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RESEARCH ARTICLE

THE DIRECTION OF MOVEMENT OF A PERSON OR AN OBJECT MOVING TOWARDS THE HORIZON ON THE EARTH'S SURFACE WOULD ALWAYS BE PERCEIVED AS UPWARDS IRRESPECTIVE OF THE LOCATION AND DIRECTION OF MOVEMENT

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ABSTRACT

The Earth is an oblate spheroid rather than a perfect sphere due to the equatorial bulge because of Earth's rotation around its axis. The Earth's terrain varies greatly but on a global scale the deviations in local topography are small compared to the Earth's radius. If we consider the Earth as a smooth sphere, as it appears from the space, ignoring the ups and downs of the terrain, what would the direction of movement of a person or an object moving towards the horizon on the Earth's surface be – upwards, downwards or both?

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INTRODUCTION

The 'spherical' Earth

The Earth is spherical in shape. It is an oblate spheroid rather than a perfect sphere due to the equatorial bulge because of Earth's rotation around its axis. Therefore, the north and south polar areas are a bit flattened. The diameter at the equator is approximately 42.6 kilometers longer than the pole-to-pole diameter. The polar radius of approximately 6356.8 kilometers is approximately 0.33% shorter than the equator radius that is approximately 6378.1 kilometers (Dicks, 1970, Heiskanen, 1962, Burša and Fialová, 1993, Milbert and Smith, 2007, "Earth Fact Sheet". NASA, 2015). The Earth's terrain varies greatly and about 70.8% of the surface is covered by water (361.132 million km^2), with much of the continental shelf below sea level (Pidwirny, 2006, "CIA – The World Factbook", 2012). On a global scale the deviations in local topography are small compared with the Earth's radius. The maximum downward deviation at the Mariana Trench (10,911 meters below local sea level) is only approximately 0.17% and the maximum upward deviation at the Mount Everest (8,848 meters above local sea level) is only approximately 0.14% of the Earth's radius.

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The low point of the land surface of −418 meters at the Dead Sea is only a deviation of approximately 0.006% (Sverdrup *et al*., 1942). Therefore, if the Earth were shrunk to the size of a cue ball, some areas of the Earth such as mountain ranges and oceanic trenches would feel like small imperfections only (Billiards Digest, 2013).

The surface of the Earth is convex everywhere if we ignore the small deviations in local topography. It is not apparent to us as during day to day life we do not look that far towards the horizon. When we walk, run or drive a car the length of the area we could see is usually short because of buildings, trees etc obstructing our view. Therefore, we perceive the Earth's surface as "flat" in general except the "uphill" or "downhill" areas and the up or down movements during travelling short distances depending on the terrain. The convexity of the Earth's surface would, however, be apparent if we stand on the sea beach and look at the horizon over the sea. The horizon will appear higher than the level of us (the sea beach). If we consider the Earth as a smooth sphere, as it appears over the oceans and seas, and from the space, ignoring the ups and downs of the terrain (the maximum deviation on the land is only approximately 0.14% of the Earth's radius) what would our direction of movements on the Earth's surface towards the horizon be – upwards, downwards or both?

