

# Climate change, extreme events, & climate victims

**Prof. Dr. Wim Thiery**

# This presentation

- Brief self-introduction
- Glacier volume
- Lifetime extreme event exposure
- Heat-related mortality

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- **Research Professor, VUB** (2017-pres.)
- **Forbes 30 under 30** (2017)
- **FWO Scientific Award Climate Research** (2024)
- **Laureate of the Academy – Royal Academy of Belgium** (2024)
- **EGU Arne Richter Award** (2023)
- **2x IPCC Author** (2019; 2021)
- **139 scientific articles** (GS h-index 56)
- **24 Science/Nature-family articles in last 5 years**
- **Research Interest Score > 99% of ResearchGate members**

Wim Thiery



**KU LEUVEN**

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BRUSSEL

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- Brief self-introduction
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## Science

### Glacier preservation doubled by limiting warming to 1.5°C versus 2.7°C

Harry Zekollari<sup>1,2,3,\*†</sup>, Lilian Schuster<sup>4,\*†</sup>, Fabien Maussion<sup>5</sup>, Regine Hock<sup>6,7</sup>, Ben Marzeion<sup>8,9</sup>, David R. Rounce<sup>10</sup>, Loris Compagno<sup>2,11,12</sup>, Koji Fujita<sup>13</sup>, Matthias Huss<sup>2,11,14</sup>, Megan James<sup>15</sup>, Philip D. A. Kraaijenbrink<sup>16</sup>, William H. Lipscomb<sup>17</sup>, Samar Minallah<sup>17</sup>, Moritz Oberrauch<sup>18,19</sup>, Lander Van Tricht<sup>2,11,1</sup>, Nicolas Champollion<sup>20</sup>, Tamsin Edwards<sup>15</sup>, Daniel Farinotti<sup>2,11</sup>, Walter Immerzeel<sup>16</sup>, Gunter Leguy<sup>17</sup>, Akiko Sakai<sup>13</sup>

Glaciers adapt slowly to changing climatic conditions, with long-term implications for sea-level rise and water supply. Using eight glacier models, we simulated global glacier evolution over multicentennial timescales, allowing glaciers to equilibrate with climate under various constant global temperature scenarios. We estimate that glaciers globally will lose 39 (range, 15 to 55)%

(Zekollari, Schuster et al., 2025 Science)

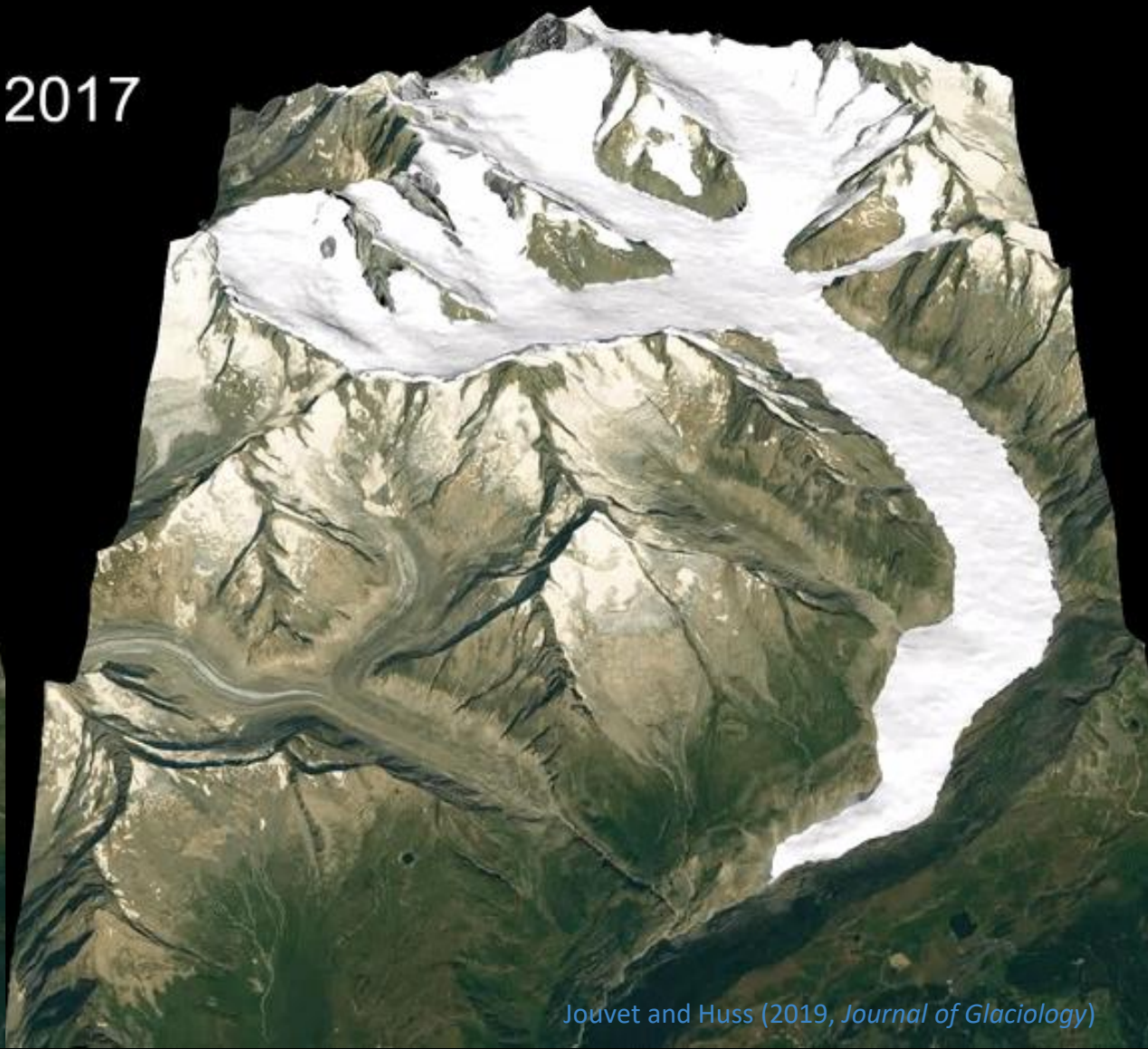
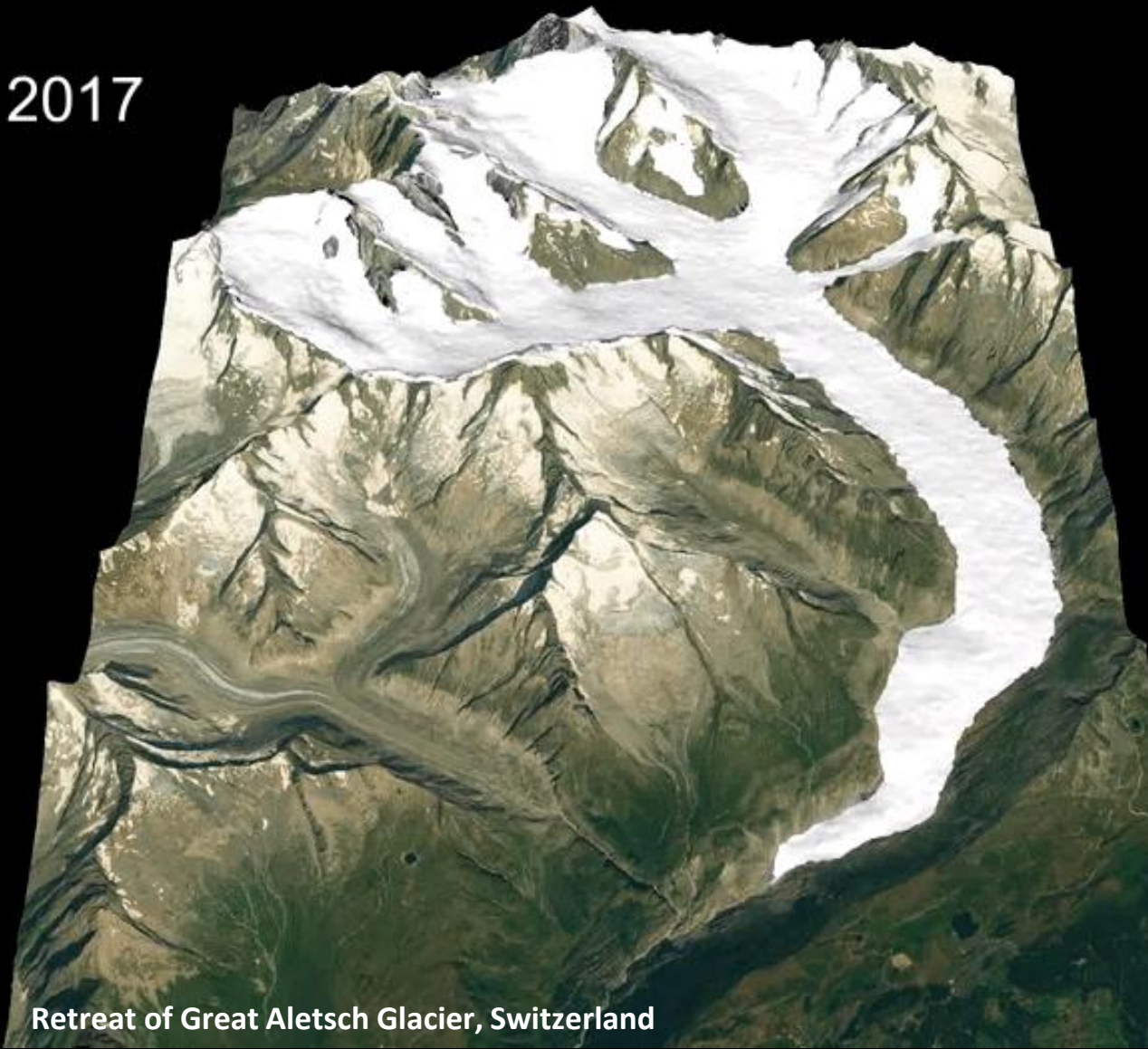


