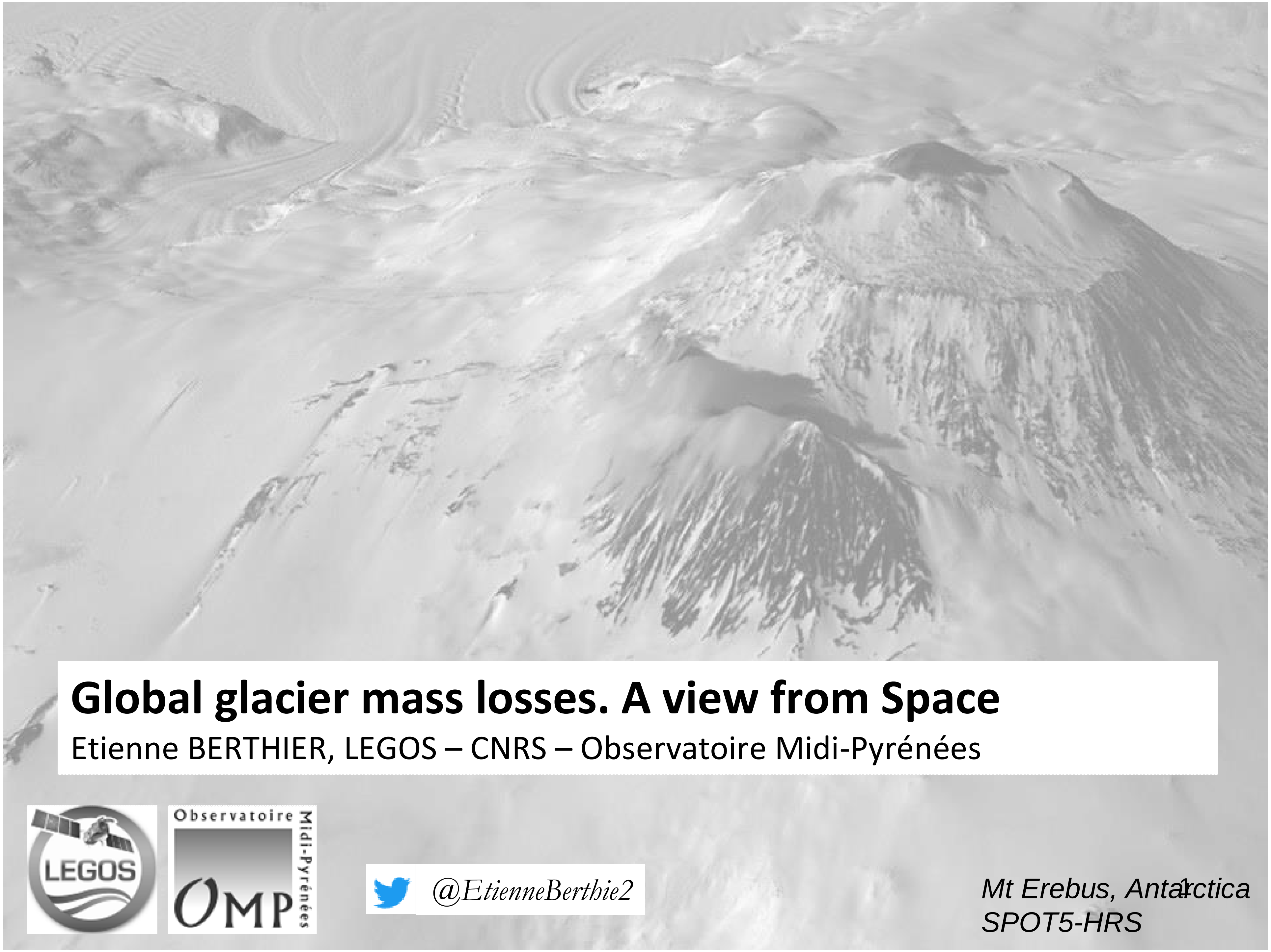


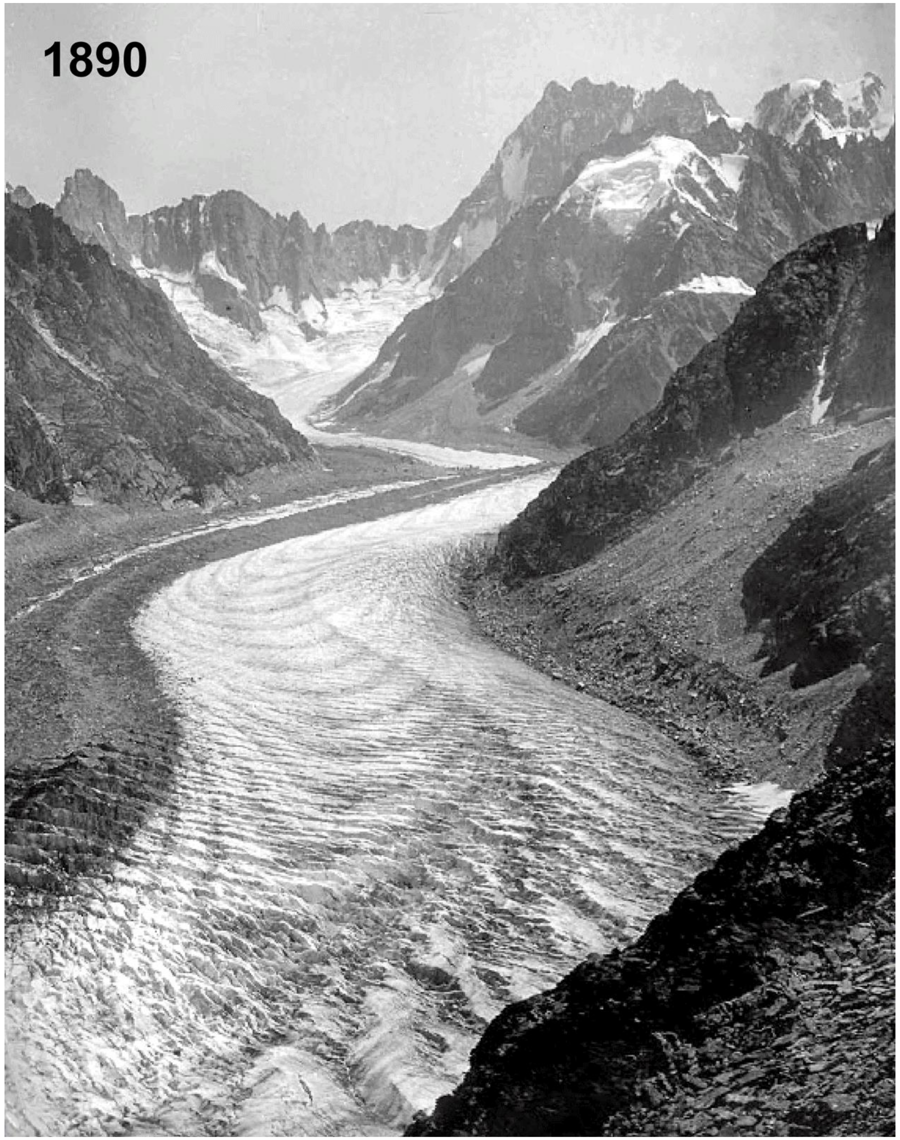
Global glacier mass losses. A view from Space

Etienne BERTHIER, LEGOS – CNRS – Observatoire Midi-Pyrénées

@EtienneBerthie2

Mt Erebus, Antarctica
SPOT5-HRS

Lower Mer de Glace 1890 ï 2013 - 2021



Melaine Le Roy @subfossilguy

Ossoue Glacier in 1911 & 2012

P. René, La Météorologie, 2014

Outline

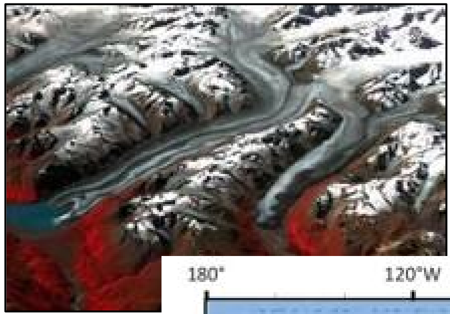
I. **Glaciers: who and where are they?**

