Warming seas double snowfall around North America's tallest peaks

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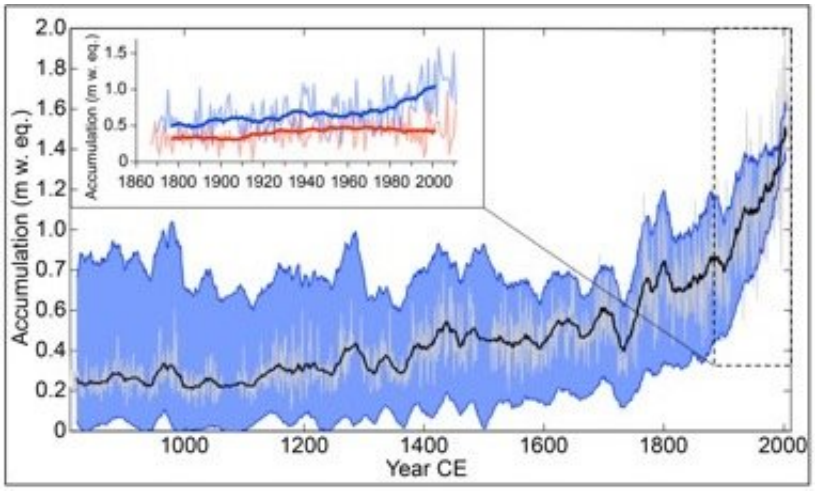

Time series shows the dramatic doubling of snowfall around North America's highest peaks since the beginning of the Industrial Age. Inset shows summer (red) and winter (blue) snowfall since 1870. Credit: Figure provided by Dominic Winski.

December 19, 2017 - Snowfall on a major summit in North America's highest mountain range has more than doubled since the beginning of the Industrial Age, according to a study from Dartmouth College, the University of Maine, and the University of New Hampshire.

The research not only finds a dramatic increase in snowfall, it further explains connections in the global climate system by attributing the record accumulation to warmer waters thousands of miles away in the

tropical Pacific and Indian Oceans.

The research demonstrates that modern snowfall in the iconic Alaska Range is unprecedented for at least the past 1200 years and far exceeds normal variability.

"We were shocked when we first saw how much snowfall has increased," said Erich Osterberg, an assistant professor of earth sciences at Dartmouth College and principal investigator for the research. "We had to check and double-check our results to make sure of the findings. Dramatic increases in temperature and air pollution in modern times have been well established in science, but now we're also seeing dramatic increases in regional precipitation with climate change."

According to the research, wintertime snowfall has increased 117 percent since the mid-19th century in southcentral Alaska in the United States. Summer snows also showed a significant increase of 49 percent in the short period ranging less than two hundred years.

The research, appearing in *Scientific Reports*, is based on analysis of two ice cores collected at 13,000 feet from Mount Hunter in Denali National Park. According to the authors, accumulation records in the separate samples taken from just below the summit of the mountain known as "Denali's Child" are in nearly complete agreement.

"It is now glaringly clear from our ice core record that modern snowfall rates in Alaska are much higher than natural rates before the Industrial Revolution," said Dominic Winski, a research assistant at Dartmouth and the lead author of the report. "This increase in precipitation is also apparent in weather station data from the past 50 years, but ice cores show the scale of the change well above natural conditions."

Once the researchers established snowfall rates, they set out to identify

why precipitation has increased so rapidly in such a short amount of time. Scientific models predict as much as a 2 percent increase in global precipitation per degree of warming because warmer air holds more moisture, but this could not account for most of the dramatic increases in Denali snowfall over the studied period.

The research suggests that warming tropical oceans have caused a strengthening of the Aleutian Low pressure system with its northward flow of warm, moist air, driving most of the snowfall increases. Previous research has linked the warming tropical ocean temperatures to higher greenhouse gas concentrations.

The analysis includes a series of dramatic graphs that demonstrate extreme shifts in precipitation and reinforce the global climate connections that link snowfall in the high reaches of the North American continent with warm tropical waters. As noted in the paper, this same atmospheric connection accounts for a decrease in Hawaiian precipitation.

"Everywhere we look in the North Pacific, we're seeing this same fingerprint from warming tropical oceans. One result is that wintertime climate in the North Pacific is very different than it was 200 years ago. This doesn't just affect Alaska, but Hawaii and the entire Pacific Northwest are impacted as well," said Winski.

The research builds on a recent study using the same ice cores that showed that an intensification of winter storm activity in Alaska and Northwestern Canada, driven by the strengthening Aleutian Low, started in 1740 and is unprecedented in magnitude and duration over the past millennium. The new record shows the result of that increase in Aleutian Low storm activity on snow accumulation.

For this analysis, researchers were able to segment the ice core records

by seasons and years using markers like magnesium from spring dust to separate winter snow from summer snow. To account for snow layers getting squeezed and thinned under their own weight, the researchers applied four separate equations used in other studies, and in all cases the corrected record shows at least a doubling of snowfall.

According to the paper, while numerous snow accumulation records exist, "to our knowledge, no other alpine ice core accumulation record has been developed with such a thorough characterization of the thinning regime or uncertainties; all of the thinning models produce a robust increase in accumulation since the mid-19th century above late-Holocene background values."

The researchers note that the findings imply that regions that are sensitive to warming tropical ocean waters may continue to experience rain and snowfall variability well outside the natural range of the past millennium.

"Climate change can impact specific regions in much more extreme ways than global averages indicate because of unexpected responses from features like the Aleutian Low," said Osterberg. "The Mount Hunter record captures the dramatic changes that can occur when you get a double whammy from climate change - warming air combined with more storms from warming ocean temperatures."

However, the researchers also note that the regional findings do not necessarily mean that the same level of snowfall increases will occur elsewhere throughout the mid- and high latitudes.

"Scientists keep discovering that on a regional basis, climate change is full of surprises. We need to understand these changes better to help communities prepare for what will come with even more carbon dioxide pollution in the air," said Osterberg.

As part of the analysis, the authors suggest that current climate models underestimate the sensitivity of North Pacific atmospheric connections to warming tropical ocean temperatures. They argue that refining the way the modeled atmosphere responds to tropical ocean temperatures may improve rain and snowfall predictions in a warming world.

More information: Dominic Winski et al, Industrial-age doubling of snow accumulation in the Alaska Range linked to tropical ocean warming, *Scientific Reports* (2017). DOI: 10.1038/s41598-017-18022-5

Provided by Dartmouth College