THE DIRECTION OF MOVEMENT OF A PERSON OR AN OBJECT MOVING TOWARDS THE HORIZON ON THE 'SPHERICAL' EARTH'S SURFACE

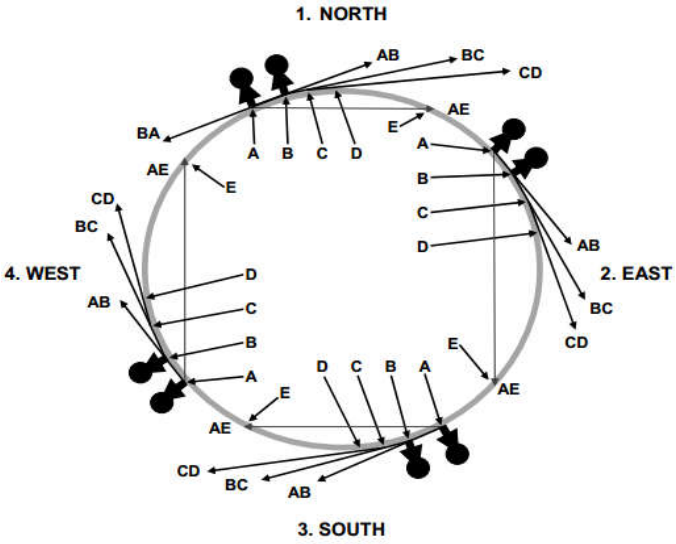
MATERIALS AND METHODS

Review of the literature was undertaken regarding the shape and dimensions of the Earth, its terrain, gravity etc. A figure (Fig 1) of the spherical (flattened at the poles) Earth with the direction of movements of a person at different locations (latitudes) and moving towards different latitudes e.g. south to north and north to south was drawn. In Figure 1 the sign of a person shows a person standing at 90^0 to the Earth's surface at various locations (latitudes). The dark arrows show the starting and destination points and direction of movements from the starting points towards the horizons. The light arrows show the direction of movements from the starting points towards the imaginary point E indicating the direction of movements if the Earth was flat. The sign of a person has been used only for points A and B to avoid obscuring other features near points C and D. Figure 2 was similarly drawn to show some of the features not included in Figure 1.

The person starts at point A and moves to point B, and subsequently to points C and D. Point B is the horizon at point A, point C is the horizon at point B and point D is the horizon at point C. Point E is an imaginary point indicating the direction of movements if the Earth was flat, and the direction of movements would have followed the lines between the starting points and E. If the Earth was flat, the destination points B, C, D would have been on the lines AE, BE, CE respectively (Fig 1 and Fig 2). If the direction of movement is upwards then the lines connecting the starting points and the horizons e.g. AB, BC, CD would be above (anticlockwise shift) the lines AE, BE, CE respectively forming a positIve angle. If the direction of movement is downwards then the lines connecting the starting points and the horizons e.g. AB, BC, CD would be below (clockwise shift) the lines AE, BE, CE respectively forming a negatIve angle. Lines BE and CE have not been included in Figure 1 to avoid overlapping of the lines and complexity. These are shown in Figure 2. Point E for starting points of B and C would be further along the Earth's surface and would not be at the same point as it is for starting point A (Fig 2).

RESULTS

Near the North pole (1. North in Fig 1), the horizons e.g. points B, C and D from the starting points A, B and C respectively appear above the levels of the respective starting points. To the person the horizon would appear at a higher level than the starting point where he/she stands and the area beyond the horizon would not be visible. Therefore, the person starting at point A would move upwards up to point B. The upward movement from point A to point B is shown by the line AB drawn between point A and point B direted towards point B, and the angle of the upward movement is shown by the angle between the lines AB and AE that is positive with AB above AE (Fig 1). If the direction of movement was downwards the line AB would have been below line AE forming a negative angle, but that is not the case. Similarly, lines BC and CD would be above lines BE and CE respectively forming a positive angle (Fig 2).



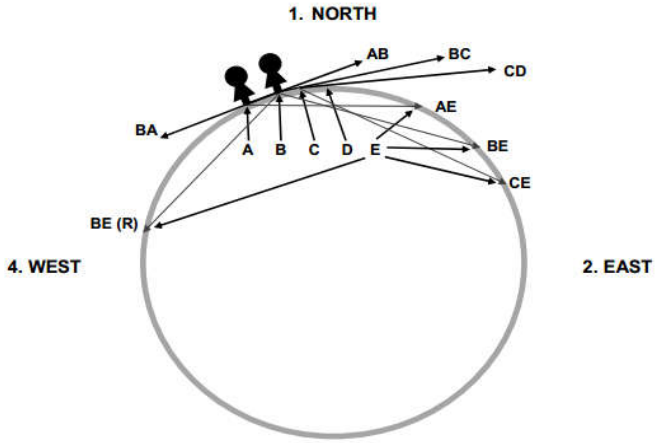
= a person (the object) standing at 90^0 to the Earth's surface at various latitudes

