Clarification of Selected Misconceptions in Physical Geography

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A number of student misconceptions commonly surface in introductory physical geography classes. They often seem to have a life of their own and persist from one generation to the next. The repetition of and a reluctance to discard such erroneous notions result in their perpetuation. In addition to locational misplacements, misconceptions are also common in the oceanographic, atmospheric, and geomorphic realms. Appropriate correction and explanation is offered, where possible, to clarify problem situations. Exposure of these myths can serve as a useful pedagogical tool.
Key words: *world grid, sea level, Coriolis effect, greenhouse effect, pressure gradient, humidity, lightning, magma, volcano, mass wasting.*

Misconceptions are common to academic disciplines and often seem to have a life of their own. In some cases, people are proud to believe in ideas generally viewed as false (e.g., the Flat Earth Society). Typically, however, misconceptions provide quick and superficially reasonable explanations. if misconceptions are learned early on, a stable but incorrect view of the world may result. Students will then interpret subsequent knowledge in light of past incorrect experiences, episodes, and images. This mode of organizing knowledge, known within the educational psychology literature as the "constructivist approach," begins at an early age and has the potential to perpetuate misconceptions (Science Education in Michigan Schools Project 1991).

Long-held misconceptions and inaccuracies have been discussed previously by others regarding groundwater (Meyer 1987), rainfall genesis (Bar 1989), and even the evolution of scientific thought (Kuhn 1962). In this paper, a number of misconceptions relating to location, and to the earth's hydrosphere, atmosphere; and lithosphere are discussed with appropriate correction and explanation. This list is selectively drawn from ahalfcentury of teaching undergraduate physical geography at various locations in the United States. While of potential value to educators at all levels, it is intended principally for elementary and secondary level teachers who may have limited training and background in geography.

Locational Misconceptions

When students are asked to locate continents on a map with only latitude and longitude grid lines, several interesting errors repeatedly occur. One involves the general latitudinal location of Africa. Commonly perceived as being a southern hemisphere continent similar in latitudinal range to South America, Africa actually extends northward to about the same latitude as Norfolk, Virginia, with approximately two-thirds of its area positioned north of the equator (Figure 1). Likewise, Europe is typically perceived as being farther south than it is. The Scandinavian countries actually have a latitudinal range similar to Alaska, whereas most of mainland Europe lies predominately to the east of Canada rather than to the east of the 48 contiguous states of the United States. Situated east of the Atlantic states are Portugal, the Mediterranean countries, and northern Africa. How many realize, for example, that the Mediterranean city of Venice, Italy, actually has a slightly more northerly latitude than Minneapolis, Minnesota (Figure 1)? Various reasons undoubtedly contribute to these erroneous mental maps. Tversky (1981) found that people tend to simplify their cognitive maps by aligning them with one of the four cardinal directions. Hence, the United States, minus Alaska, is perceived as being due west of Europe rather than somewhat to the south as well. Europe's relatively mild, marine-influenced climate is also a contributing factor. It seems more logical for American students to misplace Europe closer to the equator because of its climatic similarity to the 48 contiguous states. A common longitudinal mental misplacement involves the relative positions of North and South America. Frequently envisioned as due south of North America, South America actually lies well to the east of such a position (Figure 1). In fact, the westernmost part of South America actually lies directly south of peninsular Florida. The use of the cardinal terms "north" and "south" in the proper names of the continents probably contributes to this situation. The reader is referred to Muller (1985) for additional discussion of problems associated with mental maps.

Oceanographic Misconceptions

Ocean Names and Comparative Sizes

A number of misconceptions persist in varying degrees involving the nomenclature and comparative sizes and shapes of the world's oceans. Frequently mistaken are the identities of the water bodies included in the ancient mariners' expression "Seven Seas." These included the North Atlantic, South Atlantic, North Pacific, South Pacific, Indian, Arctic, and Antarctic. No doubt due to the use of the term "seas" as opposed to "oceans," a popular contemporary notion mistakenly holds that the Seven Seas expression must have referred to certain important ocean subunits such as the Mediterranean Sea, Caribbean Sea, etc. Today, the world ocean is subdivided into four interconnected parts, recognized by proper name. They

