

Lesson II: How does the general circulation of the atmosphere describe earth's climate zones?

Overview:

What causes the general circulation of the atmosphere? How does the general circulation of the atmosphere describe earth's climate zones? This exercise will help explain the mechanisms behind the general circulation of the atmosphere and provide a better understanding of earth's climate zones.

Necessary Materials:

- Internet access (for obtaining maps etc.)
- Printers for making hard copies
- Practice wind sheet
- Map of the world
- A cross section along a longitude line (North Pole to South Pole)
- Four colored pencils (**red**, **green**, **blue**, and **black**)
- Analysis sheet

Theory:

The three cell convection (Hadley cell, Ferrel cell, and Polar cell) model of earth's general circulation divides the earth into different climate zones. A climate zone is a region of the earth's surface that shares a climatic classification. The climate zones that succeed each other from the pole to the equator are polar, temperate, subtropical, and tropical or equatorial climate.

The **polar** climate zone (also frost climate or snow climate) is located in the polar latitudes where conditions are too harsh to support vegetation. The **temperate** climate zone describes the middle latitudes between the polar climate and subtropical climate zones, and is characterized by a lack of temperature and precipitation extremes. The **subtropical** climate zone is located between the tropical climate and temperate climate zones and is described by warm temperatures and little precipitation. The **tropical** or **equatorial** climate zone is located in the tropics and is characterized by a climate typical of the equatorial and tropical regions.

The **Hadley cell** is thermally driven along the equator where the sun shines directly throughout the year. As you know, when air is heated, it expands becoming less dense and more buoyant. Since pressure in the atmosphere decreases with height, the rising warm bubble of air expands adiabatically, doing work to push away surrounding air and therefore cooling as it rises and leaving low pressure behind. The **Hadley cell** consists of equator-ward motion near the surface and pole-ward motion aloft between about 30° and the equator in both hemispheres. The **Ferrel cell** has pole-ward movement near the surface and equator-ward movement aloft. The **Ferrel cell** has sinking motion in the same latitudes as the **Hadley cell** (~30°), but has rising motion at subpolar latitudes (~60°) in both hemispheres. The **Polar cell** is characterized by pole-ward motion aloft and equator-ward motion near the surface. Rising motion occurs at subpolar latitudes (~60°) and sinking motion occurs at the poles in both hemispheres. Using the Hadley,

Ferrel and Polar cells, we can examine air motion and subdivide the globe into the appropriate climate zones.

Doing the experiment:

Part I: Wind force diagrams

- Using the **wind** force balance diagram practice sheet and colored pencils, apply the principles learned from the previous lesson and draw the resulting **wind** vectors. Assume the diagram is at the surface and remember that the Coriolis “force” affects the wind direction differently in the Northern and Southern Hemispheres.

Part II: Prevailing wind and surface pressure bands

- Using the world map and colored pencils, mark the locations of the ITCZ, subtropical high, subpolar low and polar high (low (L) and high (H)) pressure bands beginning with the ITCZ. Knowledge of the pressure bands should be presented prior to this experiment.
- Applying the principles learned from the previous lesson and using the sheet from part I as a guide, draw the resulting **wind** vectors in **black**.

Part III: Cross section along a line of longitude

- This cross section is from the North Pole to the South Pole along a longitude line.
- Using your map from part II as a guide, label high and low pressure at the surface and aloft (surface low pressure has upper level high pressure and surface high pressure has upper level low pressure). When labeling pressure aloft, remember that the height of the tropopause is maximized at the equator (~17km) and decreases towards the poles (~8km) in both hemispheres.
- Starting at the ITCZ, draw and label the Hadley, Ferrel, and Polar cell.
- If you are having trouble with rising and sinking motion associated with low and high pressure at the *surface*, use the right hand rule.
- For the right hand rule, curl your right hand fingers following the direction of flow around high or low pressure. If your thumb points up, you have vertical motion (low pressure), and if your thumb points down, you have sinking motion (high pressure).
- For the upper levels, low pressure convergence forces air towards the surface, and high-pressure divergence forces air away from the surface.
- Once you are satisfied with your work, proceed to the analysis sheet.

Summary:

Clearly, an understanding of the general circulation of the atmosphere is essential for determining earth’s climate zones. After completing this lesson, students should have a good feel for how the rainforests stay green and why the deserts are located where they are, having drawn

it out for themselves. It is important to remember that a discussion of the general circulation of the atmosphere prior to this lesson is necessary.