A, B, C, D = starting and destination points (horizons) at various latitudes and in different directions

AE = direction of movement if the Earth was flat

↑from A, B, C = direction of movement of the person (the object) between the starting points and the horizons (lines AB, BC, CD, BA)

FIG. 1. Schematic diagram showing that on the surface of the "spherical" Earth the direction of movement of a moving object between the starting point and the horizon is always perceived as upwards in relation to the starting point irrespective of the locations and directions of movement



= a person (the object) standing at 90^0 to the Earth's surface

A, B, C, D = starting and destination points (horizons)

AE, BE, CE, BE (R) = direction of movement if the Earth was flat

↑from A, B, C = direction of movement of the person (the object) between the starting points and the horizons (lines AB, BC, CD, BA)

The angles between AB & AE, BC & BE, CD & CE and BA & BE (R) are positive indicating upward movement

FIG. 2. Schematic diagram showing that on the surface of the "spherical" Earth the direction of movement of a moving object between the starting point and the horizon is always perceived as upwards in relation to the starting point irrespective of the locations and direction of movement

In Figure1, the direction of movements between point A and point B, point B and point C etc might appear downwards in

areas in the north-east and near the south pole. But in fact these are in an upward direction in relation to the starting points based on the perception of the person that he/she is standing vertically on the top of the world. Therefore, the direction of movements would be similar to that shown around the North pole. It would be evident from the relationship between the lines AB and AE. In fact, for all locations, the line AB would be above the line AE forming a positive angle that indicates upward movement from point A to point B. Similarly, lines BC and CD would always be above lines BE and CE respectively forming a positive angle (Fig 2).

If the person reverses his/her direction by 180^0 at point B and comes back to point A (the new horizon now), the direction of movement in relation to the starting point B would still be upwards as shown by line BA direted towards point A in the area near the North Pole (Fig 1 and Fig 2). The line BA would be above the line BE (R) forming a positive angle that indicates upward movement from point B to point A (Fig 2). This has not been included for other areas, but the results would be the same due to the Earth's spherical shape.

When the person reaches point B and wants to go to point C (the horizon at point B when going towards point C), it would appear at a higher level than the starting point B where he/she stands. This would happen between point C and D and in fact, anywhere on the surface of the Earth the horizon would appear higher than the point where one stands due to the spherical shape of the Earth as the lines BC and CD would always be above the lines BE and CE respectively forming a positive angle that indicates an upward movement.

DISCUSSION

The person standing at 90^0 to the Earth's surface at various locations would appear from the space as standing vertically in different directions. The perception of the person, at any locations, however, would be that he/she is standing vertically on the top of the world (1. North in Figure 1). A person standing vertically on the North pole would consider another person standing vertically on the South pole as upside down and vice versa. Therefore, one's direction of movement on the Earth's surface that may also be called outwards would be perceived by that person as upwards.

Figure 1 shows movements towards different latitudes e.g. north to south and south to north directions. The results would be the same for movements towards different longitudes e.g. east to west and west to east directions, and combination of different latitudes and longitudes e.g. north-east to south-west, south-west to north-east, north-west to south-east, south-east to north-west directions etc due to the Earth's spherical shape. Anywhere on the Earth's surface the lines AB, BC and CD would always be above the lines AE, BE and CE respectively forming a positive angle that indicates an upward movement.

Therefore, the direction of movement between the starting point and the horizon, of a person moving in any directions at any locations on the surface of the Earth, would always be perceived by that person as upwards in relation to the starting point. The upward direction of movement would be more pronounced while moving near or towards the equator compared to the poles due to the equator bulge (Fig 1). The other interesting finding is that after reaching the horizon if the person reverses his/her direction of movement by 180^0 and comes back to the same starting point where he/she originally started (the horizon now) the direction of movement would still be perceived by him/her as upwards, not downwards.

Competing interests

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