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Not My Fault: The Turkey – Humans don't make the world go round but can change how it spins

Lori Dengler for the Times-Standard
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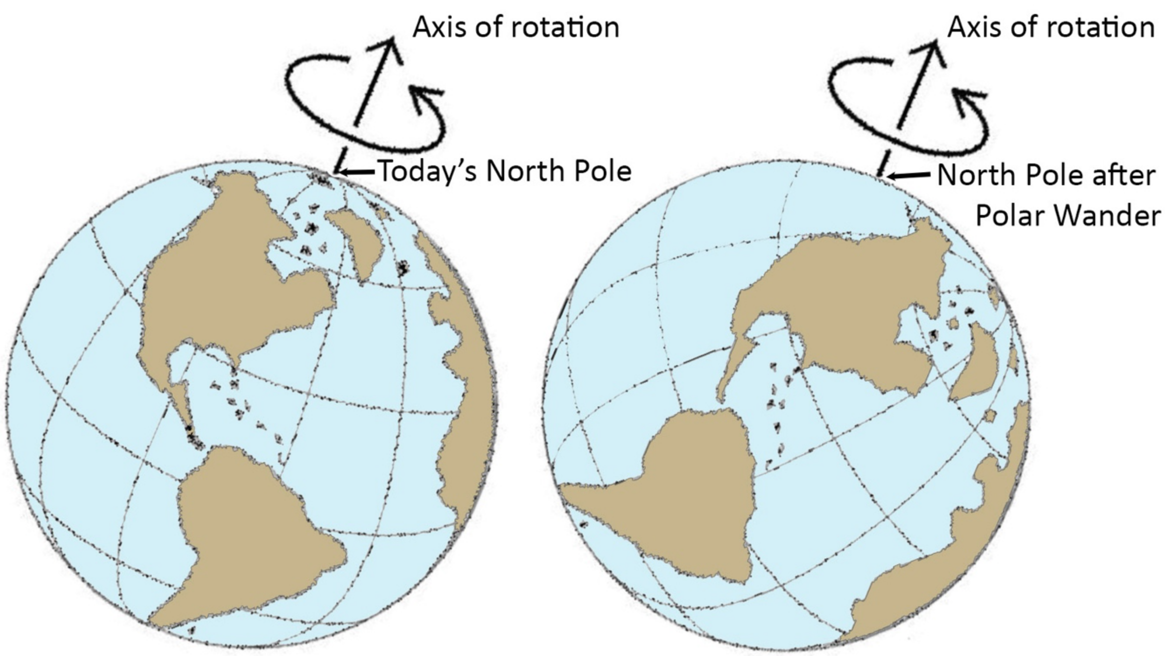

Today's spin axis passes through central Antarctica and the Arctic Ocean. True polar wander means that the earth would shift relative to the axis and the north and south poles would change relative to surface features. Actual measured shifts in pole position over the past century are far smaller than shown in this cartoon.

We take it for granted that the world goes round, counting on the daily rotation of day to night and seasonal changes from summer to winter. As a geophysics major, I took a course in geodesy, the study of the earth's shape and gravity. Rotation was central and turned out to be far more complicated than I had thought, changing in speed, direction of the spin axis in space, and orientation of the earth's surface relative to that axis.

Speed, or the length of the day, is the easiest to visualize. The day is 24 hours long, right? Not quite. You know about adding a day for leap year and may have heard about leap seconds, added now and then so that clocks on earth based on the solar day are in sync with the more precise International Atomic Time.

Leap seconds are always added because the long-term trend is slowing, and the day is getting longer. Back in the Devonian about 400 million years ago there were 420 days in the year, and each day only 21 hours long. The cause is the gravitational tug of the moon and the sun, producing friction in shallow seas and viscous drag on the solid earth as it deforms in the twice-daily dance of the tides. Other processes affect the rotation rate as well including plate motion and complex coupling between the earth's core and mantle (see Not My Fault 2/4/23).

Where the earth's spin axis points in space changes as well. Like a top spinning on the floor, the rotation axis is at an angle to the plane made by the earth's rotation around the sun. Right now, the axis points to the star Polaris in the Little Dipper (Ursa Minor) constellation. But, like the spinning top, that axis changes. 12,000 years from now our North Star will be Vega in the constellation Lyra, at an angle in the night sky nearly 40 degrees away from Polaris.

It's the third type of change that has my attention today, movement of the poles relative to the surface of the earth. Classroom globes show the north pole in the middle of the Arctic Ocean and the south pole in Antarctica. But it hasn't always been this way and will be different in the future.

We call this polar wander, and two things contribute. The first and easiest to visualize is plate motion. The surface of the earth constantly changes as plates move relative to one another. The Arctic Ocean only took shape about 65 million years ago. Antarctica has not always hovered over the south pole. 400 million years ago it was further north with a temperate climate and lush vegetation.

The second reason requires more imagination to visualize. Imagine a perfectly round, uniform spinning sphere. A giant fly lands on it. Suddenly there is more mass where the fly has landed. The body of the sphere will immediately adjust its position so that the rotation axis is perpendicular to the fly. No matter where the fly walks, it will find itself on the equator. We call this true polar wander.

The earth is not a uniform sphere, so the fly analogy does not perfectly apply. But rotation is affected by the shape of the earth and will respond to changes in how mass is distributed. Many processes contribute including melting glaciers and seasonal movement of weather from north to south and back again. Changes can occur over millions of years as plate motion rearranges continents and oceans, or in an instant when great earthquakes suddenly move large masses of rock.

In the late 18th century, Sir Isaac Newton predicted that the earth could move or wobble relative to its poles. A century later, astronomical observatories began compiling nightly measurements of the north pole's position, confirming what Newton had predicted. The earth's spin axis moves or wobbles by as much as 30 feet over a 14-month period.

Measurements of the pole position today are far more accurate. Modelers can detect the signal of melting glaciers and the rebounding of the earth's surface as the glacial load disappears. Even the slow movement of plates can be seen. Last month a paper in Geophysical Research Letters suggested something even more surprising. How people use and redistribute water also affects the location of the poles.

The research team led by Ki-Weon Seo of the Seoul National University argue that pumping groundwater and moving it elsewhere has caused the north pole to shift nearly three feet between 1993 and 2010. To make this assertion, the group compared the astronomical pole positions to estimates of global groundwater extraction. They ran a number of models varying different scenarios of groundwater changes.

The amount of groundwater extracted for human consumption and agriculture each year is staggering. U.S consumption is about 27 trillion gallons a year. Seo's team estimated that the global extraction of groundwater was 2150 gigatons over the 27-year study period. Most of that water ended up in the ocean, contributing about a quarter of an inch to sea level rise over that period.

The study concluded that they could only replicate the astronomically measured pole movement by including the full 2150 gigatons of groundwater extraction. Midlatitude regions had the biggest impact, and the two largest contributors were western North America and northwestern India.

What are the potential long-term impacts? The groundwater-caused pole motion is small, less than two inches per year and smaller than contributions to wobble from other sources. Climate change is dominated by human-caused release of greenhouse gasses and a few feet of polar movement is likely to have little impact. But redistributing groundwater into the ocean is a measurable contribution to sea level rise and one that we can ill afford.

In the past decade we've learned that one consequence of human activity, the pumping of drilling waste fluids into deep well, increases earthquake risk. Now sadly with wastewater extraction, we add the redistribution of groundwater to the list of human-caused global consequences.

More about the Seo et al. study at https://news.agu.org/press-release/weve-pumped-so-much-groundwater-that-weve-nudged-the-earths-spin

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