II. Measuring glaciers from Space

III. Glaciers, climate sentinels

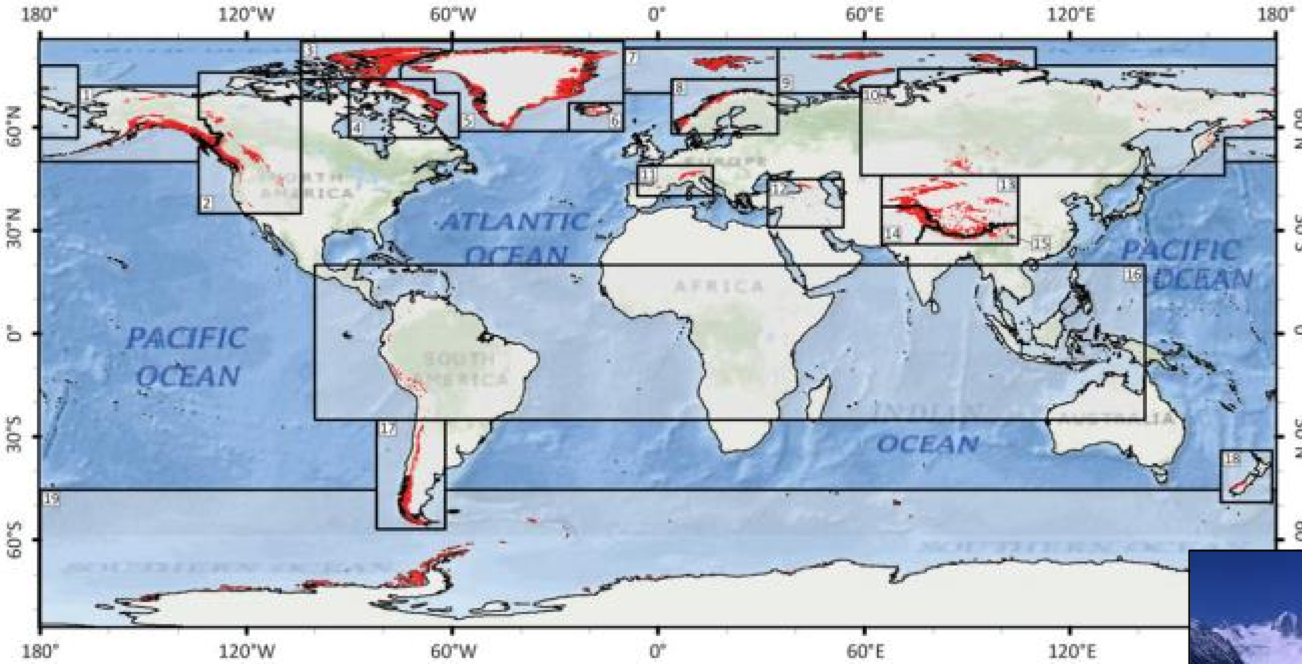
IV. Consequences of glacier change

Glaciers around the globe



Icefields in Alaska

Vatnajökull (Iceland)



Pfeffer et al., 2014

Area = 700 000 km^2
Mean thickness = ~150 m
Sea-level équivalent = 0.3 m
Number : >200 000?

Mer de Glace

Accumulation area

Mass balance measurements in the field

MORAINE
Association Pyrénéenne de Glaciologie

Ablation area

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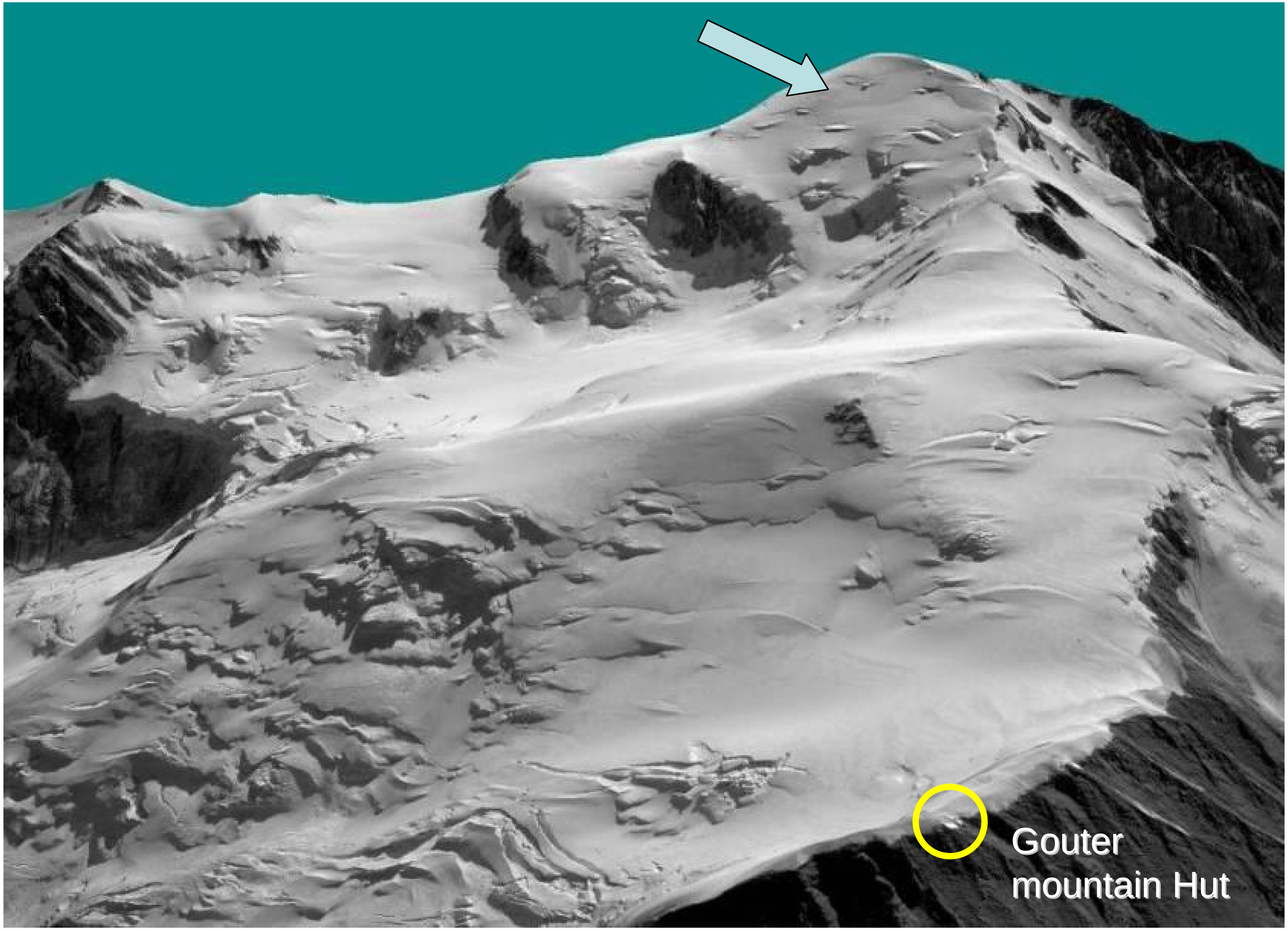
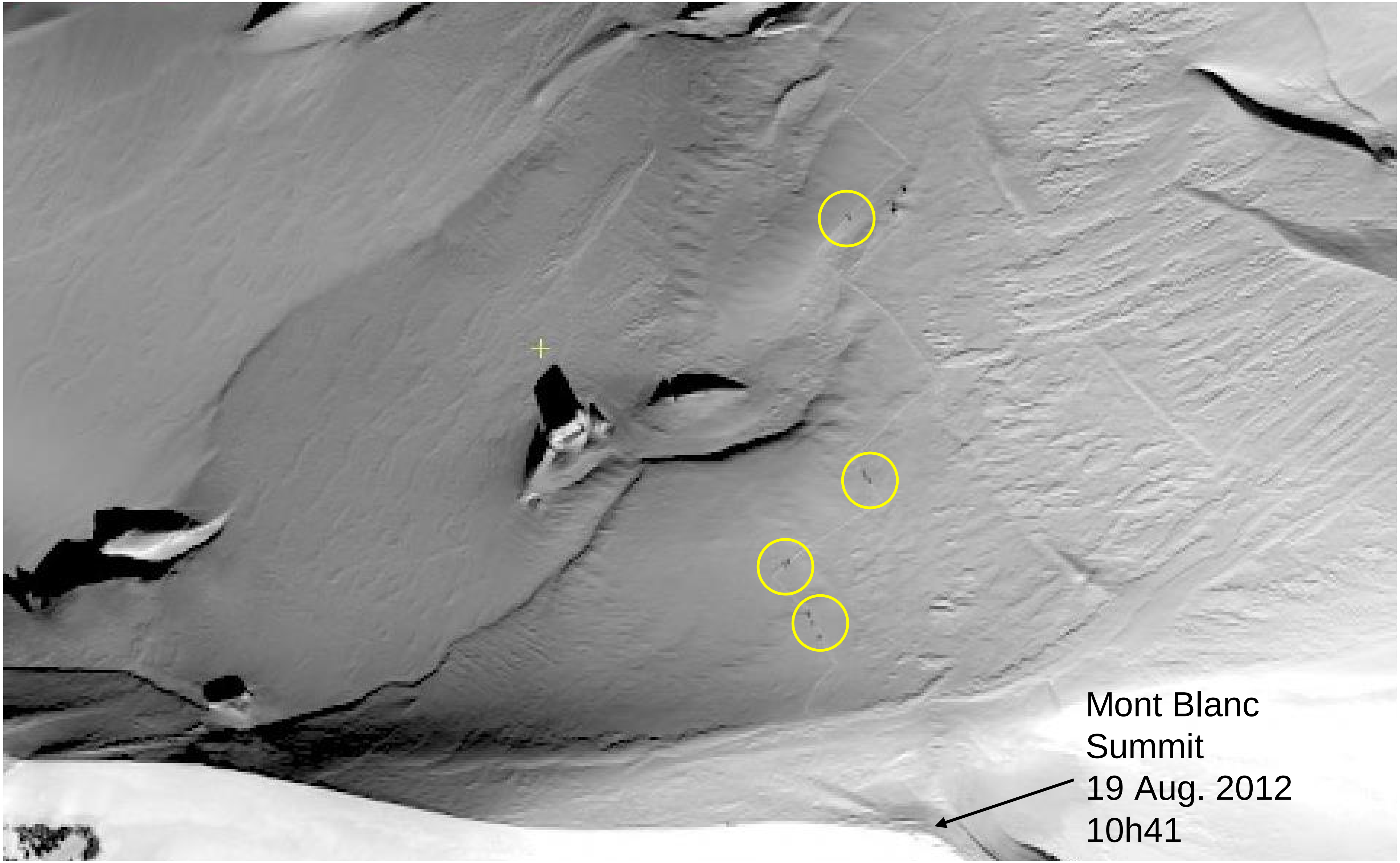
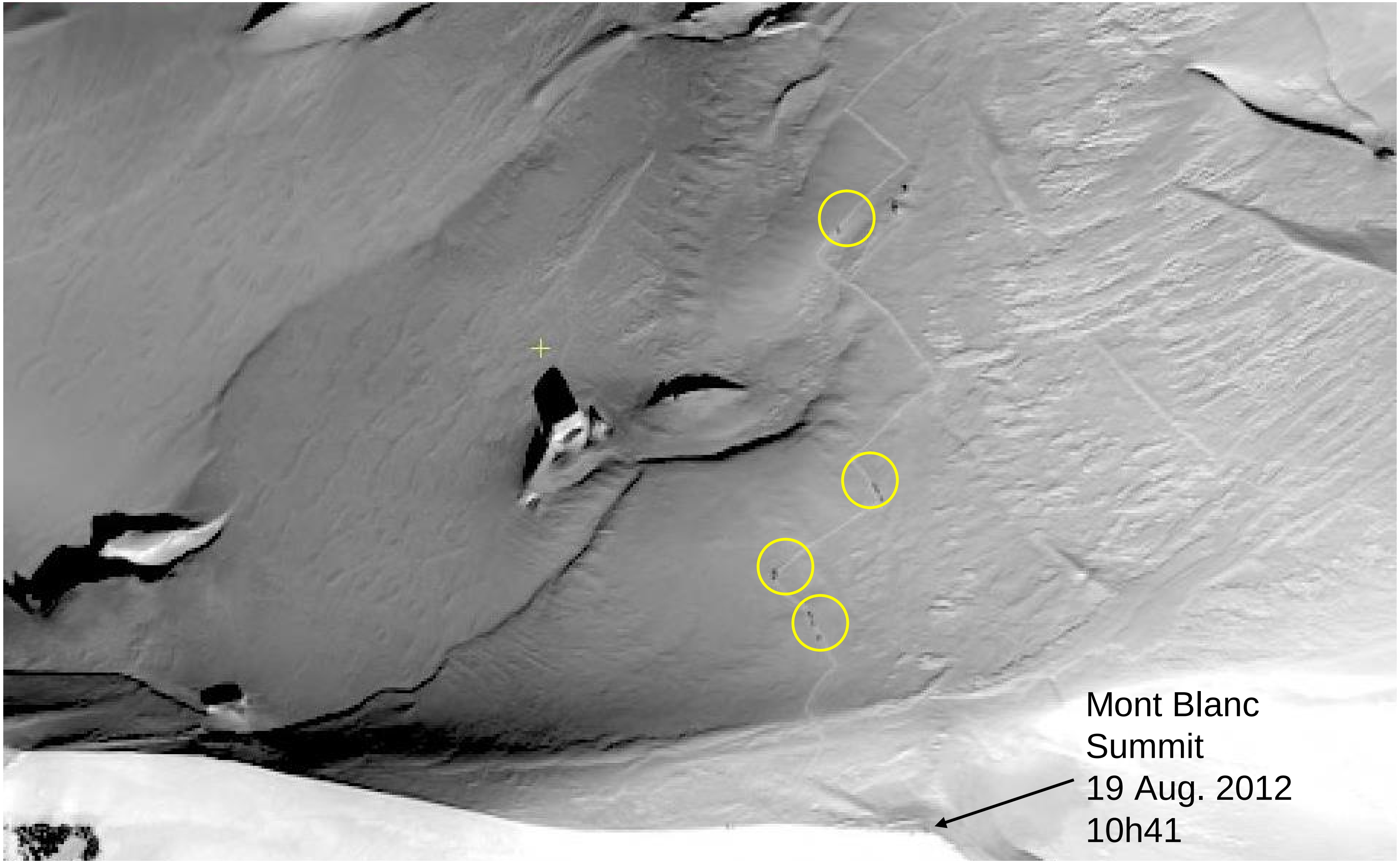
High resolution optical images