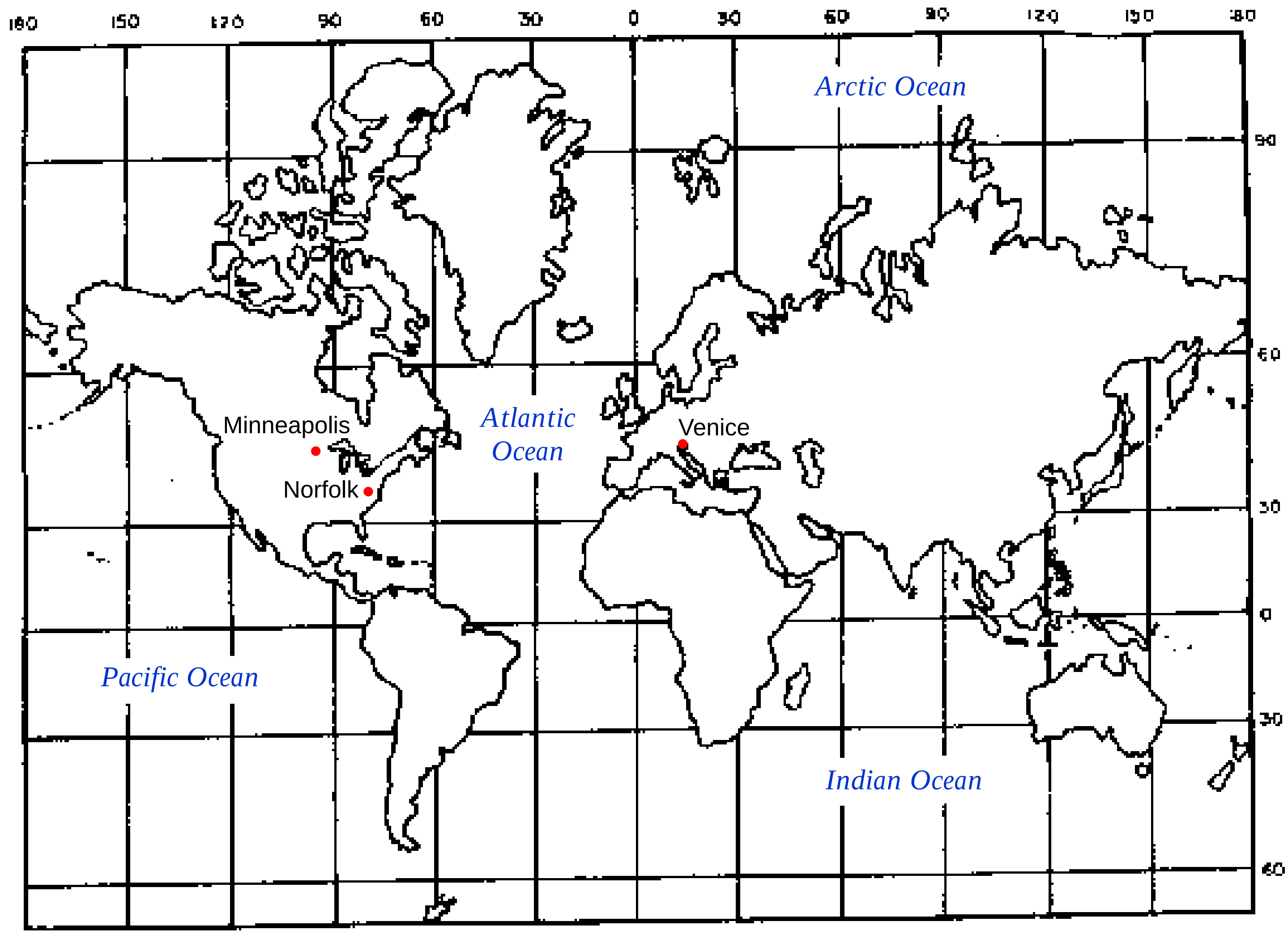

Figure 1. World map.

include the Pacific, Atlantic, Indian, and Arctic oceans (the ocean name Antarctic, as seen in many older atlases and other references, has fallen out of common use). Interestingly, this list of four may soon shrink to three. A growing tendency of many oceanographers is to regard the Arctic not as a separate ocean at all, but rather as a "sea," forming a northern extension of the Atlantic (Ross 1988).