## Current emissions

## Very low emissions

2017

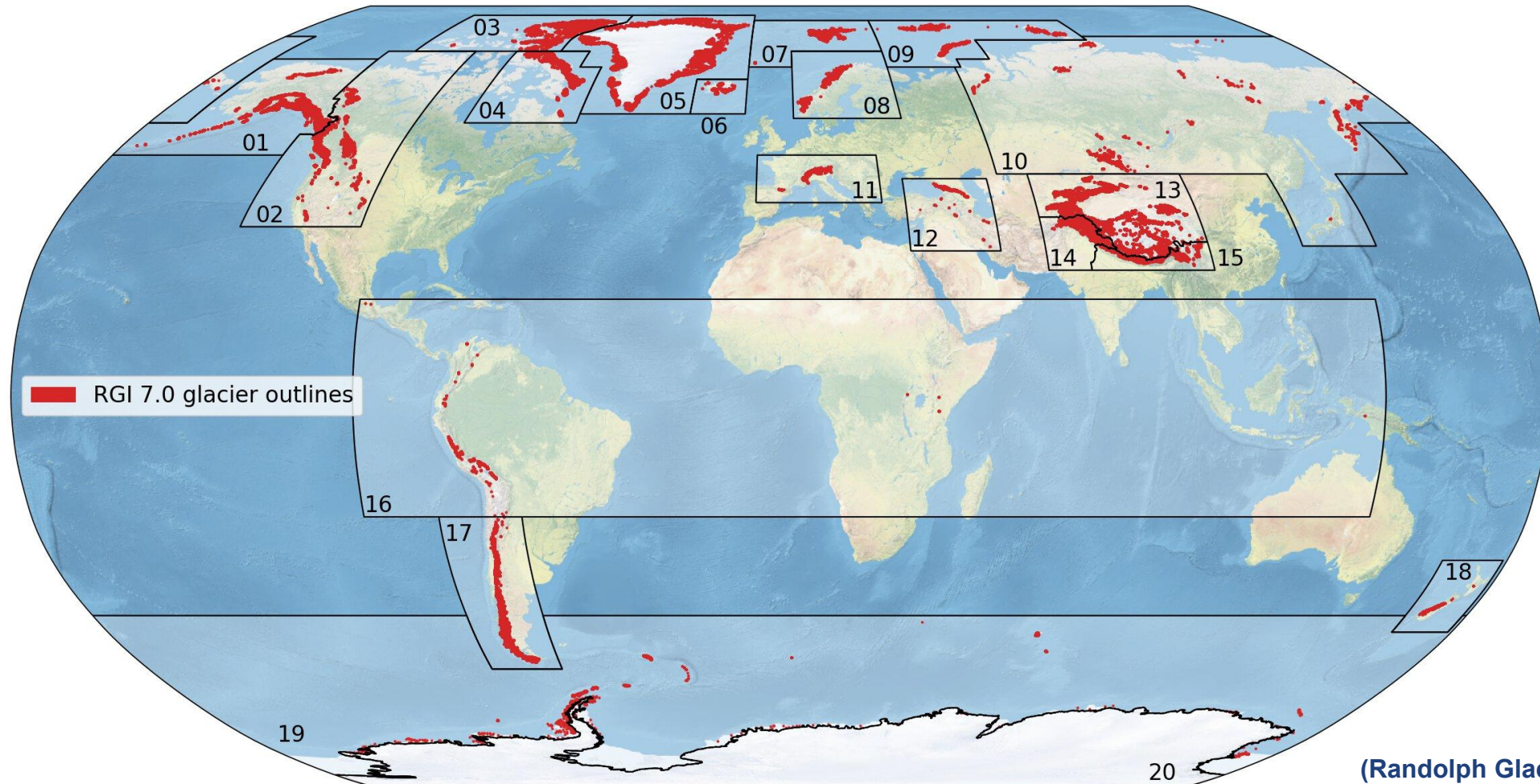
2017



Retreat of Great Aletsch Glacier, Switzerland

# Global glacier models

consistently represent 200 000 glaciers in the world

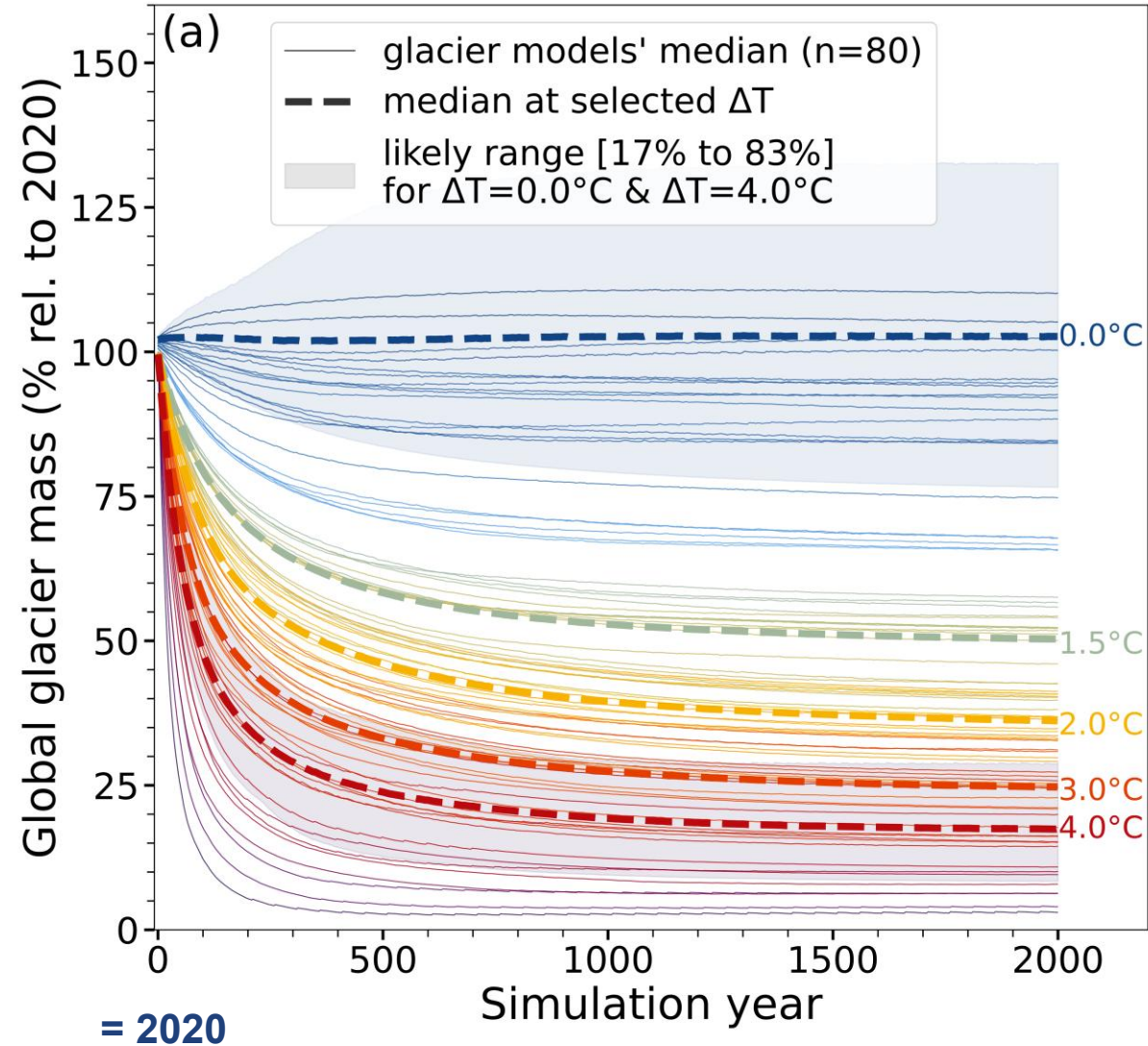


(Randolph Glacier Inventory 7.0;  
[https://www.glims.org/rgi\\_user\\_guide/02\\_regions