Images Pléiades RTU, © CNES 2012, Distribution ADS

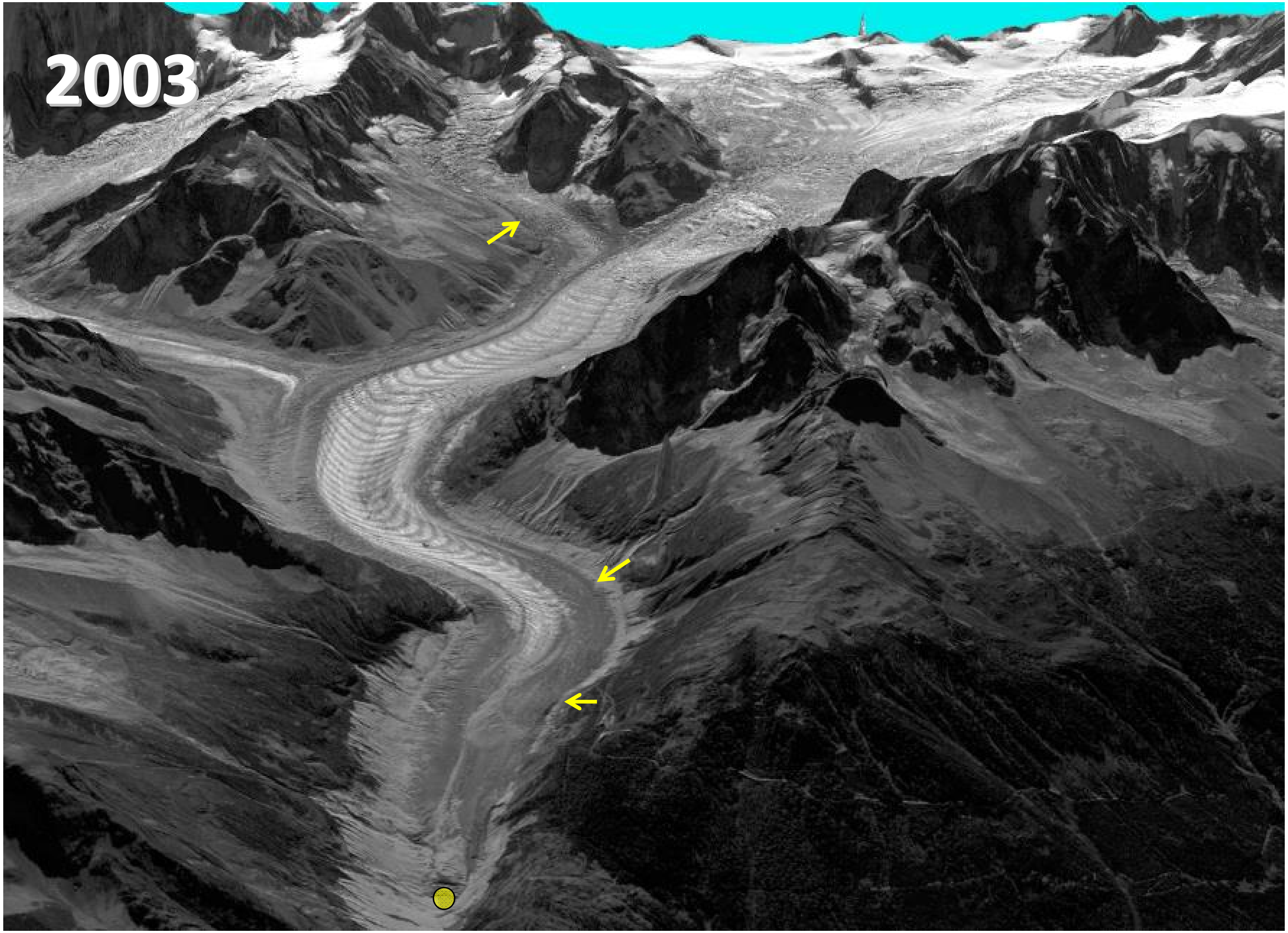


t

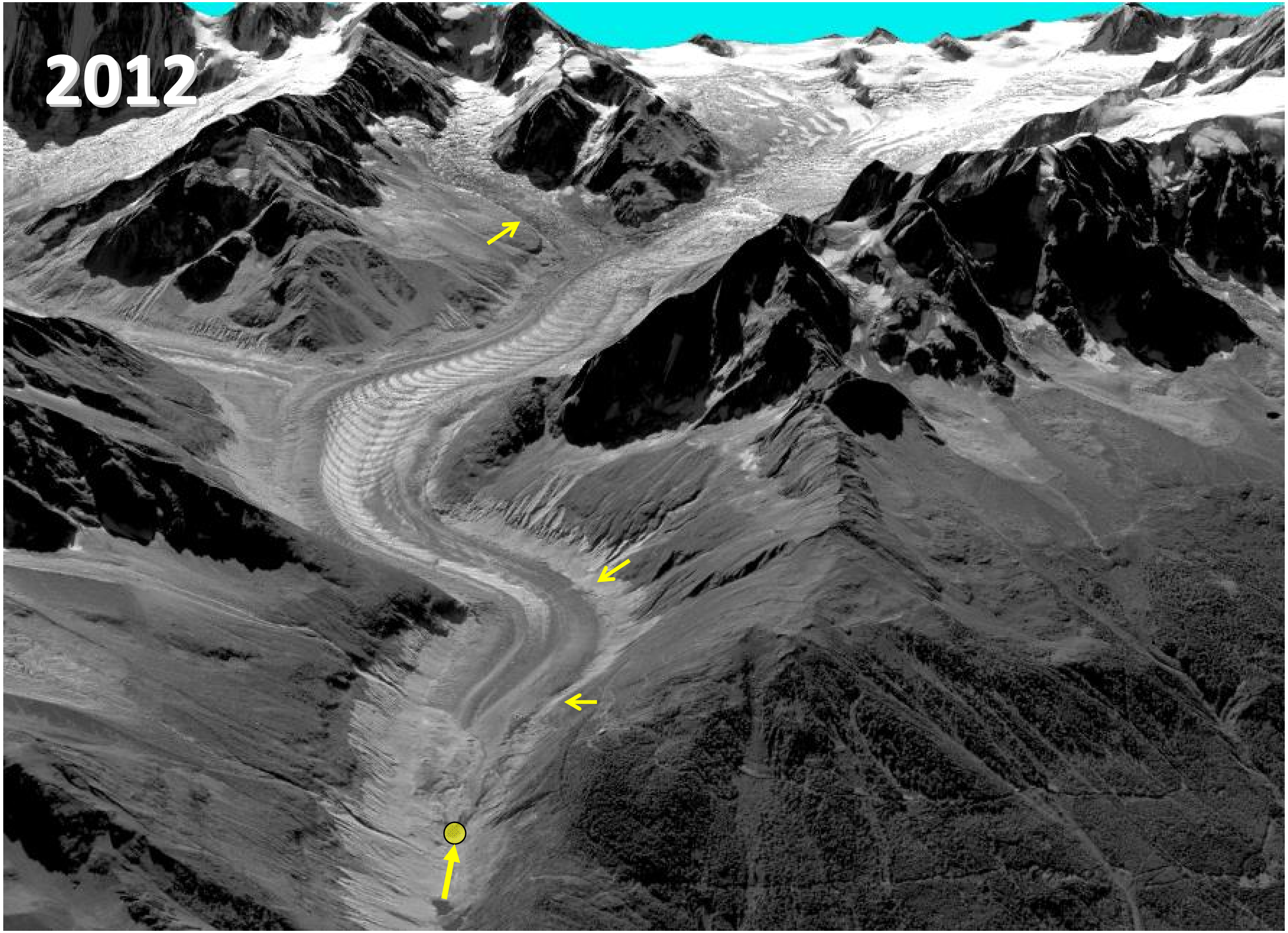


t + 27 sec

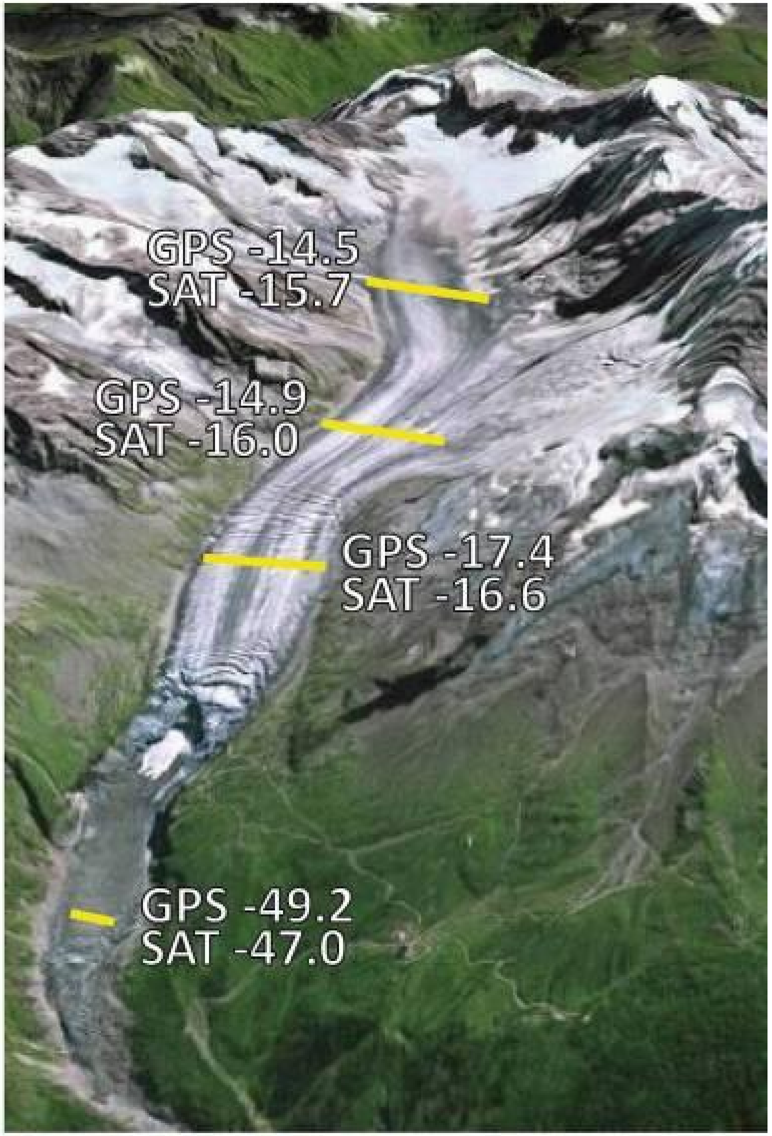
Mer de Glace in 2003 & 2012



Mer de Glace in 2003 & 2012

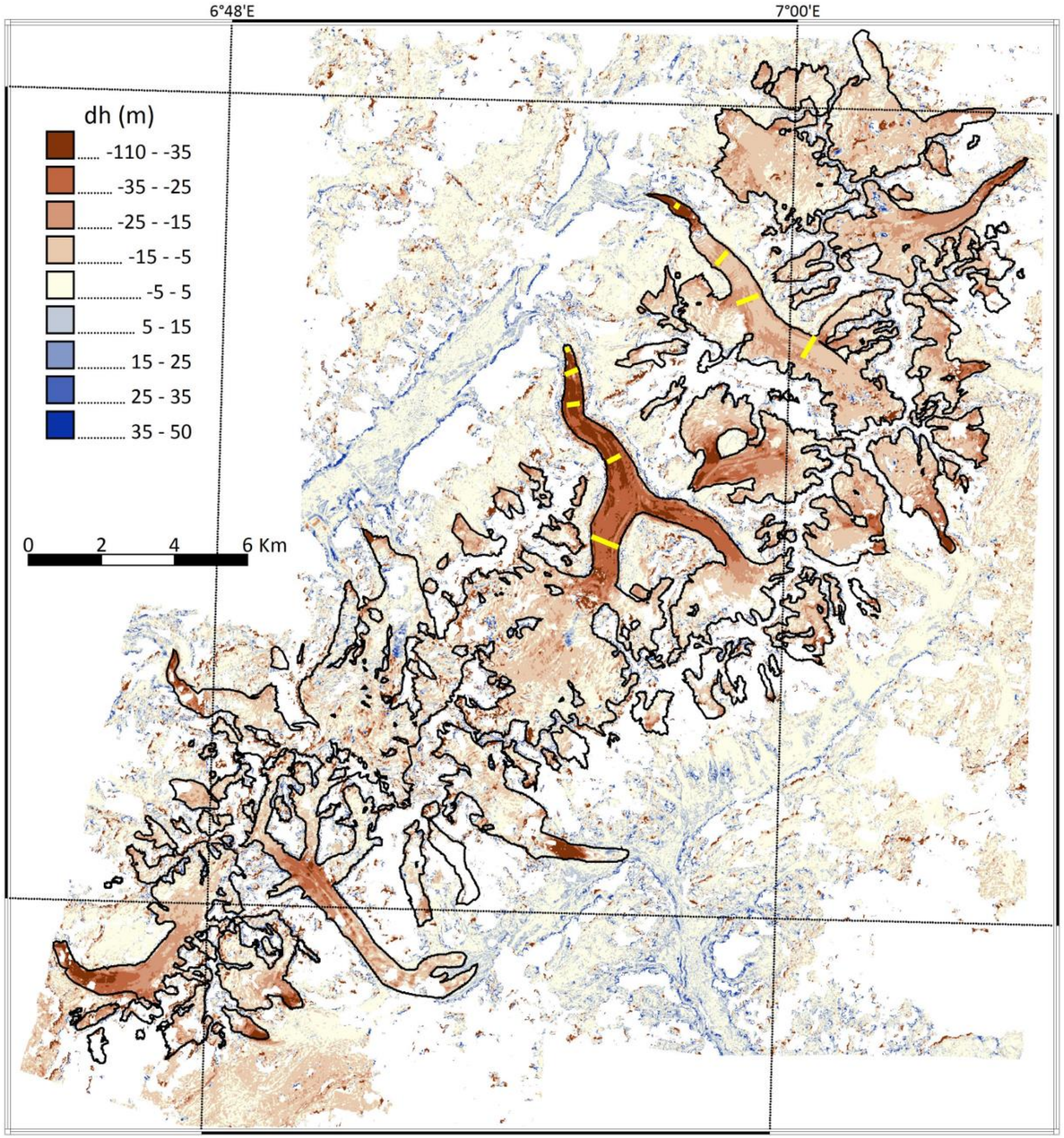


Validation using in situ data



Thickness change (m) along 8 profiles on Argentière Glacier and Mer de Glace between 2003 & 2012 from GPS and satellite data. μ *= 0.3 m;* σ *= 1.3; N = 8*

