HYDROLOGY

Snow sensors seek best way to track the white stuff

Airborne experiments aim to fill in the blanks of global water resources as the climate changes.

BY ALEXANDRA WITZE

When it comes to monitoring the world's frozen places, ice gets most of the love. Satellites such as CryoSat-2, run by the European Space Agency (ESA), measure minute changes in Earth's melting ice sheets. Now another group of cryospheric scientists hopes to get in on the action — by monitoring not ice, but snow.

Snow measurements are crucial for understanding the world's water resources. But observations lag behind those of ice, mainly because remote sensing doesn't work consistently across all snowy environments. From mountains to prairies to tundra, the sheer variety of landscapes has frustrated efforts to produce high-resolution, worldwide maps.

"The biggest hole in our knowledge of the global water budget is snow," says Jeffrey Deems, a research scientist at the US National Snow and Ice Data Center in Boulder, Colorado. "We really have no idea how much is out there."

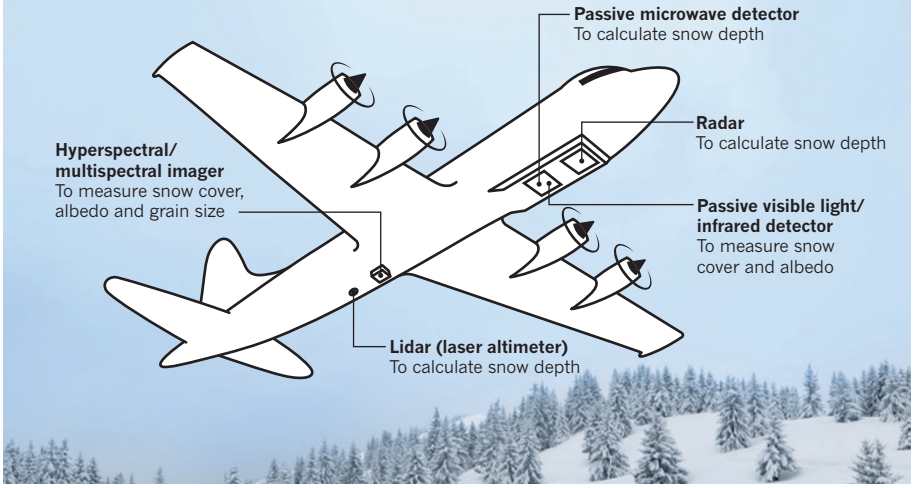
Last week, at a workshop in Seattle, Washington, Deems and his colleagues settled on a plan to change that, when they laid out details for a multiyear NASA field campaign scheduled to begin in September. The SnowEx experiment will fly aeroplanes carrying a combination of remote-sensing instruments — including radar, laser altimeters (lidar) and multispectral imagers — over snowy landscapes. The goal is to see which techniques work best for studying snow, and to combine those in a design for a snow-sensing satellite.

Snow information is becoming more crucial as the climate changes, says Matthew Sturm, a snow scientist at the University of Alaska Fairbanks. More than 1.2 billion people worldwide rely on mountain snowpacks for water — but in many areas, snowfall may decrease in the future (J. S. Mankin *et al. Environ. Res. Lett.* **10,** 114016; 2015). In California, for example, the ongoing drought means that water managers are increasingly eager for any information about how much runoff to expect, and when, throughout the summer.

In Alaska, changing snow cover affects how fast permafrost thaws, destabilizing the landscape. And as Arctic sea-ice cover shrinks, so too does its protective snow cover, leading to feedback loops of increasing ice destruction.

EYES ON THE SNOW

Remote-sensing measurements could finally let scientists monitor Earth's snow resources — which provide drinking water for billions of people. NASA is planning to test various combinations of sensors to see which do best at quantifying how much snow lies on a landscape and how quickly it is likely to melt away.



SOURCE: NASA; PHOTO: MMAC72/GETTY

Current satellites have limited ability to track these changes. ESA's now-concluded GlobSnow project used satellite microwave data to map global 'snow water equivalent' — the crucial estimate of how much water is contained in the world's snowpacks, calculated by multiplying snow depth by density. But GlobSnow's maps, with pixels 25 kilometres on each side, are too low-resolution for precise estimates in individual watersheds.

In the past few years, NASA and ESA have each rejected proposals for more-detailed snow-observing satellites. Both missions would have used radar to measure snow depth and calculate snow water equivalent, and both were doomed by doubts that researchers could reliably extract that information from the type of radar proposed. "For a long time we were on a quest for a single sensor," Sturm says. "The snow's just not that simple."

Now the focus is shifting to testing multiple sensors simultaneously, to see which combination works best. The first SnowEx flights will carry lidar instruments and several types of radar (see 'Eyes on the snow') over the Sierra Nevada or Rocky Mountains in western North America. Each will measure snow cover by monitoring how lidar or radar pulses bounce off the ground and reflect back to the plane. The instruments will include new technologies that, when used together, may avoid the problems of the rejected satellite radar, says Edward Kim, lead scientist for SnowEx at NASA's Goddard Space Flight Center in Greenbelt, Maryland.

One method is already becoming enormously popular in California and other parts of the western United States. For the past several years, NASA has flown a lidar-equipped plane called the Airborne Snow Observatory (ASO) over several western watersheds. The observatory measures the shape of the terrain in the summer, when there is no snow on the ground, and then returns throughout the winter to measure the changing depth of the snowpack.

Project scientists can build up highly detailed maps — down to 1.5-metre resolution — of watersheds such as the Tuolumne River Basin, which supplies the city of San Francisco in California. Water managers use the resulting data to estimate how much runoff to expect in the spring. "We've never had that across these mountain basins before," says Thomas Painter, who heads the ASO project at NASA's Jet Propulsion Laboratory in Pasadena, California.

SnowEx will build on the ASO by testing extra instruments. "This is the number one priority," says Jessica Lundquist, a hydrologist at the University of Washington in Seattle. "We need to figure out how to measure snow right." ■