For More Information:

CMMAP, the Center for Multi-Scale Modeling of Atmospheric Processes:
<http://cmmmap.colostate.edu>

Little Shop of Physics: <http://littleshop.physics.colostate.edu>

Practice wind sheet

L



H



NH

Equator



L



SH



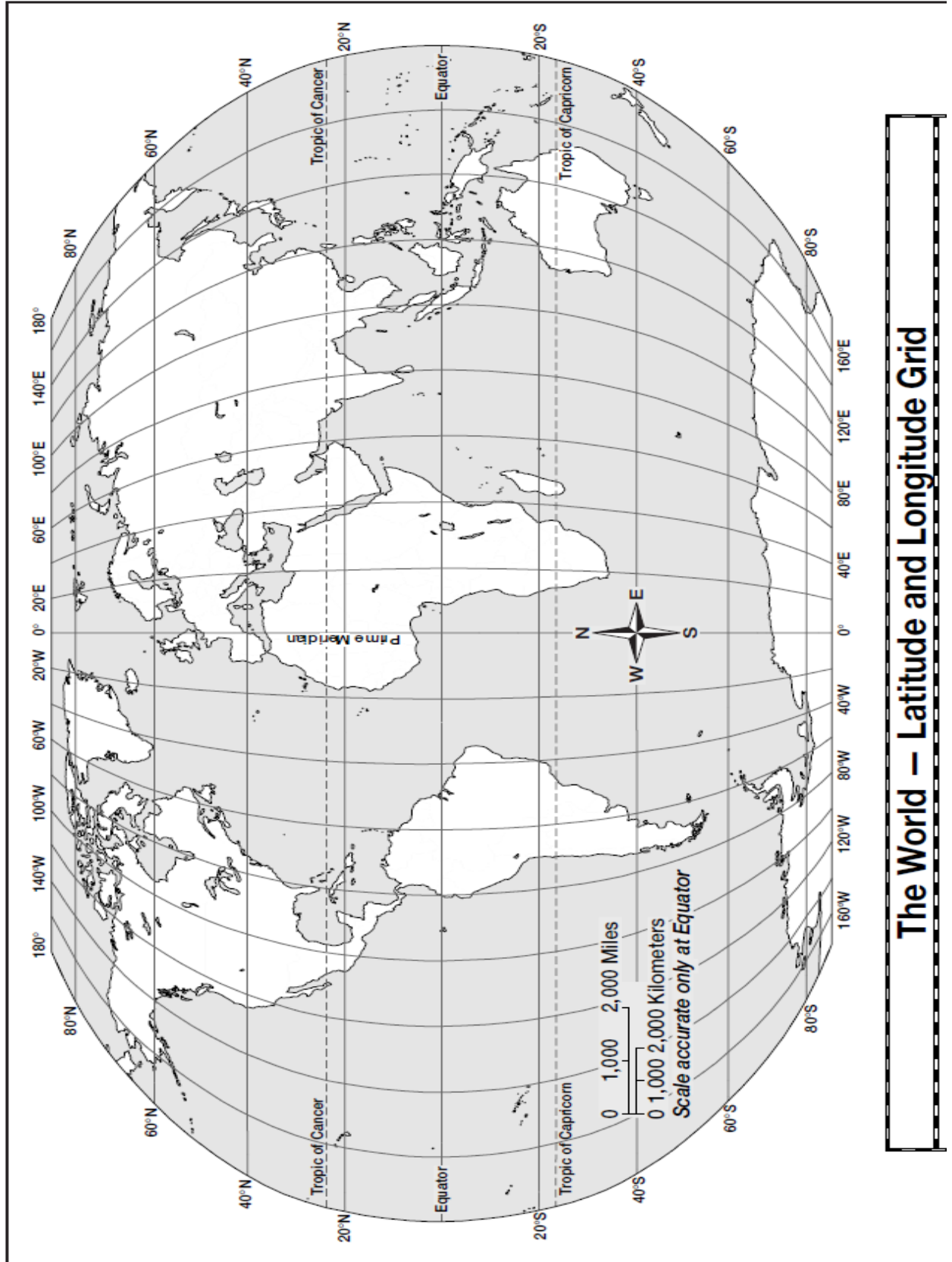
H



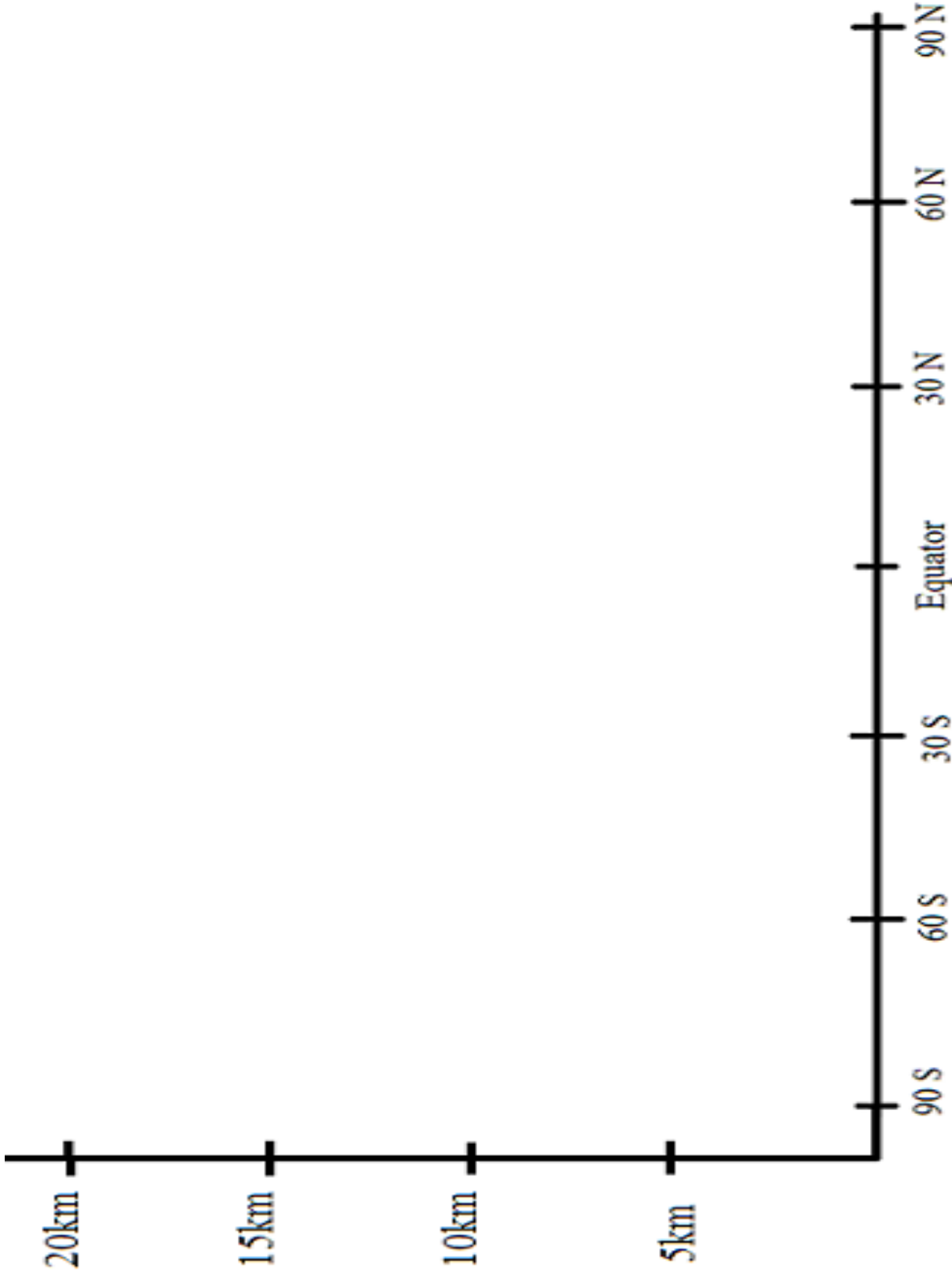
L

The World — Latitude and Longitude Grid

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The World — Latitude and Longitude Grid



Analysis Sheet

1. What type of climate is expected where the near surface winds diverge? Why?
2. What type of climate is expected where the near surface winds converge? Why?
3. Match each location to its corresponding general circulation cell.

