

As Skiers Go Down, Moguls Migrate Up, Study Finds

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(PhysOrg.com) -- Gravity always wins, one might think. Avalanches roar and skiers plunge inexorably downhill. But moguls -- or bumps, as skiers know them -- move uphill.

Just ask Tad Pfeffer, a professor of civil, environmental and architectural engineering at the University of Colorado at Boulder; David Bahr, a Regis University professor and former CU geological sciences student; and Ray Browning, a professor at Colorado State University and former CU integrative physiology student.

The three teamed up to confirm their hunch that moguls move uphill. The results of that work, an article titled "The surprising motion of ski moguls," was published in the November issue of *Physics Today*.

As the researchers note, skiers cruise down fresh slopes, unimpeded, turning whenever they choose. With each cut, with each calculated turn, they push snow into small piles. These piles build over time, creating "bumps" that can't easily be ignored.

To save knees and ligaments from damage, skiers turn on the underside of moguls.

"To control speed, [skiers](#) turn and scrape the snow on the downhill side of the moguls they encounter," the authors write. "In so doing, they push snow down the mountain and pile it onto the uphill side of the following mogul. As a consequence, each mogul loses material on its downhill side

but gains new material on its uphill side."

The process causes the moguls to migrate uphill. Each skier who traverses the mogul field adds new snow on the uphill side of the bumps and shaves some snow off the downhill side.

Essentially, this pushes moguls up the hill. This process of "backward propagation" is not unique to moguls.

"Moguls are a type of kinematic wave, an entity rather different from the more commonly studied dynamic wave," according to the study. "The classic example of kinematic waves, and the setting in which kinematic wave theory was formulated, is the flow of cars on a highway," said Pfeffer.

Furthering the analogy between car and mogul, the article states, "If a car taps its brakes, then the cars behind bunch up and the density of cars increases. That bunching travels backward through the traffic, even though the cars continue to move forward, and so the bunched cars, like moguls, are said to be backward-propagating."

The study found that moguls move uphill at roughly 8 centimeters a day, or about 10 meters a season.

Just how do three scientists come to study moving moguls? "Dave and I both skied for many years and actually suspected that moguls migrate uphill," said Pfeffer. "This seemed like a fun opportunity to find out if they actually do migrate uphill and work on some new time-lapse photogrammetric methods at the same time."

Photogrammetry uses photographs to measure objects, in this case the distance moguls travel uphill. When the project started, Pfeffer was just starting to work on time-lapse photogrammetry, a process he now uses

for his work with the Extreme Ice Survey.

Provided by University of Colorado at Boulder

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