Another misconception involves the relative sizes and shapes of the oceans, which typically are greatly distorted in students' minds. while most are aware that the Pacific Ocean is the largest and the Arctic the smallest, they usually fail to comprehend the magnitude of size difference between them. The Pacific accounts for about one half of the entire world ocean's area, whereas the Arctic totals only slightly more than 3 percent. Also, the Pacific is nearly twice as large as the Atlantic. Two factors appear to promote these mental distortions, both of which result from the common use of certain map projections which distort and divide the world in waysunfavorable to the accurate perception of the oceans. First, most world maps used in the western hemisphere longitudinally bisect the Pacific and thus portray that ocean in two parts, typically on the map's right and left margins (Figure 1). This practice distorts the Pacific Ocean's image as a single entity, making it difficult to ascertain its true size and shape relative to other water bodies and continents. How many people realize, for example, that the Pacific Ocean's area is significantly larger than all of the earth's land masses combined? Second, several commonly used map projections, including the Mercator, greatly distort the area of high latitudes (Figure 1). In the far north, for example, the small Arctic Ocean stretches from one side of the map to the other and seems to extend indefinitely to the north, resulting in a greatly distorted picture of its relative small size.

Sea Level

Another ocean-related misconception involves the supposed constancy of sea level. Students are usually aware of certain temporal sea level changes, for example, its past lowering during Pleistocene glaciafion and its proposed rising by future global warming. The general notion, however, is that the ocean surface has no actual relief of its own, discounting short-lived changes due to waves, tides, surges, etc. In actuality, the ocean surface possesses "hills" as well as "depressions" with a maximum variation of approximately eight feet. This is the direct result of the circular pattern of surface currents or gyres that produce areas of water convergence (high areas) and divergence (low areas). Water is generally pulled away from coastal and equatorial areas and piles up in subtropical ocean areas of both the northern and southern hemispheres. The highest point or "hill" is found well off Japan's Pacific coast while the lowest surface levels are those surrounding Antarctica and in the equatorial zone (Gross 1990).

Atmospheric Misconceptions

Coriolis Effect

There is a commonly held notion that as water drains from bathtubs and washbasins, it circles counterclockwise in the northern hemisphere and clockwise in the southern hemisphere. This is thought to be due to the Coriolis effect (the apparent deflection of freely moving objects to the right in the northern hemisphere and to the left in the southern due to the earth's rotation). As water drainage occurs, however, the time is so short, the distance covered so small, and the speed so slow that the Coriolis effect is too weak to be significant. Other factors such as the acceleration of draining water, the shape of the sink or tub, and even the action of a person stepping out of a bathtub, will typically overwhelm any Coriolis influence (McKnight 1990; Anrens 1991).

Greenhouse Effect

Much of the solar energy that reaches the earth system passes through the atmosphere and is absorbed at the earth's surface. The earth then re-radiates energy. Because the earth is cooler than the sun, its energy is emitted at a longer average wavelength than that of the sun (Wien's Law). Most of the earth's emitted energy is absorbed by atmospheric water vapor, water droplets, carbon dioxide, and dust. It is suggested that this process should be called the "atmospheric effect"; however, it is often inappropriately referred to as the "greenhouse effect." This misnomer suggests that a greenhouse is warmed by the same process as the atmosphere, the implication being that greenhouse glass allows short-wavelength radiation to pass through but absorbs outgoing long-wavelength radiation. This was proven to be essentially false by R. W. Wood in 1909 (Fleagle and Businger 1980). Wood built two equal-sized model greenhouses, one constructed of glass and the other of rock salt, the latter being transparent to both short and long wave radiation. when placed in the sun, both models reached about the same internal temperature level. This indicated that the greenhouse's higher temperature is not primarily a result of absorption of outgoing long-wave radiation by glass. Rather, the primary reason a greenhouse or a car with closed windows is warmer than the external air is due to the reduction of mixing. When the sun heats the ground and the ground in turn heats the air, this warmed air may rise many thousands of feet. In a greenhouse or a car the mixing is limited by the walls and the roof and thus the heat is confined to a relatively small volume. This reduction in mixing is four to five times as important as the absorption of long-wave radiation by glass in explaining the temperature excesses found in a greenhouse (Fleagle and Businger 1980).

Air Flow and the Pressure Gradient

One common notion holds that atmospheric pressure is the weight of the atmosphere pressing down upon the earth's surface due to gravity. Because the precise pressure exerted at any given atmospheric level is due largely to the weight of the overlying air, this idea should not necessarily be viewed as incorrect. The problem arises, however, when one mistakenly concludes that this force acts only in a downward direction. In reality, the major pressure gradient force in the atmosphere constantly acts in an upward direction, opposing and being closely balanced by the earth's gravitational pull. Atmospheric pressure is better thought of as the force per unit area exerted on a plane surface as determined by the number and speed of air molecules and atoms which strike it. This force is, in fact, equal in all directions at any point in the atmosphere. Without this understanding, it is difficult to comprehend the atmosphere's very strong upward pressure gradient.