Mass balance of Mont-Blanc glaciers



Elevation changes of glaciers in Mont-Blanc area between 2003 and 2012

$$MB \doteq \int_S \rho_i \frac{\partial h_i}{\partial t}$$

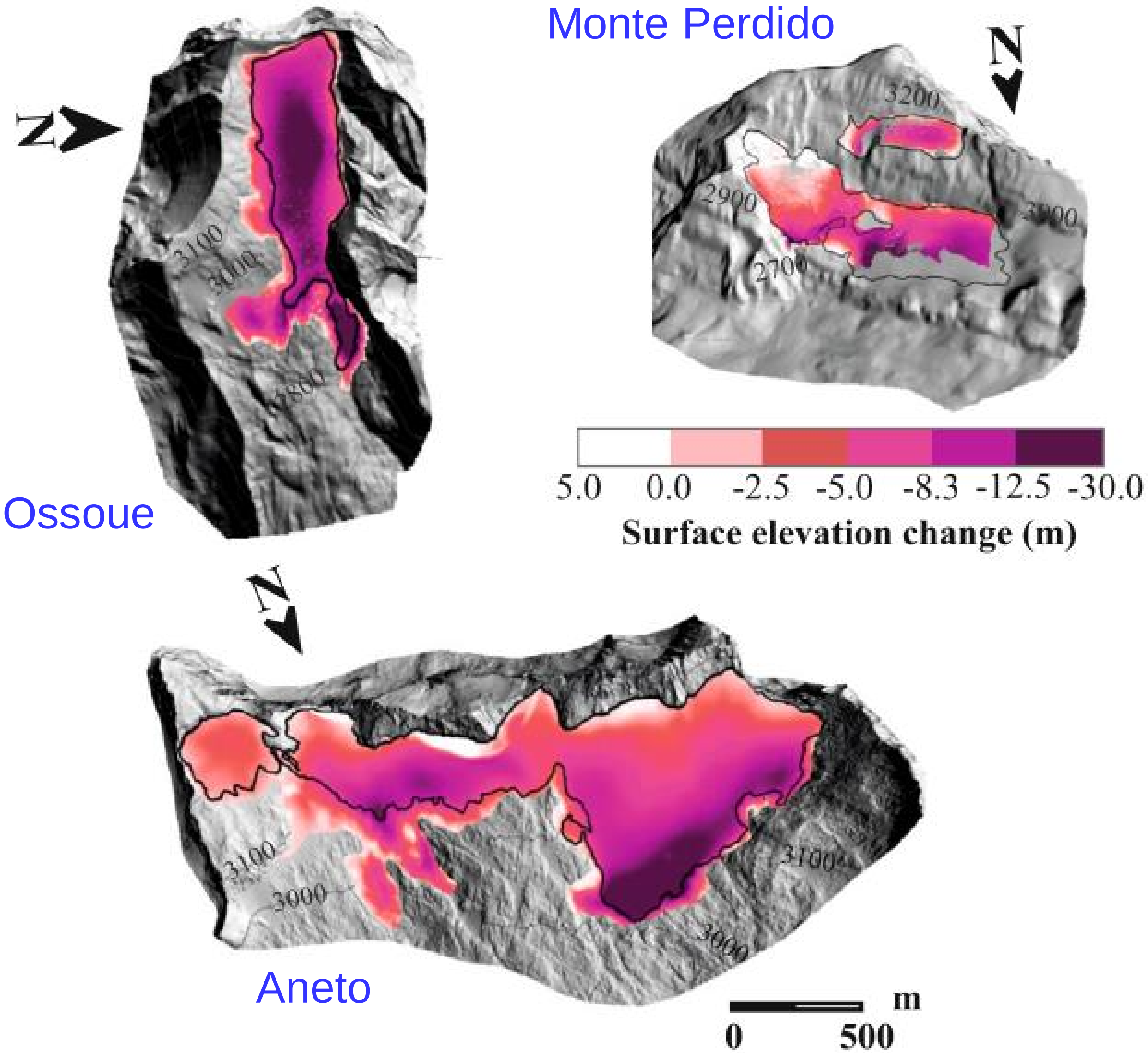
-1.04 ± 0.23 m w.e./a

The same technique works for seasonal snow pack monitoring

Deschamps-Berger, Gascoin et al., TC, 2020

Berthier et al., TC, 2014

Mass balance of Pyrénean glaciers



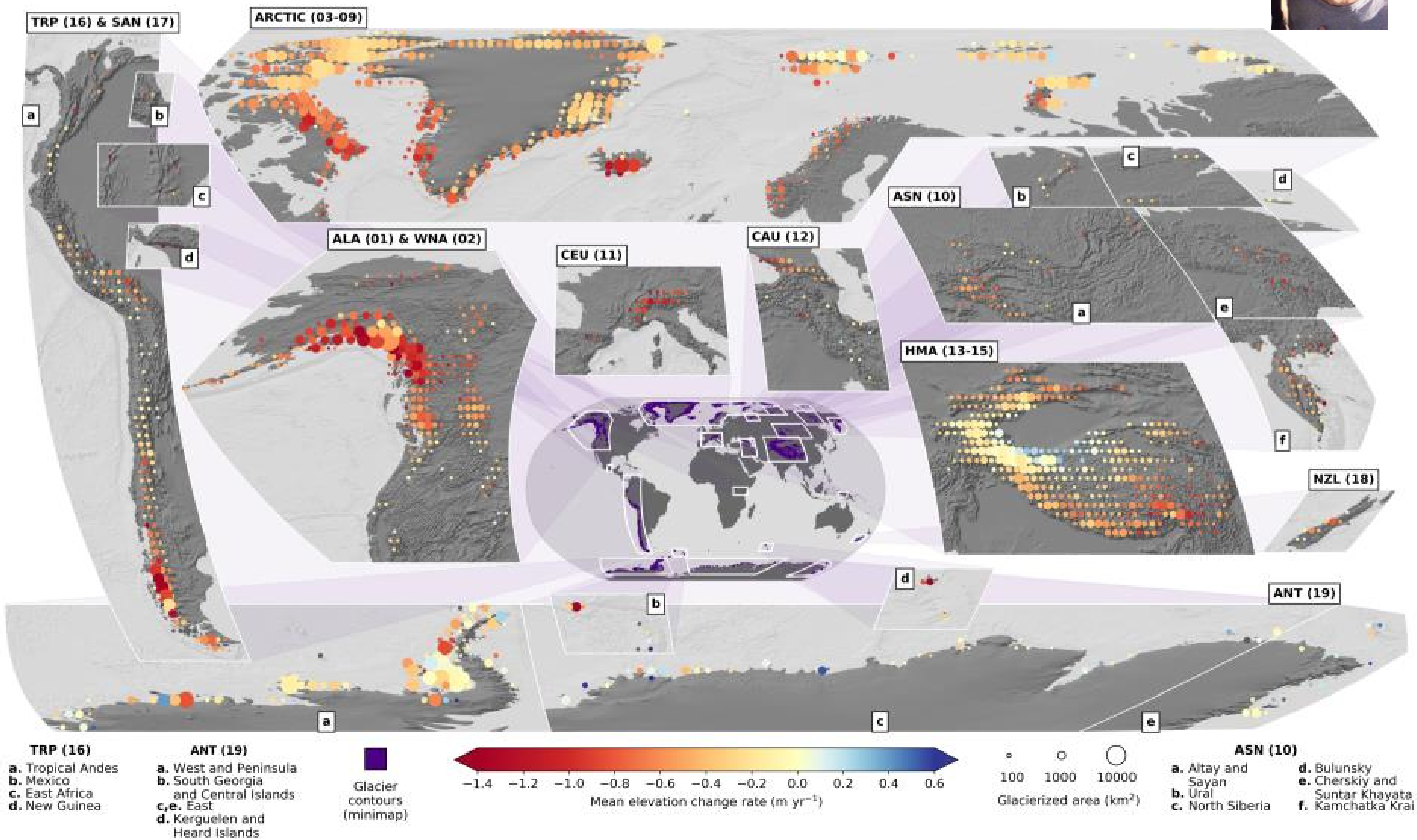
Elevation changes of the three largest Pyrénean glaciers 2011-2020

