Novel, uniquely large-scale snowfall observations:

a breakthrough for constraining atmospheric models over mountain terrain

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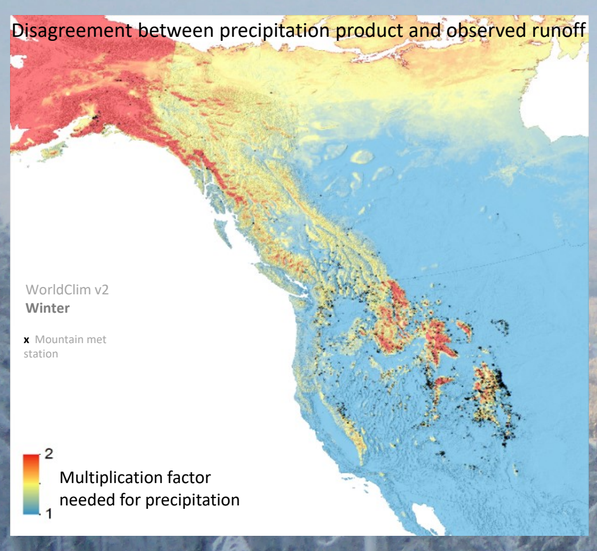
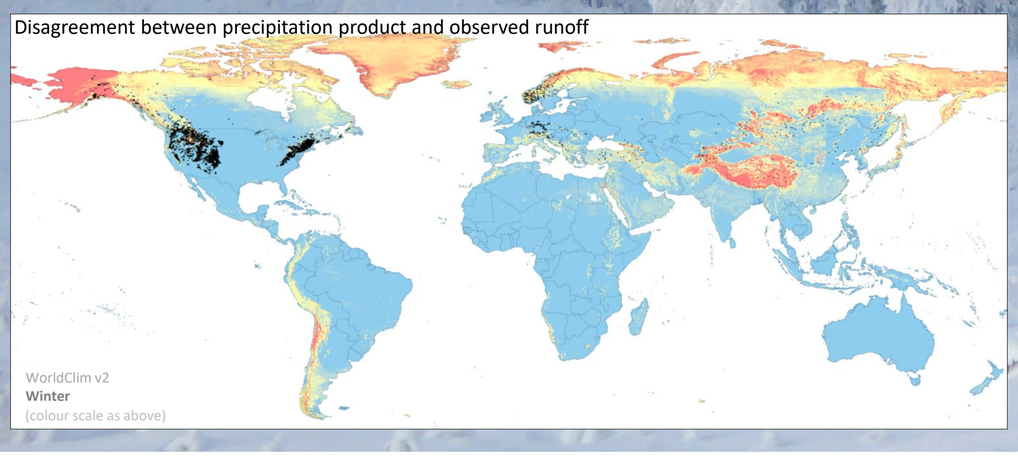
<u>The problem</u>:
Snowmelt is underestimated by 50-100% in the world's major mountain ranges. This is because mountain precipitation measurements, and therefore gridded products and atmosphere models, are biased.



After Beck et al. (2020) Bias Correction of Global High-Resolution Precipitation Climatologies Using Streamflow Observations from 9372 Catchments. J Clim. 2020;33(4):1299-315.

See also: Pritchard, H.D. (2021a) Global data gaps in our knowledge of the terrestrial cryosphere. Frontiers in Climate 3:51.



What's wrong with conventional measurements?