Another notion holds that air in motion always obeys the pressure gradient force and flows in a direction from high to low pressure. while surface winds do flow essentially from high to low pressure areas, high altitude winds may not. when considering vertical air flow (air currents), movement in a downward direction always violates the pressure gradient by flowing from low to high pressure. In this case the downward force of gravity predominates and is simply stronger than the upward pressure gradient force. In reality, the direction of movement of an air parcel is a function of all of the forces acting upon it, not just the pressure gradient. Even though pressure difference is the driving force causing air to move, gravitational attraction, Coriolis effect, centrifugal force, and friction (including viscosity) cannot be ignored.

Air Weight and Humidity

There is a general view that on days of high humidity, the air is heavy due to the water vapor content. This comes, in part, because people are prone to equate the properties of the more familiar liquid water with those of gaseous water vapor. Liquid water is obviously denser than dry air. Therefore it would logically follow that the higher the humidity the greater the density. Also, humid air seems to feel heavier or more oppressive than dry air. This perception is false because the water molecule's molecular weight (18), is substantially lower (lighter) than that of dry air (average 29). Consequently, the more humid a parcel of air is the lighter or less dense it is. As a result, contrary to popular belief, a golf ball or baseball traveling through more humid air will actually travel farther and faster than it would if hit with the same amount of force through less humid air.

Freezing of Water

It is often thought that water freezes at 32^0F; this, however, is frequently not the case. Liquid water at a temperature below f32^0F is referred to as supercooled. Surface waters of large rivers and lakes may supercool up to 5^0-9^0F before the onset of freezing (Johnson 1954). As atmospheric cloud droplets are cooled, few turn to ice above 14^0F. Between

14^0F and -4^0F an increasing minority of the droplets freeze, and between -4^0F and -22^0F most of the remaining droplets freeze. Below -22^0F only droplets which are very small and consist of very pure water will remain unfrozen. It is generally assumed that no water droplets can exist at temperatures below -40^0F (Mcllveen 1986). On the other hand, while supercooled water is common, it is impossible under normal atmospheric pressure conditions to superheat when melting ice. Thus melting occurs at a given temperature rather than through a range of temperatures. Consequently the temperature of 32^0F more accurately represents the melting temperature of ice than it does the freezing temperature of liquid water.

Lightning

There are numerous misconceptions concerning lightning that seem to persist regardless of the number of times that they have been proven incorrect. Three of the most common will be considered. First, there is the fallacy that lightning does not strike the same place twice. In reality, since lightning tends to frequently strike the highest points within a given area, such locations are likely to be struck repeatedly. According to Ulman (1971, 166), "Much of what is known about lightning today has been discovered precisely because lightning does strike the same structure over and over again." In addition, what appears to be a single stroke of lightning is usually composed of 2-27 individual strokes. The apparent flickering of lightning is due to the time between these individual strokes. Thus, in a very technical sense, it would be extremely rare for a place to be struck only once.

A second misconception suggests that conditions are safe with respect to lightning when a storm has passed or is still too distant to produce local lightning. Unpublished studies and photographic evidence suggest, however, that lighting can often occur outside of precipitation areas or even outside of clouds (Mongil 1979). An example of this occurred on June 15, 1978, when a little league game in Ames, Iowa, was delayed because of a thunderstorm. The game was resumed shortly after the storm had passed. A "bolt from the blue" then struck, injuring five youngsters (Mongil 1979).

A third misconception involves the difference between heat lightning and "normal" lightning. As opposed to a sharply defined stroke, heat lightning is a diffuse flash which illuminates large portions of the evening sky. There is neither an accompanying thunderclap nor a discrete stroke of lightning. Dissimilarities between these two phenomena lead to the erroneous assumption that heat lightning is genetically distinct from normal lightning strokes. whether or not heat lightning is observed depends upon one's location with respect to the stroke of lightning. whereas lightning can be seen from great distances, thunder is not heard accompanying heat lightning because the effective distance for hearing thunder is only about ten miles. This is due to storm convection which preferentially refracts sound waves vertically rather than horizontally (Ahrens 1991). Individual strokes are typically invisible during heat lightning because they are often obscured by clouds and the earth's curvature.