Instituto Pirenaico de Ecología

Vidaller, Revuelto et al., GRL, 2021

-0.59 m w.e./a

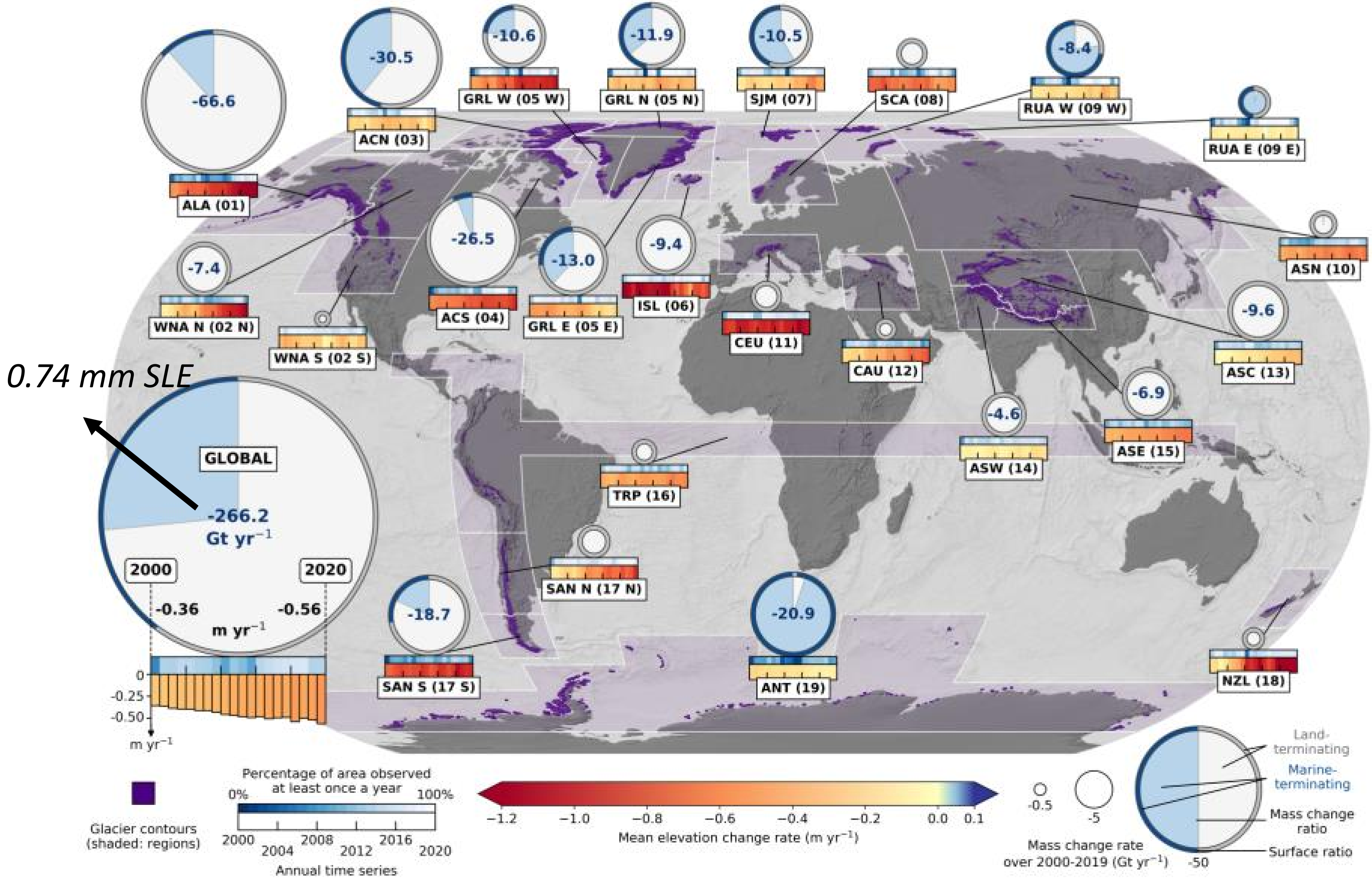
Global glacier change 2000-2019



Rate of elevation changes from 2000 to 2019 for all glaciers on Earth

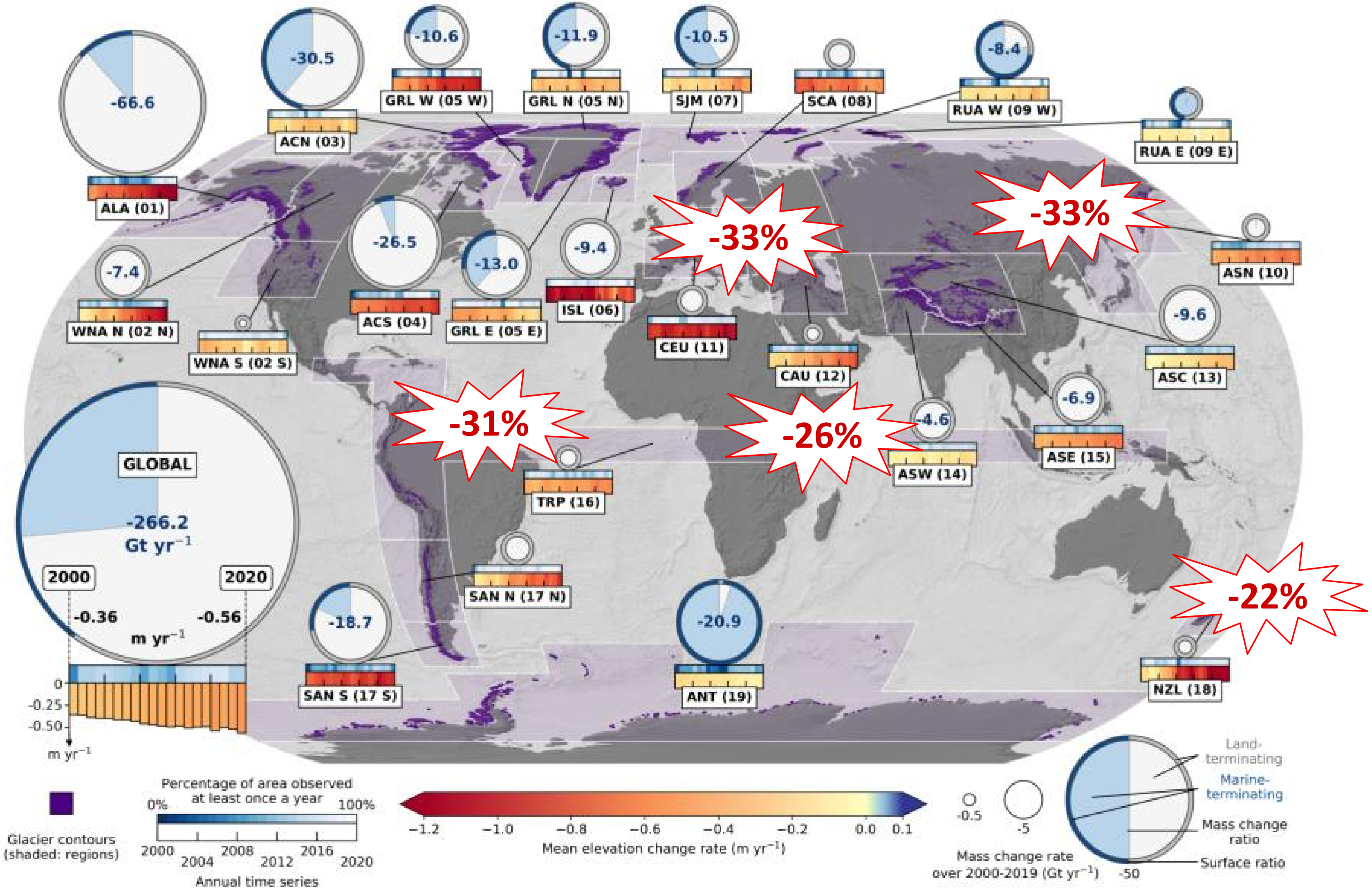
Hugonnet et al., Nature, 2021

Global glacier mass loss 2000-2019