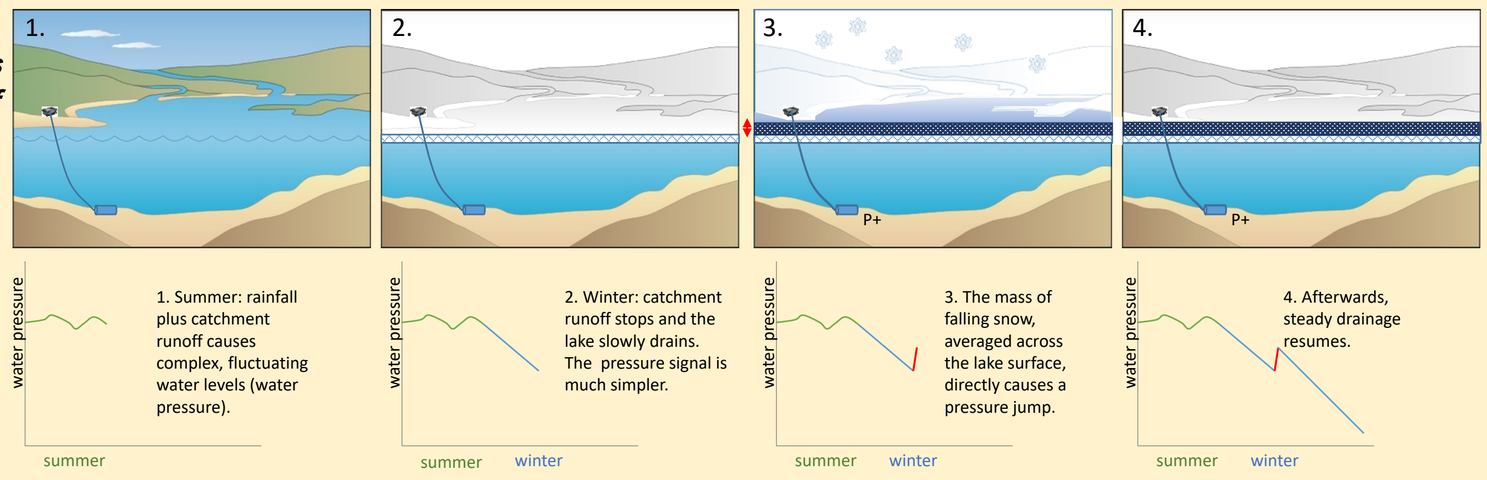
They don't represent mountain precipitation well because:

- ***They are <u>inaccurate</u>.***
- ***They are <u>much smaller</u> than model grid cells.***
- ***They are too sparse, poorly distributed, infrequent or short-lived.***

<u>A solution</u>: *Use lakes as unbiased snowfall sensors on the 'landscape scale' of model grid cells.*

Water-pressure sensor.

In winter, lake water pressure responds directly to snow falling on the lake. Water pressure is easy to measure even among mountains. Sensors are cheap(ish), low power, unbiased and autonomous.

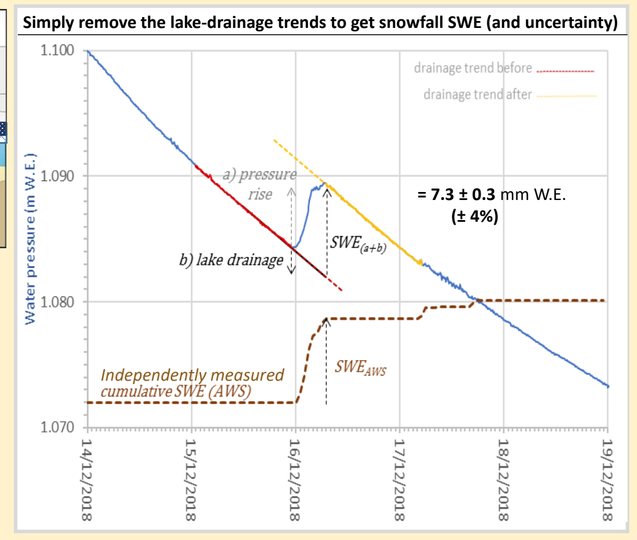


1. Summer: rainfall plus catchment runoff causes complex, fluctuating water levels (water pressure).

2. Winter: catchment runoff stops and the lake slowly drains. The pressure signal is much simpler.

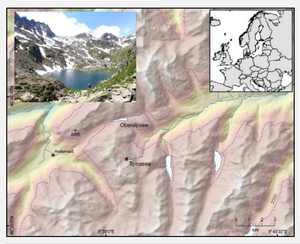
3. The mass of falling snow, averaged across the lake surface, directly causes a pressure jump.

4. Afterwards, steady drainage resumes.



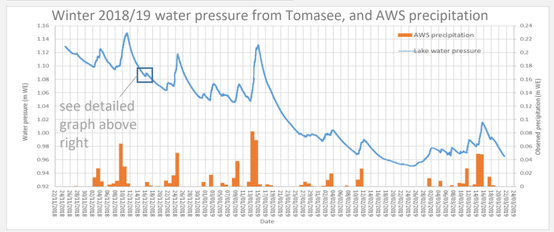
Pritchard HD, Farinotti D, Colwell S. (2021) Measuring Changes in Snowpack SWE Continuously on a Landscape Scale Using Lake Water Pressure. *Journal of Hydrometeorology*. 22(4):795-811.