\\_definition.html](https://www.glims.org/rgi_user_guide/02_regions_definition.html))

Note that glacier region 8 ('Scandinavia') roughly corresponds to mainland Norway

# Glacier Model Intercomparison Project round 3

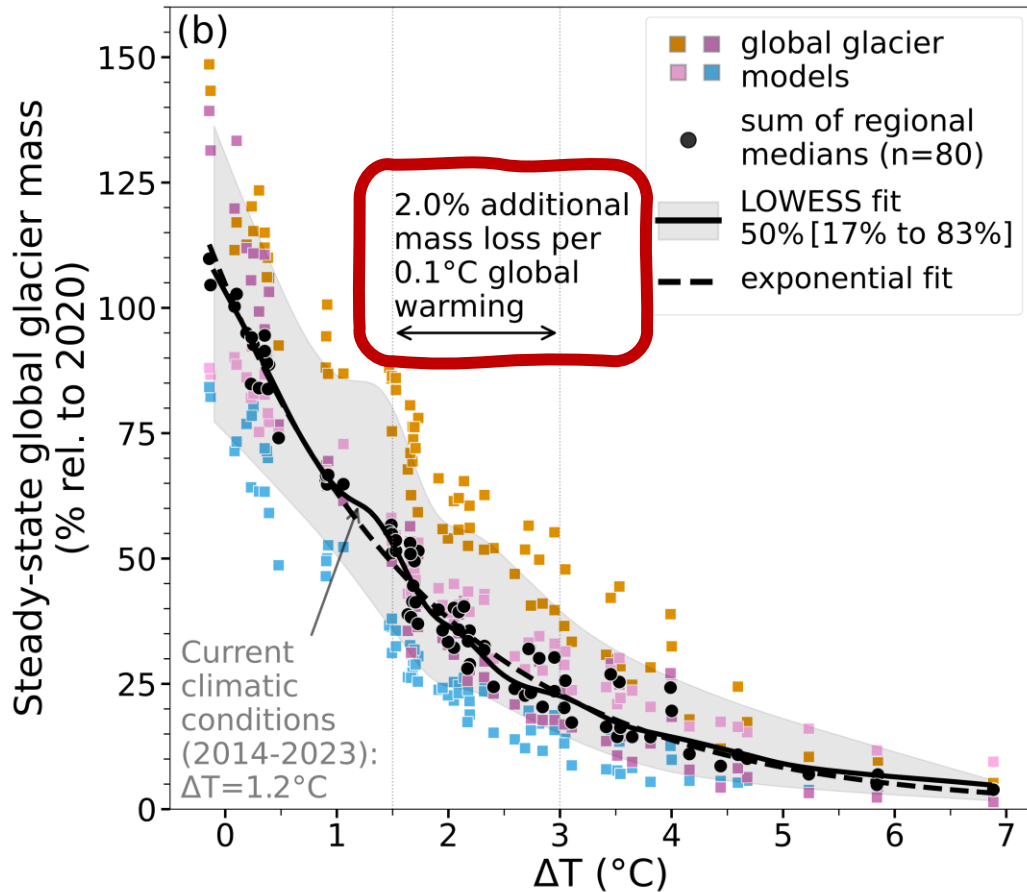
8 different global glacier models under 80 constant climate scenarios (0 – 4 °C global warming)