Hugonnet et al., Nature, 2021

Global glacier mass loss 2000-2019, the big loosers



Red : % of the total glacier volume that disappeared in 20 years

Hugonnet et al., 2021
Millan et al., 2022

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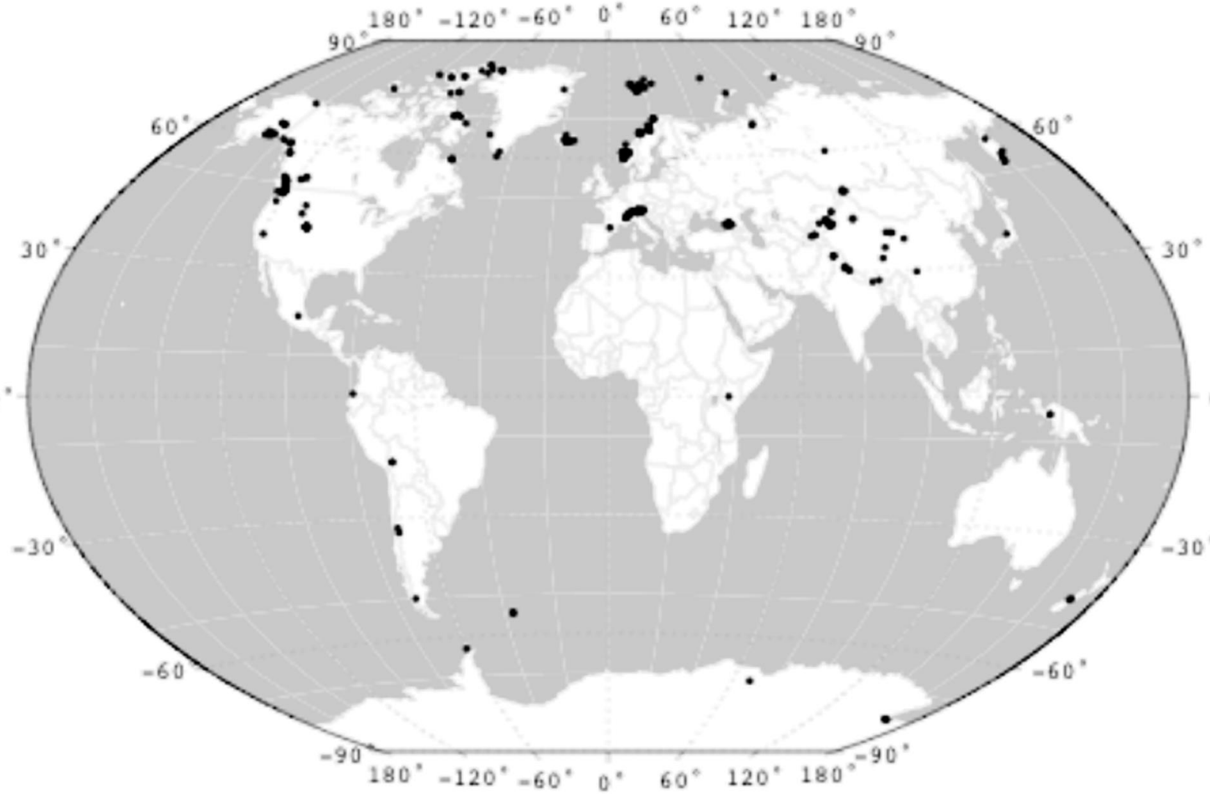
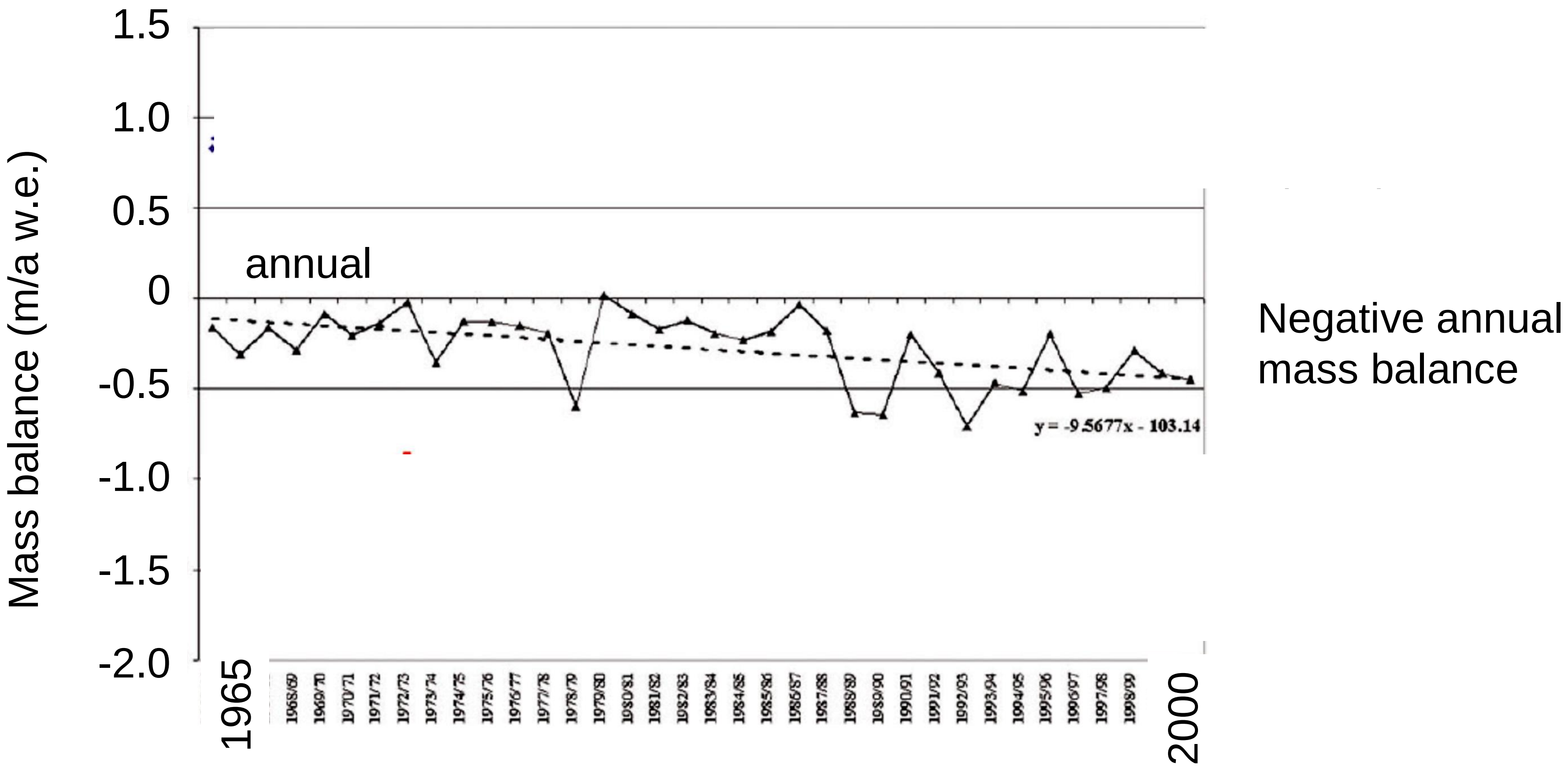
Causes of glacier mass loss



