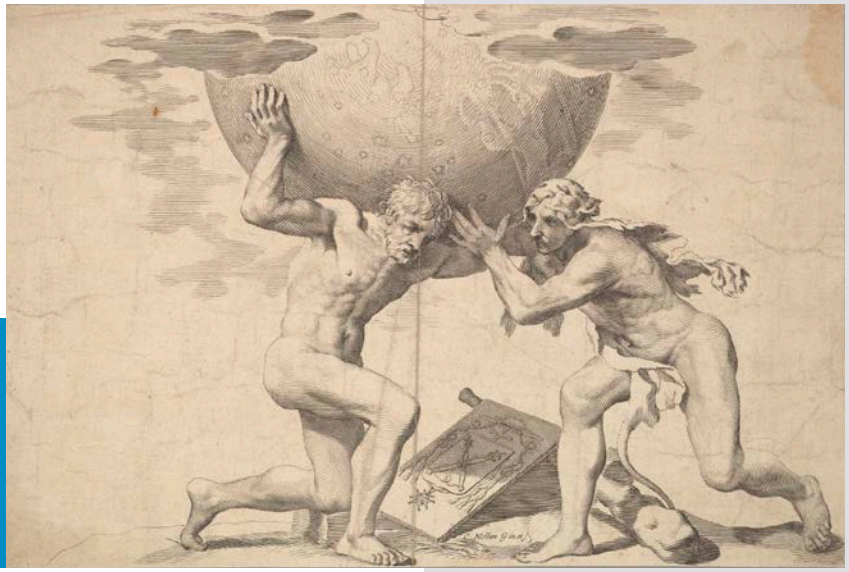
EarthDate

We Moved the North Pole



An engraving from the seventeenth century of Hercules assisting Atlas to carry Earth, by Claude Mellan (1598–1688), from the Metropolitan Museum of Art. The human activity of groundwater withdrawal shifted Earth's axis from 1993 to 2010.

Credit: Claude Mellan, public domain, via Wikimedia Commons

Water is heavy. When we move enough of it, it can change the tilt of Earth's axis.

It's that axial tilt that creates our seasons. And the tilt is always changing, due to changes in Earth's gravity.

Natural phenomena like earthquakes and volcanoes can redistribute the weight of continents, affecting Earth's gravity. But so can the movement of water.

Researchers recognized that water melting out of glaciers and ice sheets into the ocean had redistributed the weight of that water from the colder latitudes to the equator, where seawater accumulates in a bulge around Earth.

When they calculated the resulting gravitational changes, their numbers didn't add up. Until they also factored in the weight of the *groundwater* humans had extracted.

We use groundwater mainly for irrigation and in city water systems, which discharge into rivers that eventually lead to the sea. This moves groundwater from where it's concentrated underground to soils and oceans.

Across the globe, humans have pulled more than two trillion tons of water from aquifers over two decades. And, the scientists realized, weight redistribution from groundwater alone had changed the tilt of Earth's axis, causing the North Pole to move three more feet!

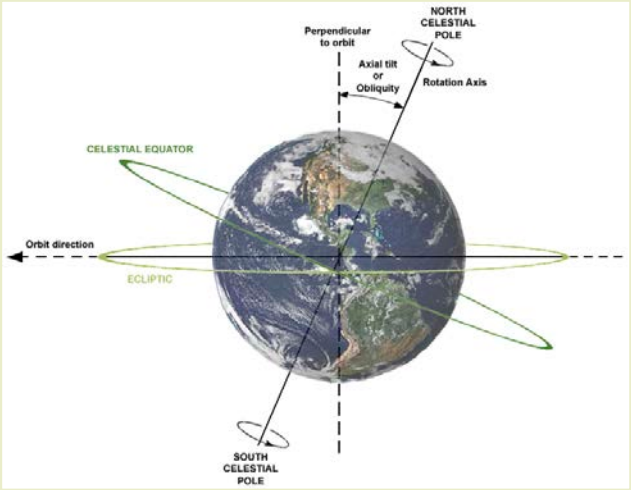
They plan to use this new understanding to look for other connections between Earth's water and gravity, and how *droughts* might also have altered Earth's axial tilt.