Geomorphic Misconceptions

Origin of Magma

A common misconception involving the earth's layers and processes that has been noted among many of our students is that molten earth material, magma, originates in the earth's very hot core. The study of earthquake or seismic wave behavior strongly suggests a liquid and, therefore, a very hot outer core. Without further study it is tempting to conclude that such material can, at various times and places, work its way to the surface and erupt as lava from such features as volcanoes and fissure flows. In reality, virtually all magmas are thought to originate in the upper portion of the mantle and crust (Larson and Birkland 1982). Such melts appear to be generated primarily by frictional heat accompanying fault movements associated with plate tectonics.

Volcano Morphology

There is a misconception that cataclysmic volcanic eruptions always produce large, steep sided cones. These cone-shaped mountains frequently exceed elevations of 10,000 feet, often producing awe-inspiring vistas. Under proper conditions, however, an equally violent eruption (the so-called phreato-plinian type) may result in a relatively subdued landscape. Two conditions are necessary for this type of eruption to occur. First, large volumes of groundwater are incorporated into silica-rich magma from surrounding rock. Second, a decrease in pressure causes liquid solutions in magma to change to the gaseous state. If the resulting volume expansion cannot be relieved either through vents or directly into the atmosphere, then a potentially catastrophic explosion will occur. The force of the explosion blows dust and ash completely clear of the vent, preventing a cone from forming. These particles are carried several miles downwind; preexisting topography is buried and a fairly level plateau is produced. The only indication of this tremendous eruption is a broad, shallow caldera marking the blast's center. Examples of this type of eruption include the Taupo Volcanic Zone of New Zealand, Krakatau in Indonesia (now inundated), and Yellowstone National Park in Wyoming (Cas and Wright 1987).

Upslope Water Flow

It is generally assumed that water flows only downslope. There are cases, however, where this is incorrect. Normally, the direction of groundwater flow responds to a pressure gradient such that groundwater flows from hills to valleys. In this sense, groundwater mirrors the movement of surficial waters, namely, downhill. In karst terrains, a different flow regime occurs. Here, water responds to a subterranean fissure system rather than a unified, regional groundwater table. As proof of this phenomenon, wells driven into limestone frequently reveal adjacent dry and water-filled cavities. This suggests that fissures within a karst network can act independently of one another. In some cases, water pressure may build preferentially in selected fissures because of a more efficient tributary system. Such increases in hydrostatic head may even cause water to flow uphill until the pressure gradient is equalized.

A regular water table can only be established when the subterranean rock is so frequently honeycombed with fissures that groundwater levels between individual fissures can become equalized (white 1988). Uphill water movement can also occur within confined aquifers associated with artesian systems and beneath glaciers where subglacial tunnels build up sufficient hydrostatic pressure to force meltwater across ridges (Sugden and John 1988).

Slope Angle and Mass Wasting

It is generally believed that the slippage of massive rock units is limited to relatively steep slopes (300). But if plastic materials such as halite, anhydrite, or calcite occur along bedding planes, then slope stability is substantially reduced. Under the tremendous weight of overlying strata, these plastic materials become a viscous slurry allowing slippage to occur on low-angle slopes. Mbeit slow, large rock units in geologically stable regions have traveled tens of kilometers on 10 to 20 slopes (Selby 1985). Low-angle slope movement is also observable at the surface in the form of soil creep as evidenced by tilted fence posts and utility poles.

Discussion

In the day-to-day teaching of physical geography, a number of misconceptions seem to resurface again and again. They span the gamut from the lithosphere to the hydrosphere and the atmosphere and include incorrect notions about location. The list of common misconceptions presented here is not intended to be exhaustive. This paper presents a few such misconceptions to an audience of predominantly teachers for purposes of greater awareness in an effort to ultimately overcome such mistaken notions and misunderstandings. What are the prospects for overcoming misconceptions? Eiser (1980) suggests that correcting along-held belief system introduces a degree of uncertainty or cognitive dissonance, an undesirable state that an individual normally avoids if p05sible or convenient (Eiser 1980). Accordingly, a certain resistance ("anchoring bias") to revising these misconceptions may surface in students. Success in dispelling myths will come first from their exposure, and second by providing clear and rational correction. Specific strategies to achieve this goal might include the appropriate use of physical models (Mattingly 1987, Lightman and Sadler 1988) and map exercises. With new and correct explanation, students can begin organizing a logically correct view of the world.

Regardless of the ultimate fate of these myths, their exposure can be a useful pedagogical tool. A misconception plausible enough to be widely accepted in vernacular thought can be employed to challenge students, both to question the existence of these notions and to understand why they are inaccurate. This paper invites a sharing of other misconceptions.

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