Location of glaciers where long term field measurements of the seasonal mass balance are available

Dyurgerov & Meier, 2006

Causes of glacier mass loss



Winter, Annual and Summer mass balance of 35 glaciers around the globe

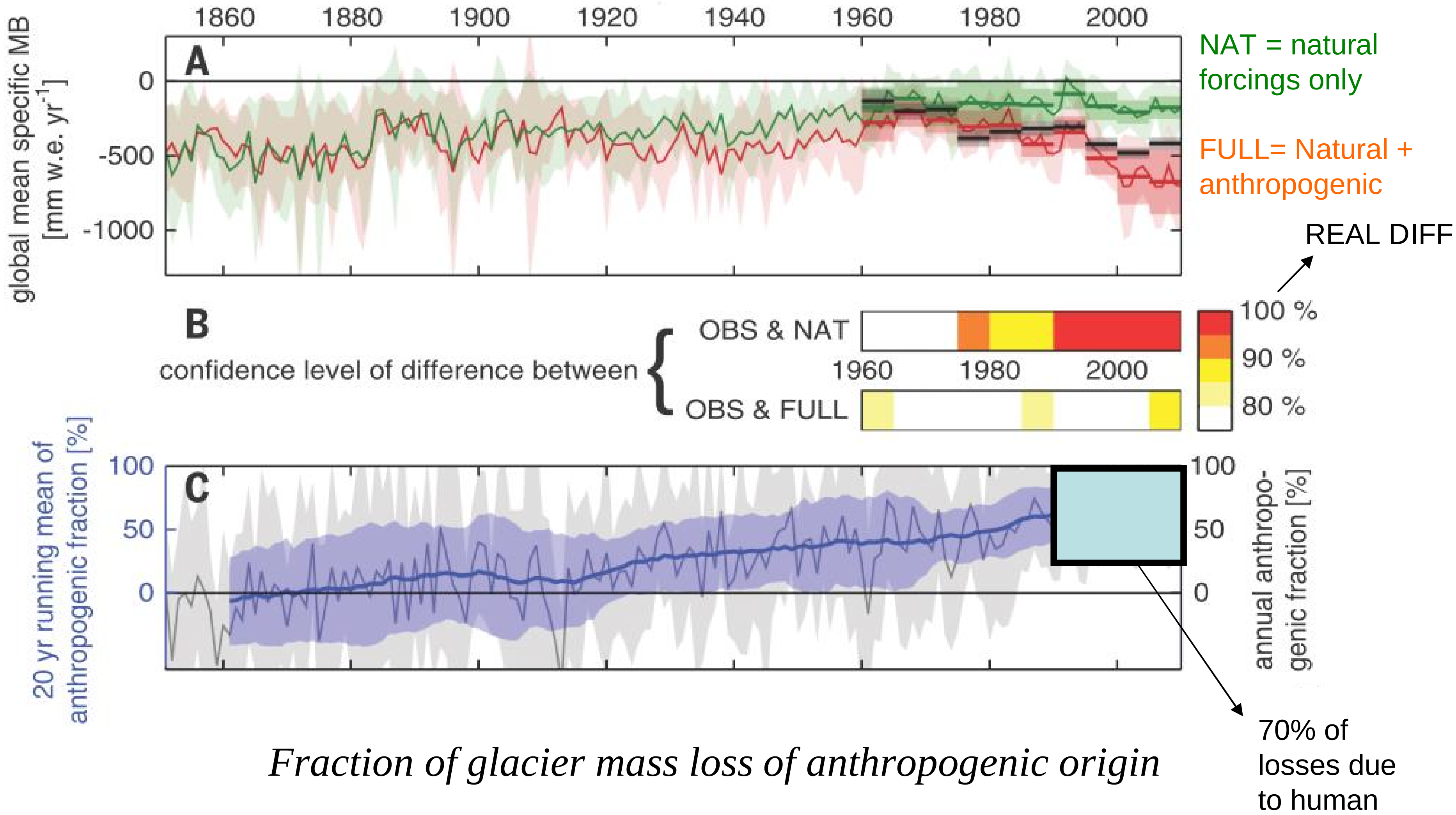
Ohmura et al, 2006, 2011

⇨ **Glacier mass loss are due to temperature increase not to changes in precipitation.**

Anthropogenic origin? Glaciers started to retreat before the sharp rise in green house gas emission

Moraine in Himalaya (Photo Jeff Kargel, Univ Arizona)