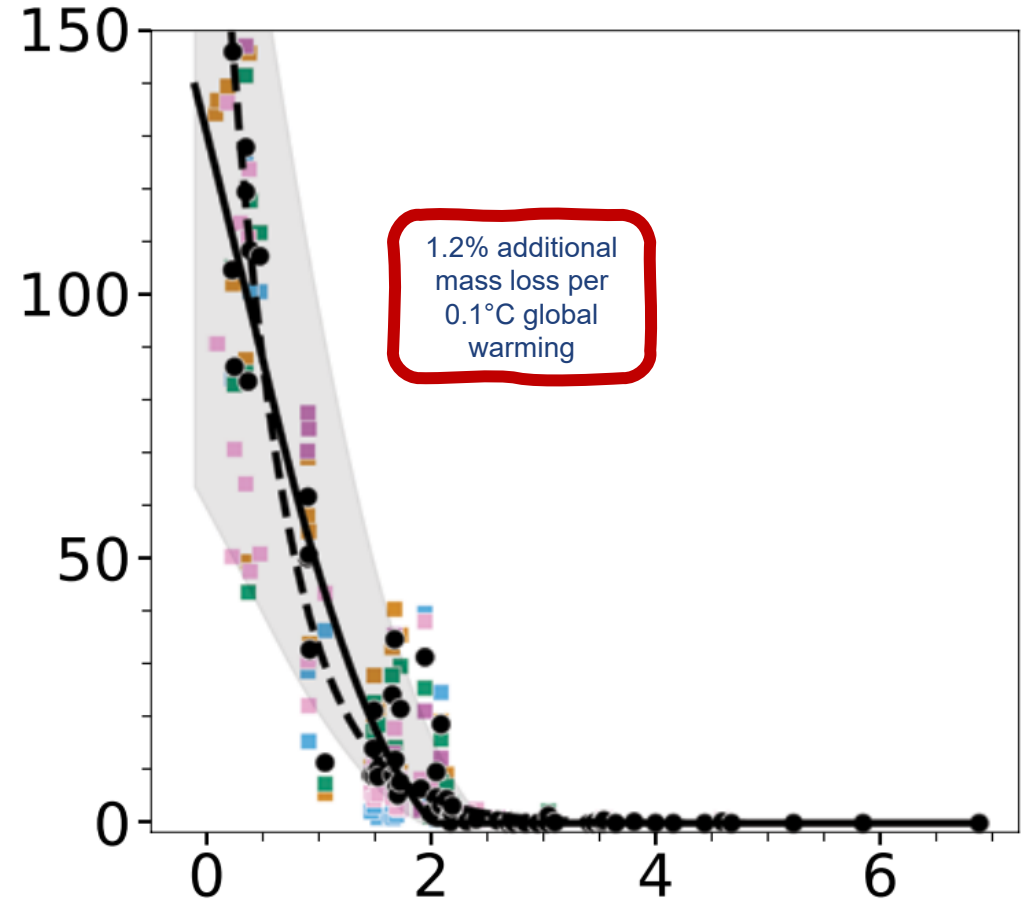
(Zekollari, Schuster et al., 2025 Science)

# Committed glacier loss as a function of global warming

## World



## Scandinavia

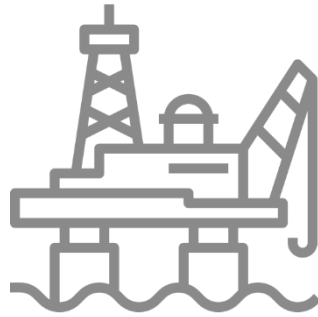


(Zekollari, Schuster et al., 2025 Science)

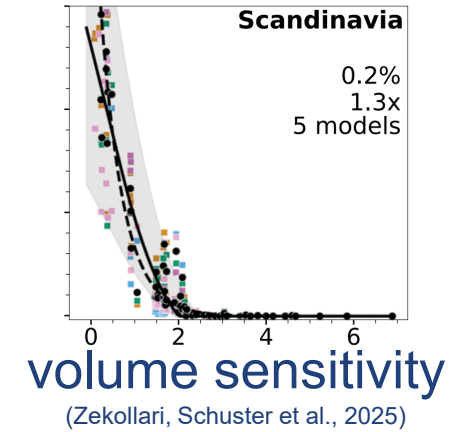
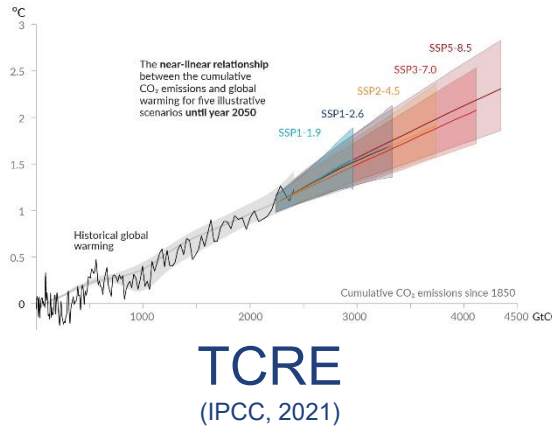
In a 2°C warmer world, Scandinavian Glaciers will vanish almost entirely

By using the sensitivity between 1,5°C and 3°C, our results are conservative, especially for Scandinavia

# Results applied to this situation



Emissions  
(values received)



$$0.48405 \text{ Gt } \cancel{\text{CO}_2 \text{ eq}} \times 0.45 \times 10^{-3} \frac{\cancel{\text{G}}}{\text{Gt } \cancel{\text{CO}_2 \text{ eq}}} \times 3.09 \times 10^{10} \frac{\text{m}^3}{\cancel{\text{G}}}$$

**Scandinavian glaciers will lose 6 883 000 m<sup>3</sup> of ice due to the total emissions of the three fields combined**

# Committed glacier mass loss

in m<sup>3</sup> at stabilisation expected per region and globally

Glacier mass loss in m<sup>3</sup> due to the total emissions of

<b>Region</b>	<b><u>Tyrving</u></b>	<b><u>Breidablikk</u></b>	<b>Yggdrasil</b>	<b>Combined</b>
<i>Arctic Canada South</i>	3484000	30858000	105295000	139638000
<i>Western Canada &amp; US</i>	576000	5102000	17410000	23089000
<i>Scandinavia</i>	171000	1521000	5190000	6883000
<i>Russian Arctic</i>	13312000	117883000	402239000	533435000
<i>Iceland</i>	4244000	37582000	128239000	170066000
<i><u>Greenland Periphery</u></i>	13769000	121929000	416045000	551744000
<i>Central Europe</i>	102000	909000	3102000	4114000
<i>North Asia</i>	105000	932000	3182000	4220000
<i>South Asia East</i>	673000	5964000	20352000	26990000
<i>Svalbard &amp; Jan Mayen</i>	9518000	84283000	287590000	381392000
<i>Southern Andes</i>	3957000	35043000	119573000	158574000
<i>Alaska</i>	19625000	173783000	592978000	786387000
<i><u>Sub &amp; Antarctic Islands</u></i>	42485000	376218000	1283721000	1702425000
<i>Arctic Canada North</i>	36024000	318997000	1088473000	1443495000
<i><u>Low Latitudes</u></i>	125000	1107000	3777000	5009000
<i><u>Caucasus &amp; Middle East</u></i>	72000	643000	2197000	2913000
<i>New Zealand</i>	92000	822000	2805000	3719000
<i>Central Asia</i>	5021000	44462000	151712000	201195000
<i>South Asia West</i>	5103000	45189000	154194000	204486000
<b>Global</b>	<b>166089000</b>	<b>1470741000</b>	<b>5018421000</b>	<b>6655251000</b>