- A. Hadley Cell
- B. Ferrel Cell
- C. Polar Cell

Caracas, Venezuela $\sim(10.5^{\circ}\text{N}, 67^{\circ}\text{W})$:

Colombo, Sri Lanka $\sim(7^{\circ}\text{N}, 80^{\circ}\text{E})$:

Timbuktu, Mali $\sim(16.8^{\circ}\text{N}, 3^{\circ}\text{W})$:

Svalbard, Norway $\sim(66^{\circ}\text{N}, 14^{\circ}\text{E})$:

Fort Collins, Colorado $\sim(40.5^{\circ}\text{N}, 105^{\circ}\text{W})$:

4. Describe the general climatic conditions and prevailing winds for the following locations:

Caracas, Venezuela:

Colombo, Sri Lanka:

Timbuktu, Mali:

Svalbard, Norway:

Fort Collins, Colorado:

5. What does the seasonal motion of the ITCZ mean for January and July climates in India and the Amazon?

SOLUTIONS

The pressure gradient force makes the air move.

The Coriolis force rotates the wind.

Friction tries to slow the wind down.

Wind is what results.

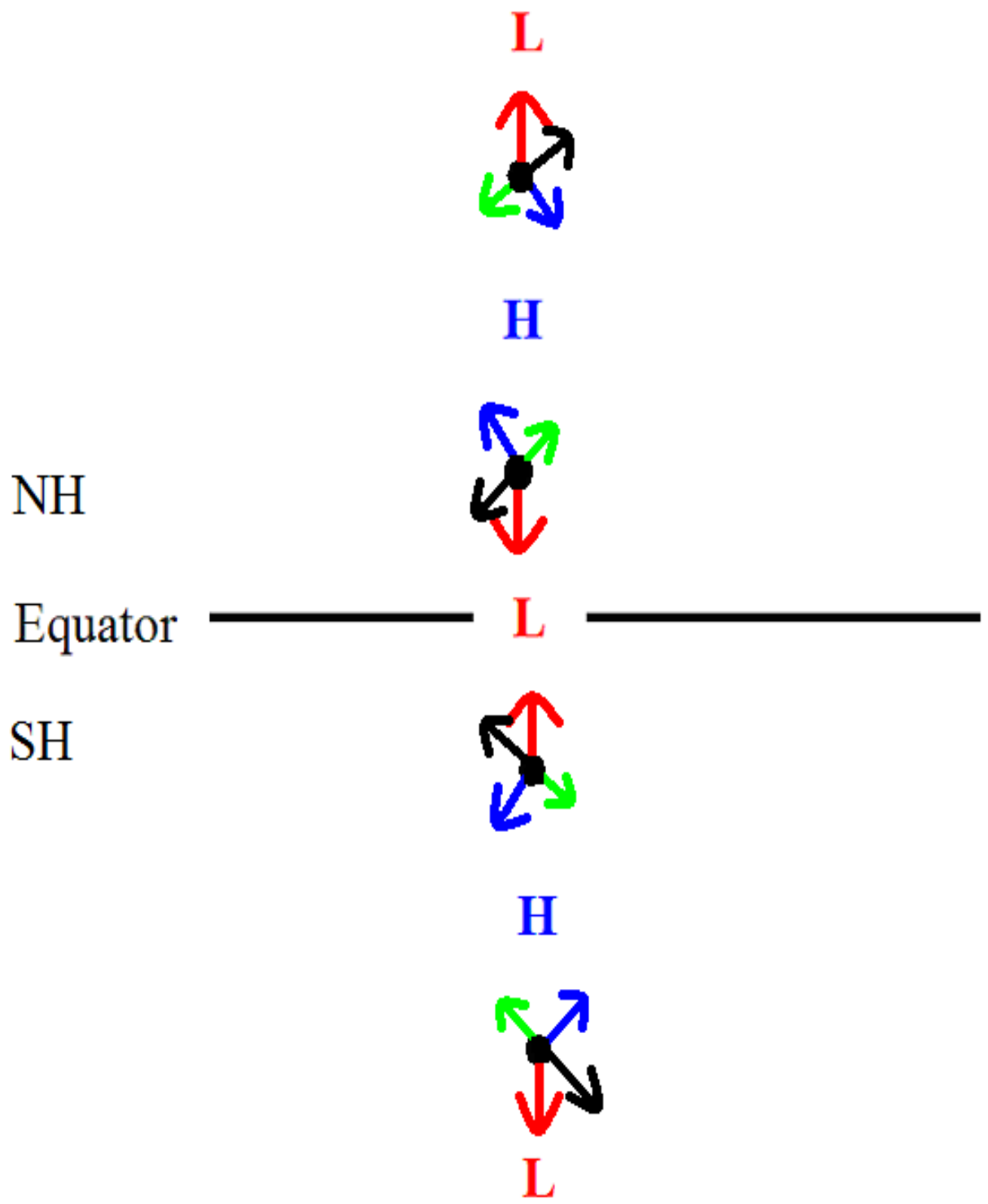
Surface and upper level low pressure:

L

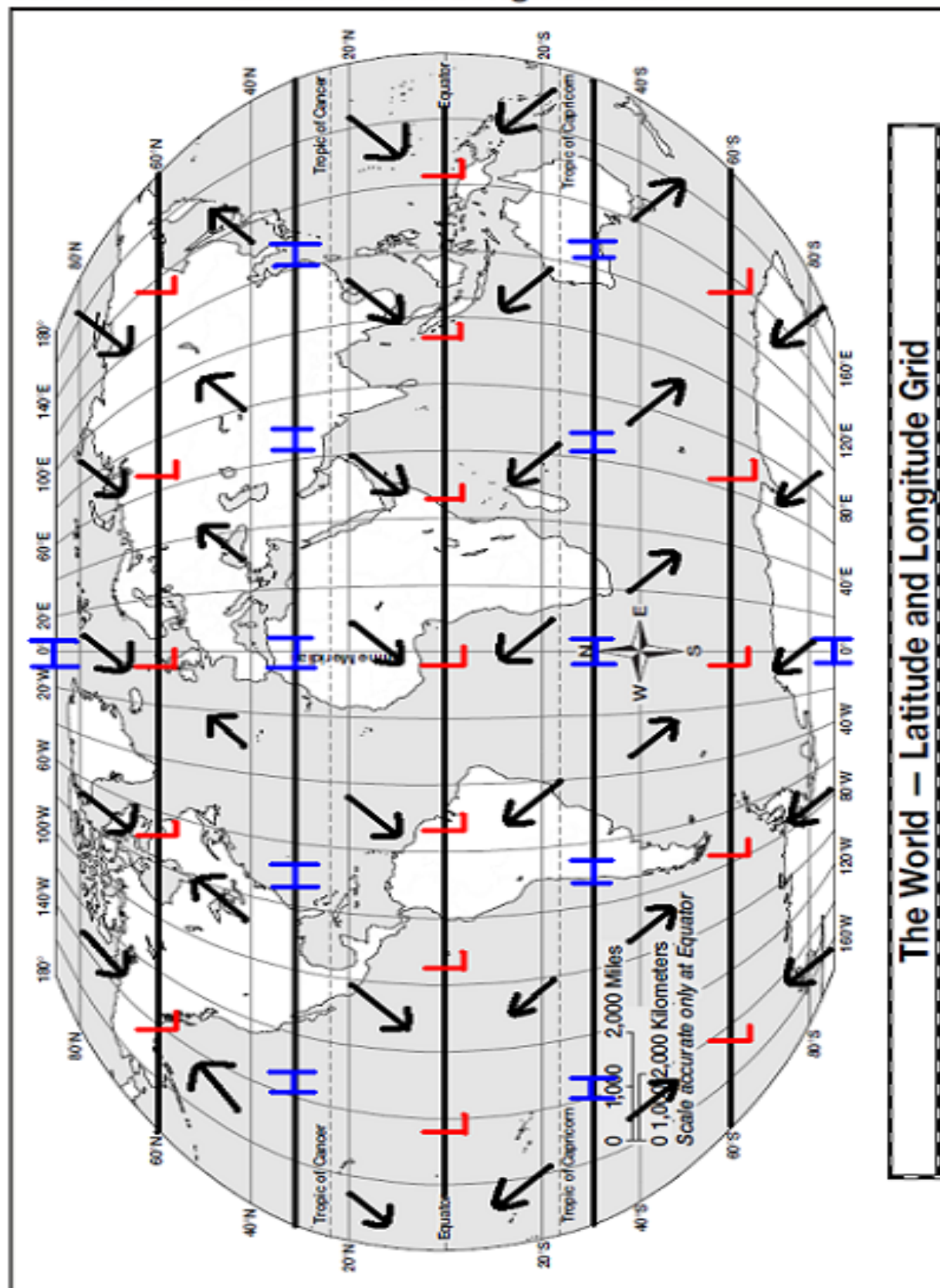
Surface and upper level high pressure:

H

Practice wind sheet



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