Role of the anthropogenic climate forcings in global glacier loss



Fraction of glacier mass loss of anthropogenic origin

Marzeion et al, Science, 2014

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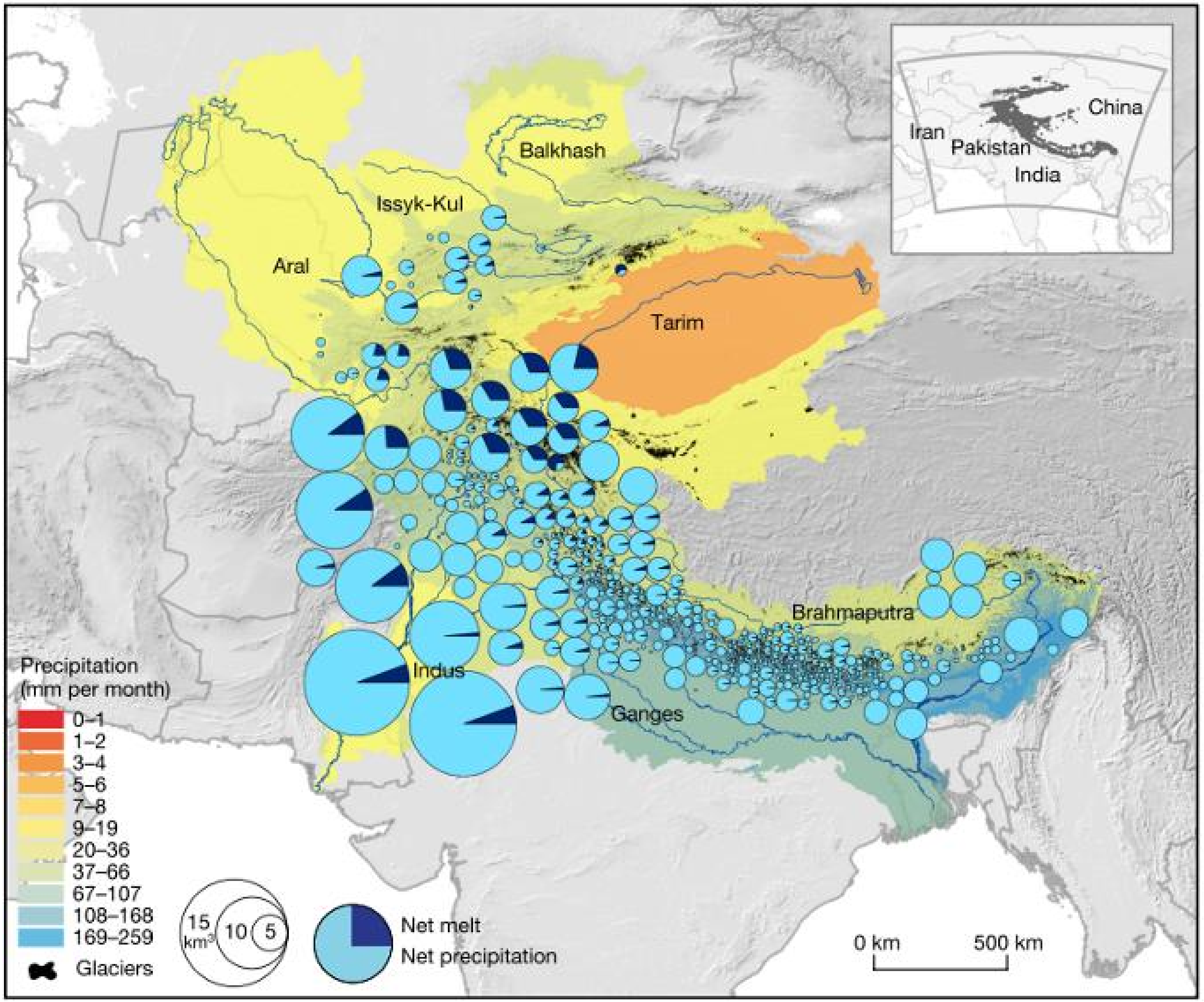
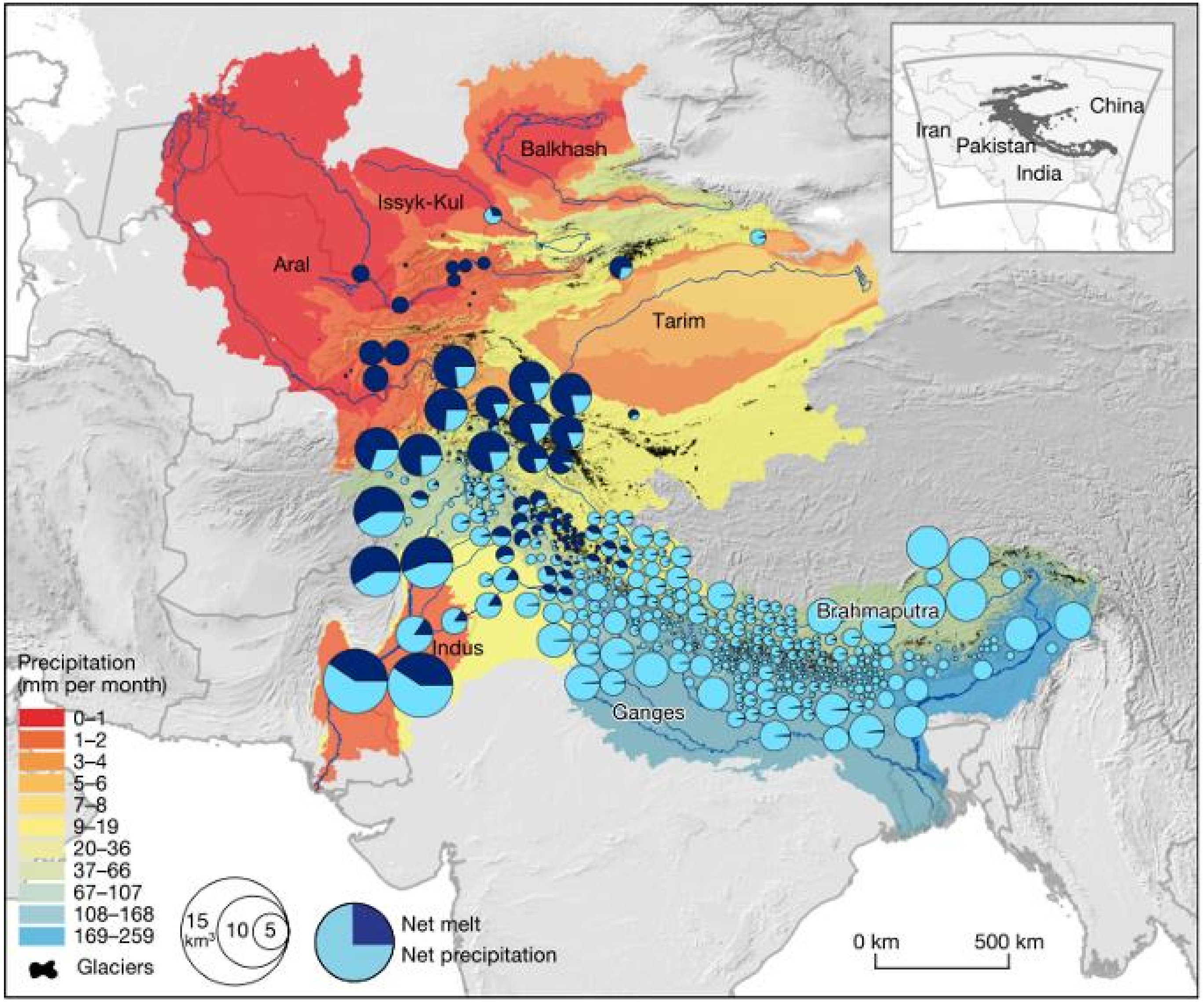
A naturel water tower for High Mountain Asia



Pritchard (2019)

Relative contribution of glacier melt and precipitation to river runoff for an average year

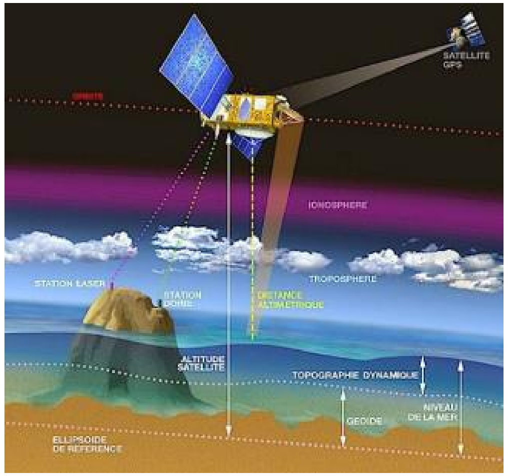
A naturel water tower for High Mountain Asia

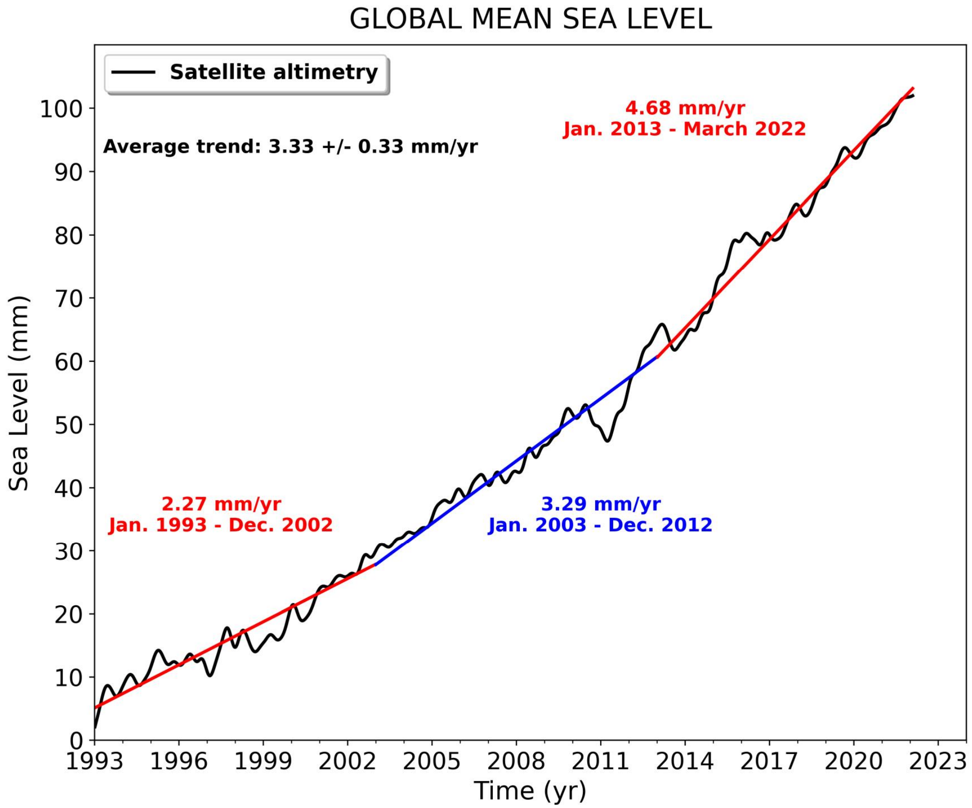


Pritchard (2019)

Relative contribution of glacier melt and precipitation to river runoff for *<u>the driest month of a drought year</u>*

Glacier contribute to sea-level rise





Observed rise	~3.64 mm/a
Thermal expansion	+1.19 mm/a
Ice sheets	+1.23 mm/a
Glaciers	+0.77 mm/a
Continental water	+0.40 mm/a

Sea-level budget from 2003 to 2016

Horwath, ESDD (2022)