# Key summary statistics

- Scandinavian glaciers will lose 171 000 m<sup>3</sup> due to the total emissions of Tyrving
- Scandinavian glaciers will lose 1 521 000 m<sup>3</sup> due to the total emissions of Breidablikk
- Scandinavian glaciers will lose 5 190 000 m<sup>3</sup> due to the total emissions of Yggdrasil
- Scandinavian glaciers will lose 6 883 000 m<sup>3</sup> due to the total emissions of the 3 fields combined
- Glaciers worldwide will lose 6 655 251 000 m<sup>3</sup> due to the total emissions of the 3 fields combined

**Note:**

- **Scandinavia ~ mainland Norway**
- **Values for annual emissions are available in the report**

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- Brief self-introduction
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- Heat-related mortality

Science

INSIGHTS

POLICY FORUM

CLIMATE CHANGE

## Intergenerational inequities in exposure to climate extremes

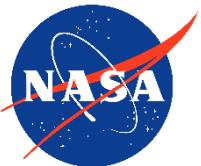
Young generations are severely threatened by climate change

By Wim Thiery, Stefan Lange, Joeri Rogelj, Carl-Friedrich Schleussner, Lukas Gudmundsson, Sonia I. Seneviratne, Marina Andrijevic, Katja Frieler, Kerry Emanuel, Tobias Geiger, David N. Bresch, Fang Zhao, Sven N. Willner, Matthias Büchner, Jan Volkholz, Nico Bauer, Jinfeng Chang, Philippe Ciais, Marie Dury, Louis François, Manolis Grillakis, Simon N. Gosling, Naota Hanasaki, Thomas Hickler, Veronika Huber, Akihiko Ito, Jonas Jägermeyr, Nikolay Khabarov, Aristeidis Koutroulis, Wenfeng Liu, Wolfgang Lutz, Matthias Mengel, Christoph Müller, Sebastian Ostberg, Christopher P. O. Reyer, Tobias Stacke, Yoshihide Wada

Under continued global warming, extreme events such as heat waves will continue to rise in frequency, intensity, duration, and spatial extent over the next decades (1–4). Younger generations are therefore expected to face more such events across their lifetimes compared with older generations.

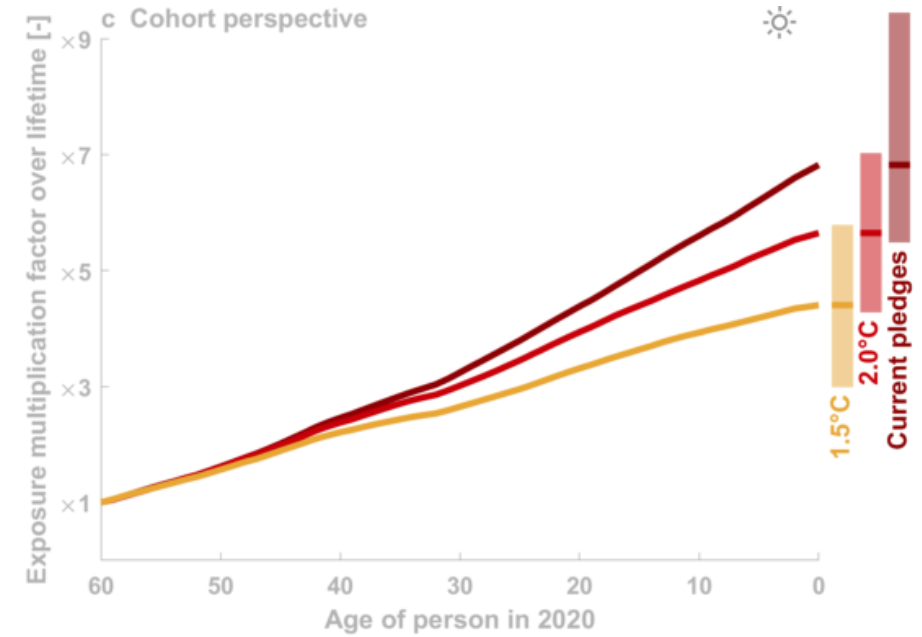
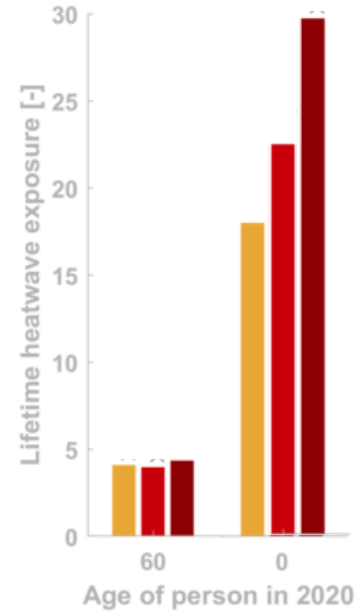
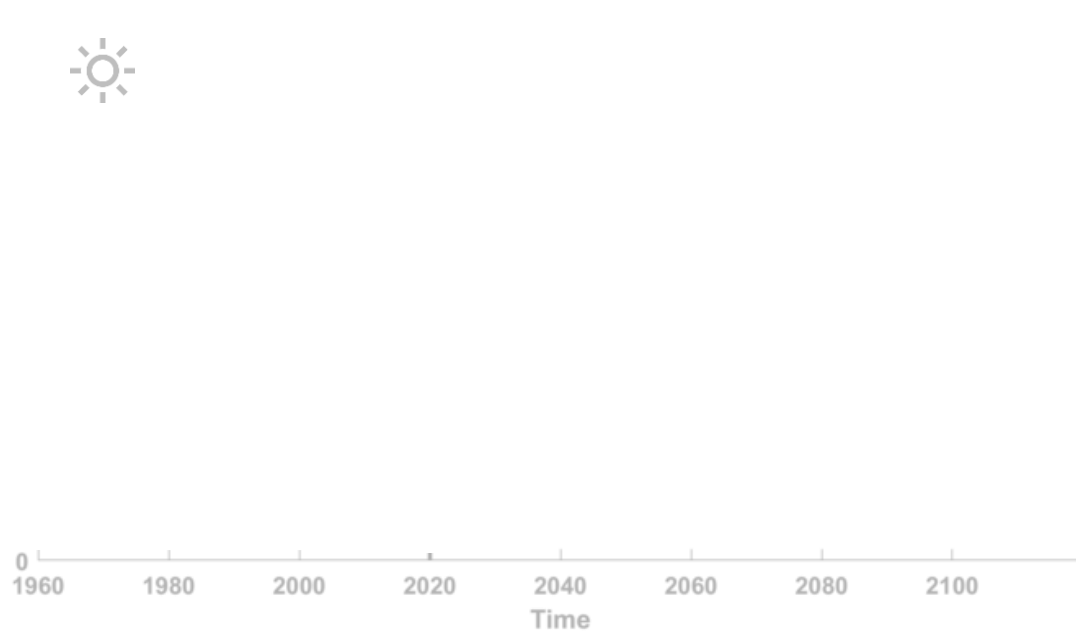
waves will increase from ~15% around 2020 to ~22% by 2100 under a scenario compatible with limiting global warming to 1.5°C, and to ~46% under a scenario in line with current emission reduction pledges (see the first figure). Recent studies extended this approach, studying aspects of climate change as a function of global mean temper-