Bureau of Economic Geology

Background: We Moved the North Pole

Synopsis: Human depletion of groundwater has shifted the global distribution of Earth's water to the point that it has had a measurable effect on the location of the North Pole. In addition to typical natural impacts, researchers have shown that this human activity added 31.5 inches (80 cm) of eastward shift to the larger annual migration of Earth's rotational axis from 1993 to 2010. It is amazing to imagine that humans can alter planetary dynamics.

- The Earth has a normal tilt, known as obliquity, that is angled at approximately 23.5 degrees. The Earth spins at a rate of 1,000 miles per hour (1,690 kilometers per hour) around this tilted rotational axis. This tilt is responsible for the changing seasons. (ED-193 Winter Sun Close Encounter).
  - Summer and Winter: When the Northern Hemisphere is tilted toward the Sun, it experiences summer, while the Southern Hemisphere has winter.
  - Spring and Autumn: These occur when the tilt is neither toward nor away from the Sun, leading to more equal day and night lengths.
  - The tilt also affects climate patterns, influencing temperature and weather around the globe.



The celestial equator and the celestial poles are perpendicular to one another. This tilted axis causes seasonal changes due to the amount of sunlight in the Northern and Southern Hemispheres.

Credit: I, Dennis Nilsson, CC BY 3.0, via Wikimedia Commons

- Recent studies revealed that Earth's axis has shifted by approximately 31.5 inches (80 centimeters) since the early 1990s due to groundwater extraction.
  - The study relied on data from the Gravity Recovery and Climate Experiment (GRACE) satellites, which measure Earth's gravitational field (ED-022 Measuring Gravity from Space).
  - By analyzing changes in gravity, scientists were able to track the redistribution of mass caused by groundwater pumping.
  - Water that is pumped from the subsurface for human use is redistributed to a wider area through runoff, evaporation, or via pipeline and relocated to other regions. Ultimately, extracted water makes its way into the ocean where it tends to add to Earth's bulging midsection near the equator.
  - The axis shift caused by groundwater extraction is smaller in magnitude than natural phenomena like the melting of polar ice and large earthquakes, however it is still significant and unprecedented for human activity to cause such a shift.
  - A previous study published in 2016 provided a model that showed the influence of thawing icebergs and the subsequent redistribution of the water mass affected the rotational pole. However, results didn't match the observations and data until pumped-out groundwater was added into the model.
  - Although small, these changes can occur when large masses shift location inside a planet and on its surface. Ki-Weon Seo, a geophysicist at Seoul National University and publisher of the study said, "Every mass moving around on the surface of the Earth can change the rotation axis."

References: We Moved the North Pole

Pole Drift Confirms Groundwater as Significant to Sea Level Rise I GRL
Human Groundwater Pumping Changes Earth's Tilt I Space.com
Rampant Groundwater Pumping Changed Earth's Tilt I Scientific American
Earth Has Tilted 31.5 Inches. That Shouldn't Happen. I Popular Mechanics
Why Do We Have Seasons? I NOAA

Contributors: Lynn Kistler, Juli Hennings, Harry Lynch

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Fact Sheet:
Episode **ED 409**