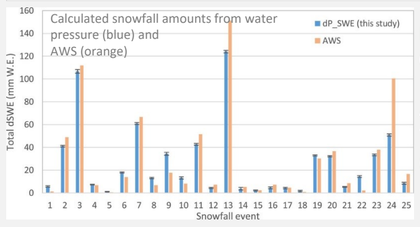
<u>Examples</u>: *Swiss Alps*



Lake Tomasee, Switzerland (alt. 2350 m), source of the River Rhine.

Tomasee is <u>1.25 million times larger</u> than the nearest AWS pluviometer, and <u>10 times larger</u> than all of the world's pluviometers combined.



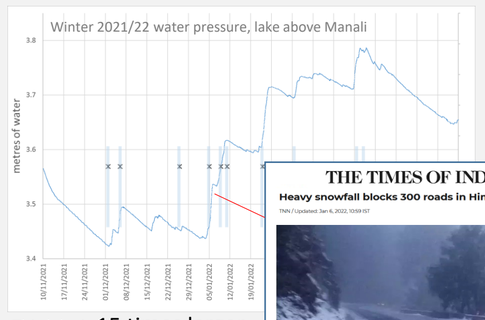


Lake winter total:
666.1 ± 4.0 mm W.E.

AWS winter total:
754.4 mm W.E.
(uncertainty <u>unknown</u>).

Indian Himalayas

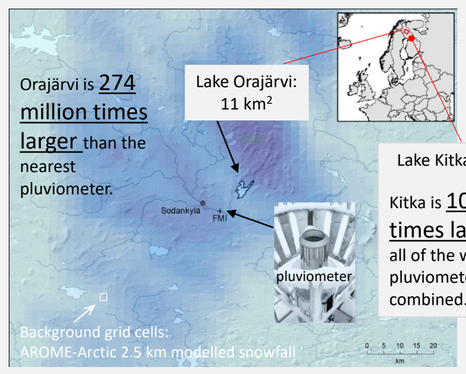
Lake above Manali (alt. 4400 m), Indus headwaters.

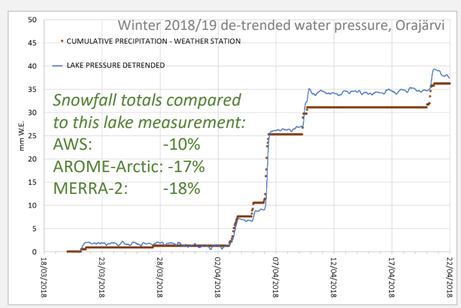



THE TIMES OF INDIA
Heavy snowfall blocks 300 roads in Himachal Pradesh
TNN / Updated: Jan 6, 2022, 10:59 IST

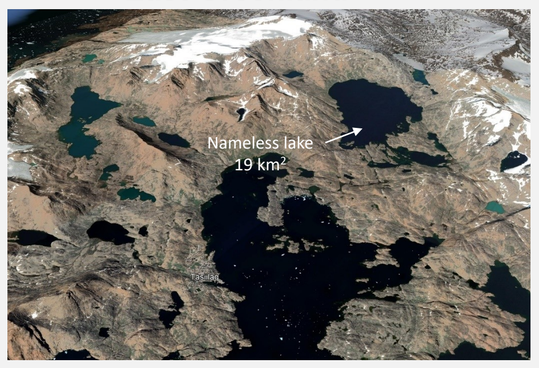
This lake is <u>15 times larger</u> than all of the world's pluviometers.

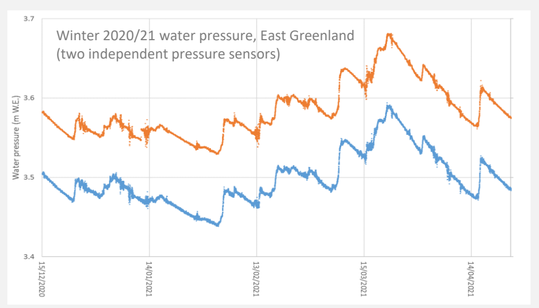
Finnish Arctic





East Greenland





<u>Conclusion</u>: We have succeeded in monitoring the water content of falling snow:

1. with high frequency, minimal bias and precision at least as good as conventional methods, AND…
2. covering areas many orders of magnitude larger than conventional instruments.

This makes our measurements the first to be directly comparable to the grid cells of atmospheric models, removing a major source of potential model bias.

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