(Thiery et al., 2021 Science)



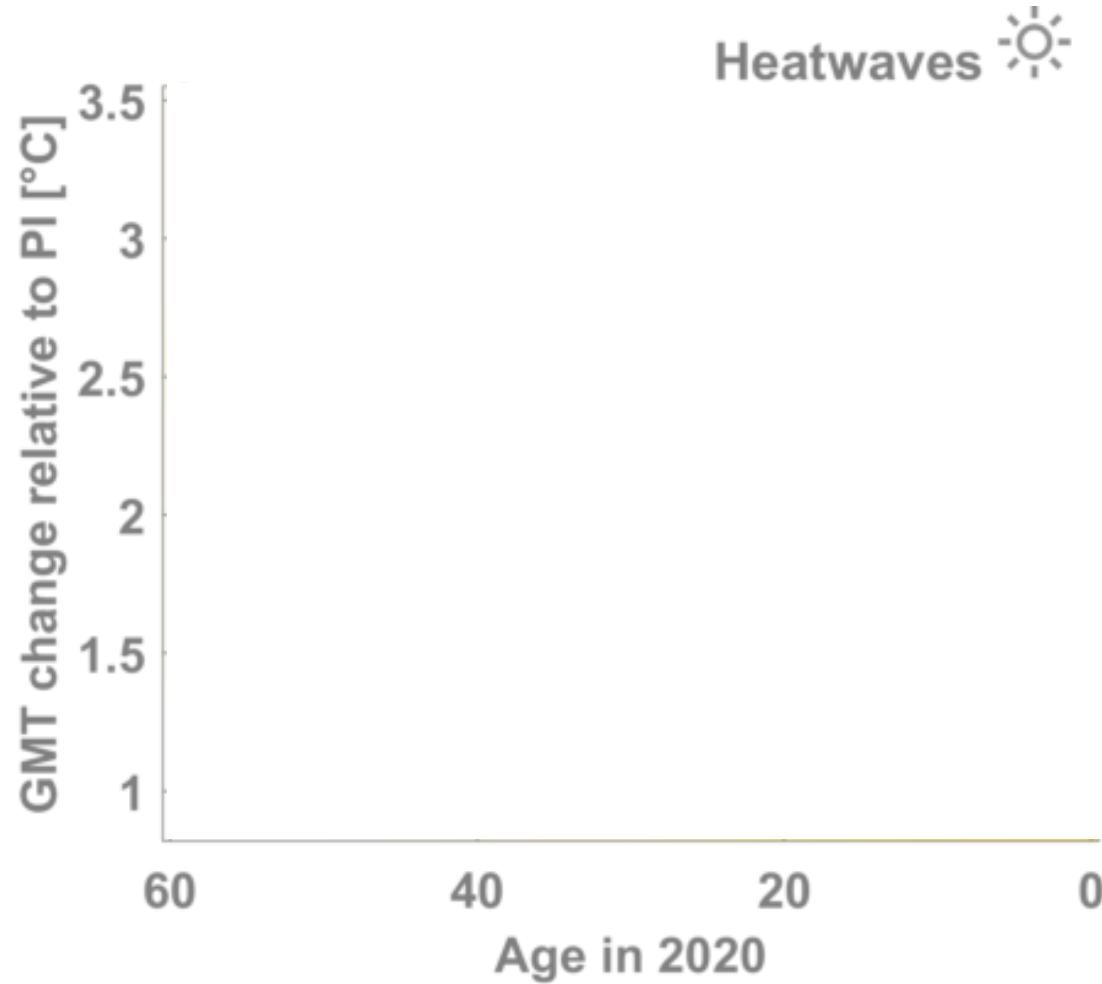
# The idea

Integrate exposure of an 'average person' to extreme events across lifetime



(Thiery et al., 2021 Science)

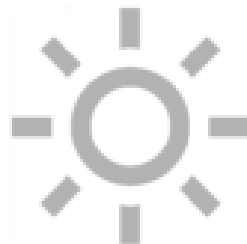
# Change in lifetime heatwave exposure



(Thiery et al., 2021 Science)

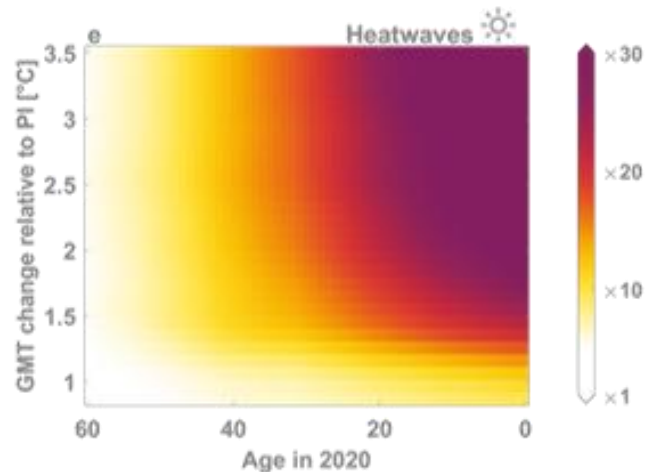
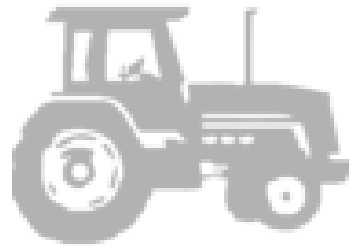
# Six impact categories

15 ISIMIP2b models, 273 global-scale projections



(Lange et al., 2020 EF)

