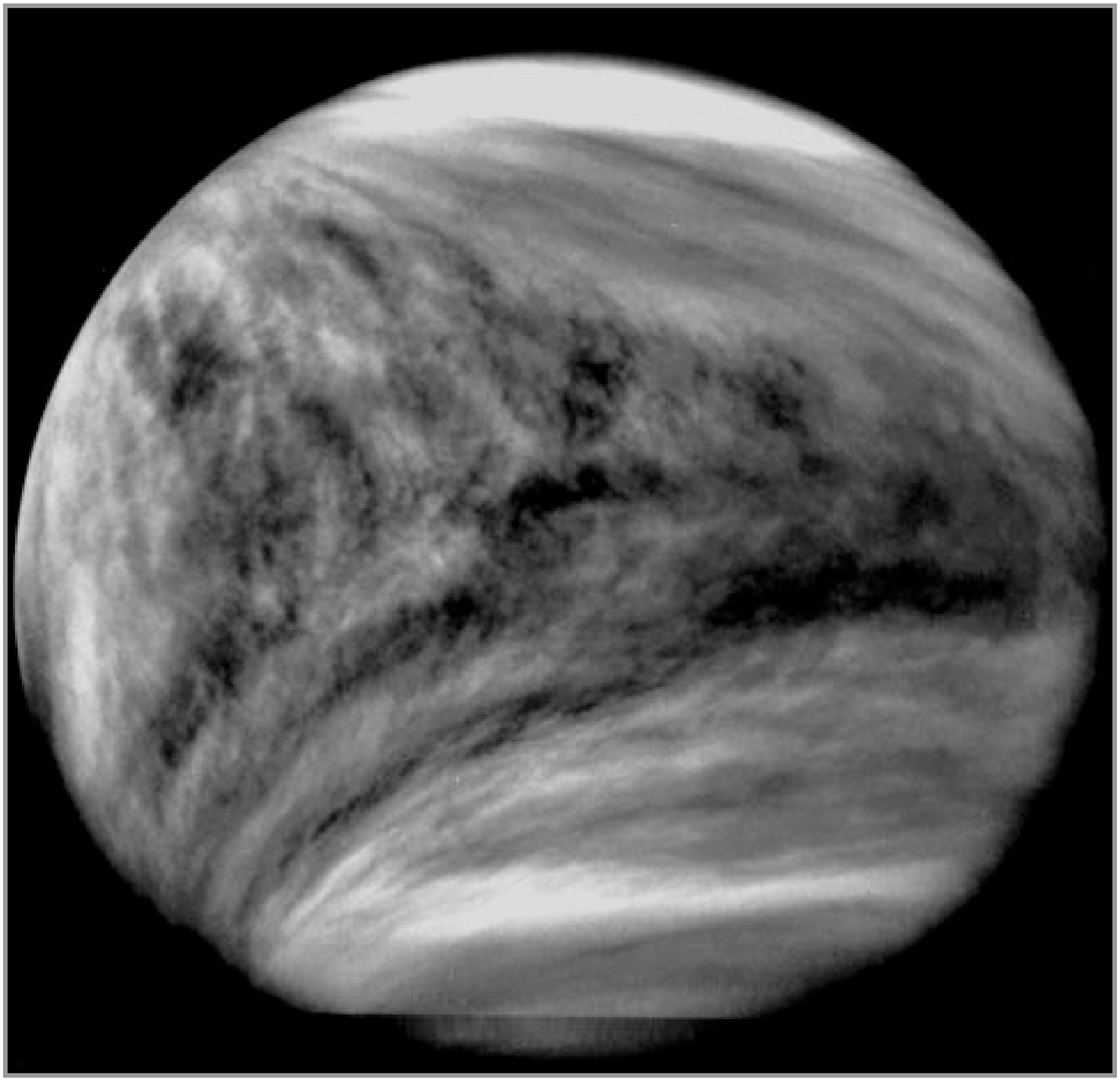

Figure 8.6. Patterns of cloud motion on Venus are revealed in this ultraviolet image, taken by the Pioneer Venus orbiter in 1979. Venus is unusual in that the planet and its atmosphere rotate from east to west. The surface of Venus cannot be seen through the thick clouds. North is toward the top; the horizontal black line is missing data. Pioneer Venus image 0202-79-046-0830, courtesy of Larry Travis.

Figure 8.7. *Jupiter as seen by the Voyager 1 spacecraft from a distance of 54 million km (34 million miles), as it approached the planet on January 9, 1979. The Great Red Spot (GRS) is a large vortex just below center. North is toward the top.*

Figure 8.8. *Closeup of the Great Red Spot (GRS) seen by Voyager 1 on February 25, 1979 from a distance of 9.2 million km (5.7 million miles). The spot is about 25,000 km (16,000 miles) across, and could hold two Earths side-by-side. White ovals and turbulent, swirling eddies are also visible.*