Automation builds bigger, better ice tower reservoirs for high, dry farming

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This artificial ice reservoir, or ice stupa, built by local farmers in Ladakh, India in 2019, is 30 meters (100 feet) tall and survived into early fall, releasing more than 8 million liters (2 million gallons) of meltwater. Credit: Suryanarayanan Balasubramanian

Towering artificial ice reservoirs called "ice stupas" have emerged since 2014 as an accessible means of storing irrigation water in dry, high-altitude mountain villages. Now, experiments with automated systems have demonstrated that construction of these giant ice cones, which top 30 meters (100 feet), can be accomplished with about one-tenth the

volume of water manual methods use, according to new research being presented today at the Frontiers in Hydrology meeting in San Juan, Puerto Rico and online.

In the high, arid region of Ladakh, India, that improvement could make all the difference. The original, manual approach to ice stupa construction typically lets the water flow all winter. Most of the water does not freeze and is lost. Cold temperatures help ice stupas grow, but too cold temperatures freeze water in the delivery pipes.

"In Ladakh right now, many of the ice structures have stopped being built not because the farmers chose to stop watering. It is because the weather chose to stop working," said Suryanarayanan Balasubramanian, a glaciologist at the University of Fribourg in Switzerland.

The best solution is to drain the pipe before it freezes. The new automated approach avoided blocked pipes, using models and weather data to predict the optimal water spray time, duration and flow rate to build ice stupas efficiently, information the researchers said could also be applied manually.

Many ice stupas have melted by summer, but larger, more efficiently shaped ice towers can last into the following year, potentially becoming permanent structures that can provide a predictable water source year-round.

Balasubramanian will speak about the new results on Thursday, June 23, 2022 during a 7:00 p.m. EDT (UTC-4 hours) live-streamed discussion session.

"The point of the experiment was to show that a better methodology exists to construct these structures and there are simple lessons that we can extract. Why is that important? It shows that these structures are

limited in their potential right now. They can grow much bigger and last much longer and use much less water," Balasubramanian said.

A fountain sprays water for an artificial ice reservoir in Ladakh, India. Low, steady flow over months can build ice towers 30 meters high. Meltwater from these structures irrigates crops in spring. Credit: Suryanarayanan Balasubramanian

Cold storage

Ice stupas are made by fountaining water into the air during the winter to fall and freeze into giant, icy stalagmites. The pipes and fountains needed to make these great ice cones are relatively inexpensive and

easily obtained, which means farmers can implement them without outside aid. Large stupas can be built from a flow rate of just 30 liters per minute, or 2-3 times the flow of a typical garden hose, if applied consistently over months, Balasubramanian said.

The method, first developed in Ladakh, India, has been adopted in dry, high-altitude locations in Chile and Kyrgyzstan. Ladakh sits higher than 3,000 meters (9,800 feet) above sea level between the Karakorum range and the Himalaya and receives less than 10 centimeters (4 inches) of rain or snow each year. Irrigation networks in this arid region depend on timely meltwater from glaciers, snow and permafrost, which are increasingly unreliable in a changing climate.

Spraying less, spraying smarter

Balasubramanian and colleagues tested an automated system that controlled how much water was sprayed, when, and for how long, based on models and weather data. Preliminary results from drone measurements found the automated system dispensed 13% of the amount of water used by the manual fountain system to create ice stupas that delivered the same or more meltwater. The automated systems also did not require winter maintenance.

Although the automated system is currently outside the budgets of most farmers using ice stupas, Balasubramanian said development and mass production could bring down the price and make the system easier to use. Lessons learned from the automation experiments about how to optimize the duration of spray and rate of water flow based on historical freezing rates in the locality could be applied by hand.

"We have just scratched the surface on these structures, because we only talk about Ladakh. But this is not just about this one location. It could be applied many places, some of which are much, much colder. We don't

know really what the upper size limit is," Balasubramanian said.

More information: Suryanarayanan Balasubramanian et al, The surprising weather conditions favoring artificial ice reservoirs (Icestupas) (2022). agu.confex.com/agu/hydrology22 … pp.cgi/Paper/1027738

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