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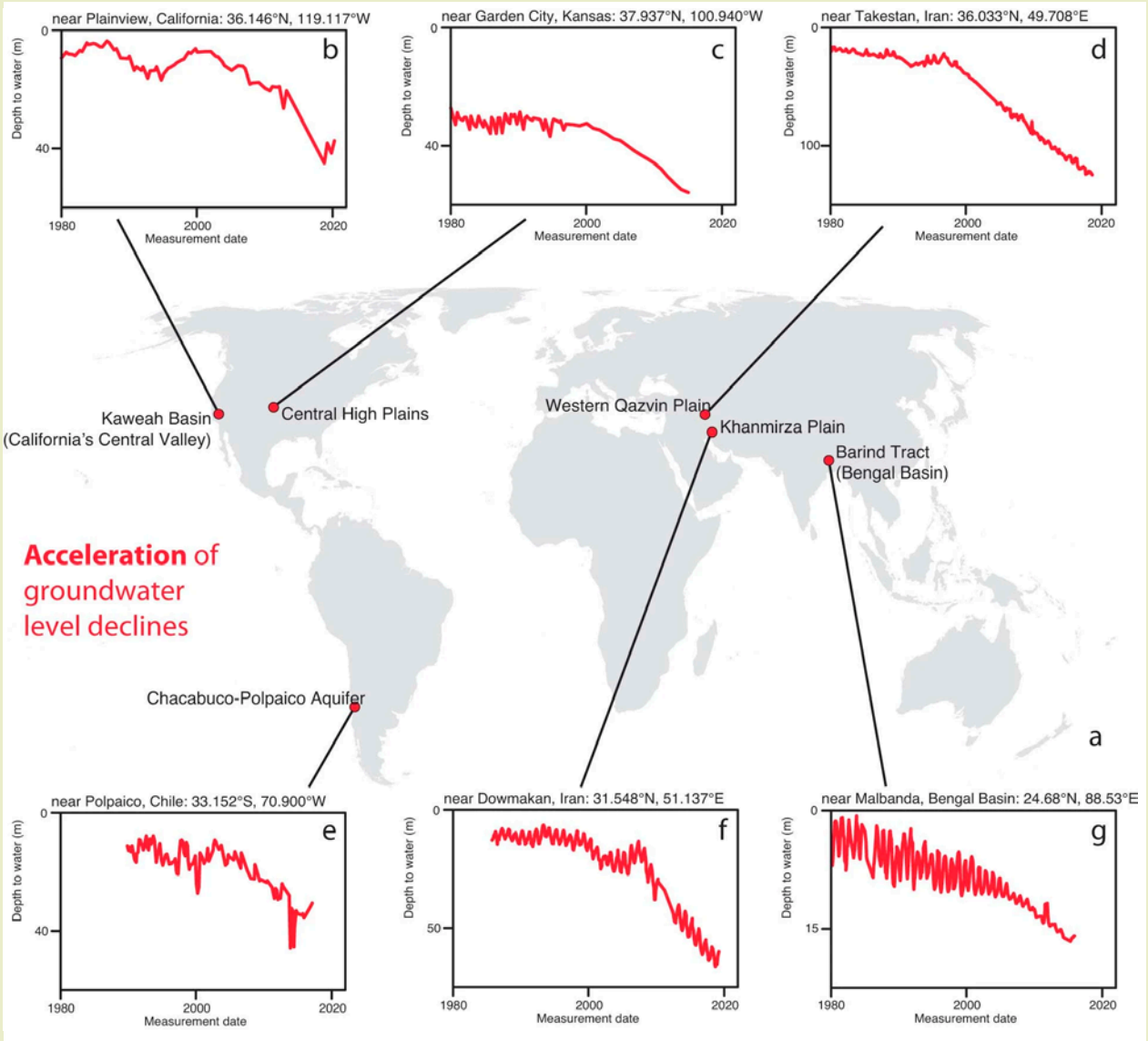

These graphs show the decreases in the depth of groundwater due to the accelerated rate of water withdrawals over a 40-year period from 1980 to 2020.

Credit: Authors of the study: Scott Jasechko, Hansjörg Seybold, Debra Perrone, Ying Fan, Mohammad Shamsudduha, Richard G. Taylor, Othman Fallatah & James W. Kirchner, CC BY 4.0, via Wikimedia Commons

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- Groundwater removal occurs when water is pumped from underground reservoirs or aquifers. The research directly linked the shift in Earth's axis to human activities, particularly large-scale groundwater extraction for agriculture and urban use.
  - Aquifers contain over 1000 times as much water as all of the surface rivers and lakes in the world.
  - Over the 17 years of the study, more than 2150 gigatons of groundwater was extracted from the Earth. That amount of water would raise the ocean level by almost one-quarter of an inch (six millimeters.)
  - Large groundwater withdrawals occurred in the western United States and northwestern India. In the United States, water was used for large-scale farming as well as water needs of a growing population in the west. India is one of the largest users of groundwater due to irregular rainfall from monsoons which create a need for crop irrigation. (ED-278 Depleting the Ogallala Aquifer)
  - The extracted water is used for farming, to irrigate crops, and municipal use. If extracted water is not replenished by rainfall, the land can sink causing damage to property, infrastructure, and even homes.
- Scientists plan to use this new model to explore the relationships between previous periods of drought and the Earth's rotational axis.
- The findings highlight the need for groundwater management practices and continued monitoring of the full implications of the axis shift.

Water flowing from a newly drilled well.

Credit: Author unknown, CC BY 4.0, via Wikimedia Commons

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