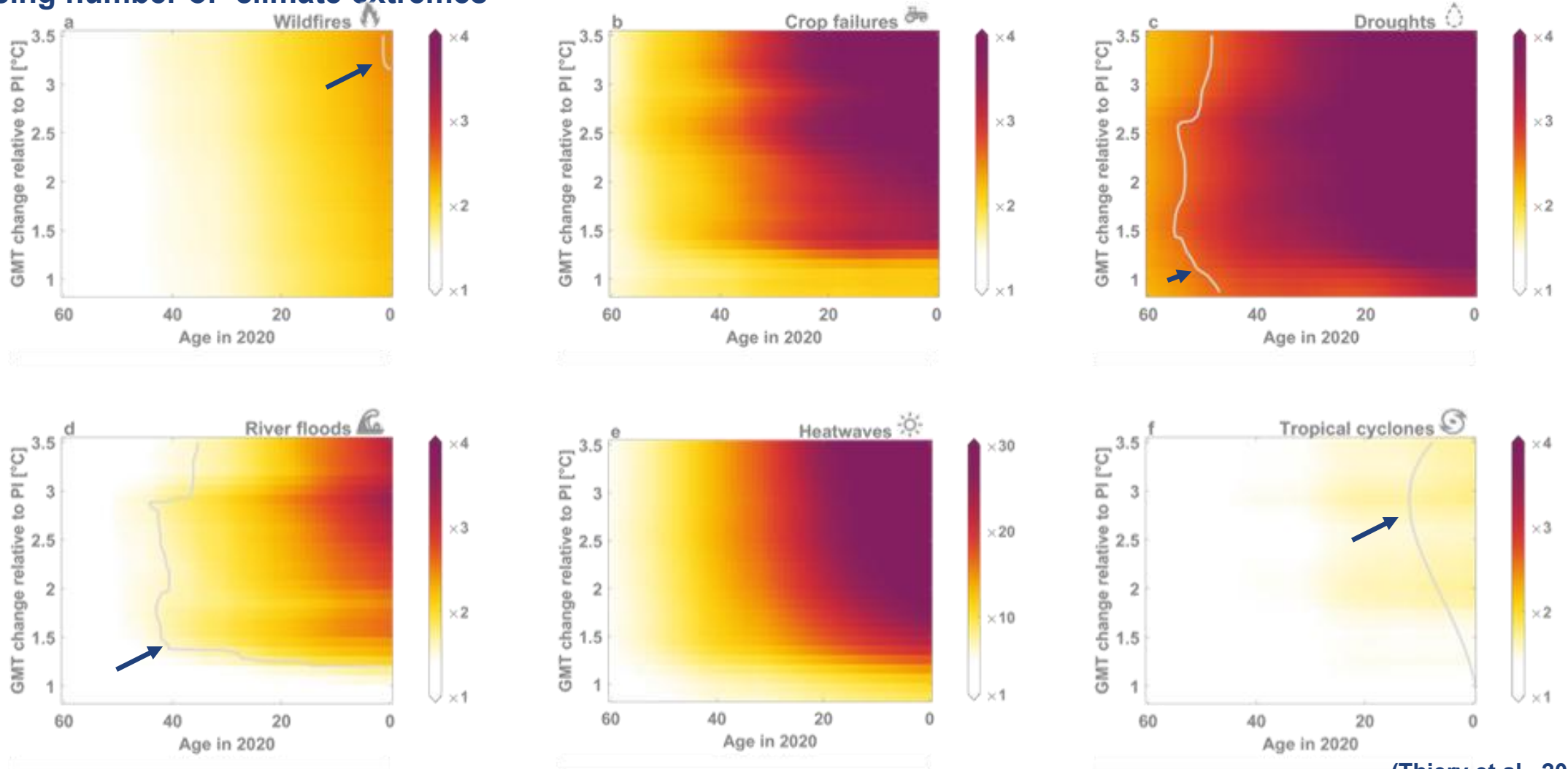
# We repeat the analysis of all 6 climate extremes



(Thiery et al., 2021 Science)

# Younger generations will be disproportionately exposed

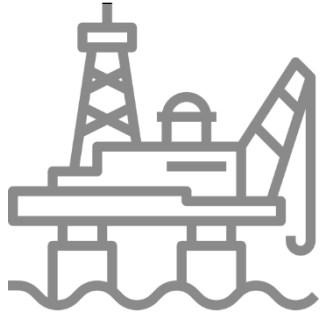
to a rising number of climate extremes



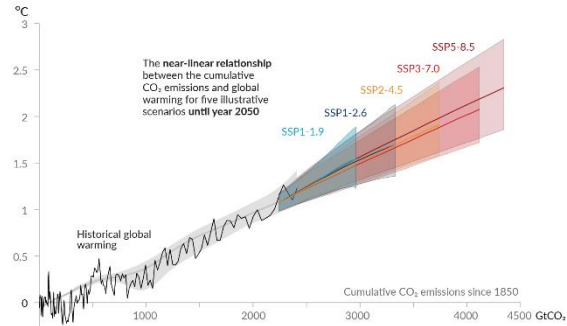
(Thiery et al., 2021 Science)

e.g. 6-yr old under 3°C: wildfires x2; TCs x2; river floods 3x; crop failures x4; droughts x5, heatwaves x36

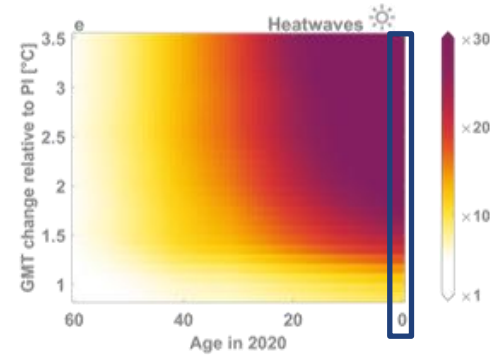
# Results applied to this situation



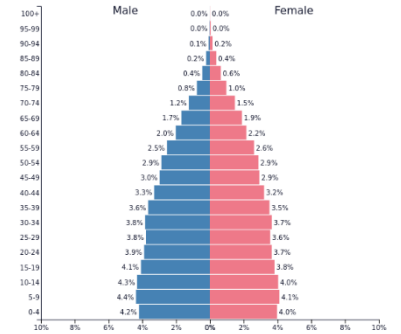
Emissions  
(values received)



TCRE  
(IPCC, 2021)



exposure slope  
(Thierry et al., 2021)



cohort size  
(UN, 2021)

$$0.48405 \text{ Gt CO}_2\text{eq} \times 0.45 \times 10^{-3} \frac{\text{heatwaves}}{\text{Gt CO}_2\text{eq}} \times 10.3783 \times 131\,702\,400 \text{ children}$$

**297 700 children born in 2020 will experience one extra heatwave due to the total emissions of the three fields combined**

## Results applied to this situation

- This example calculation represents the ‘best estimate’
- Just one example, calculation can be repeated for different emission values, birth cohorts and climate extremes
- This was done:
  - Tyrving, Breidablikk, Yggdrasil and combined
  - Annual and total values (only totals in this presentation)
  - Birth years 2010-2020
  - 6 climate extremes: heatwaves, droughts, crop failures, wildfires, tropical cyclones, river floods
- All single-cohort results rounded to the lower 100

# Results applied to this situation

Number of children facing an additional **heatwave** due to the **total** emissions of

Number of children facing an additional **drought** due to the **total** emissions of

Number of children facing an additional **crop failure** due to the **total** emissions of

Number of children facing an additional **wildfire** due to the **total** emissions of

Number of children facing an additional **tropical cyclone** due to the **total**

Number of children facing an additional **river flood** due to the **total** emissions of

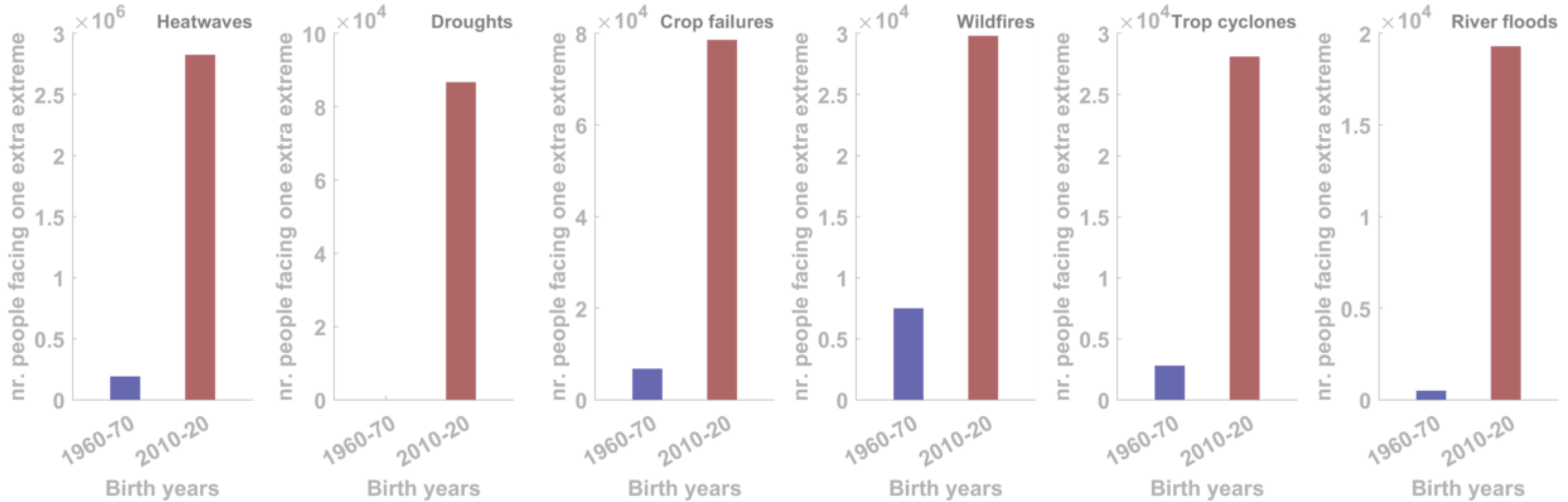
<i>Birth year</i>	<u>Tyrving</u>	<u>Breidablikk</u>	Yggdrasil	Combined
2020	0	400	1600	2100
2019	0	400	1500	2000
2018	0	400	1500	2000
2017	0	400	1400	1900
2016	0	400	1400	1800
2015	0	300	1300	1700
2014	0	300	1300	1700
2013	0	300	1200	1600
2012	0	300	1200	1600
2011	0	300	1100	1500
2010	0	300	1100	1400
<b>2010-2020</b>	<b>0</b>	<b>3800</b>	<b>14600</b>	<b>19300</b>

# Key summary statistics

- 2 824 900 children born in the years 2010 to 2020 are expected to face one additional heatwave in their lifetime due to the total emissions of Tyrving, Breidablikk, and Yggdrasil combined
- Analogously:
  - 86 700 children are expected to face one additional drought
  - 78 600 children are expected to face one additional crop failure
  - 29 800 children are expected to face one additional wildfire
  - 28 100 children are expected to face one additional tropical cyclone
  - 19 300 children are expected to face one additional river flood

# Additional exposure affects young generations disproportionately

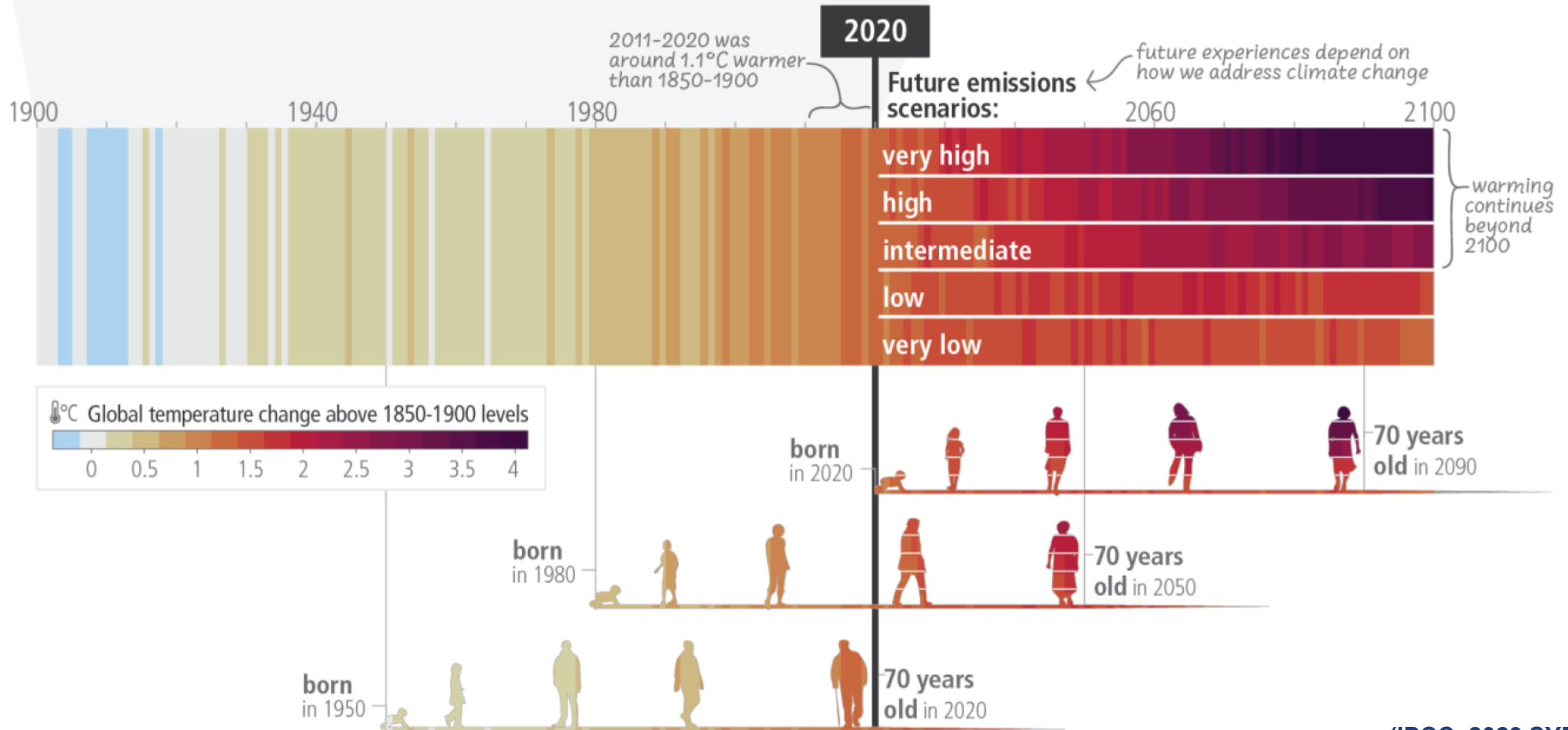
as this is a larger group & as they will live more years under a climate affected by near-term emissions



Note the different y-axis ranges

(Thiery, 2025)

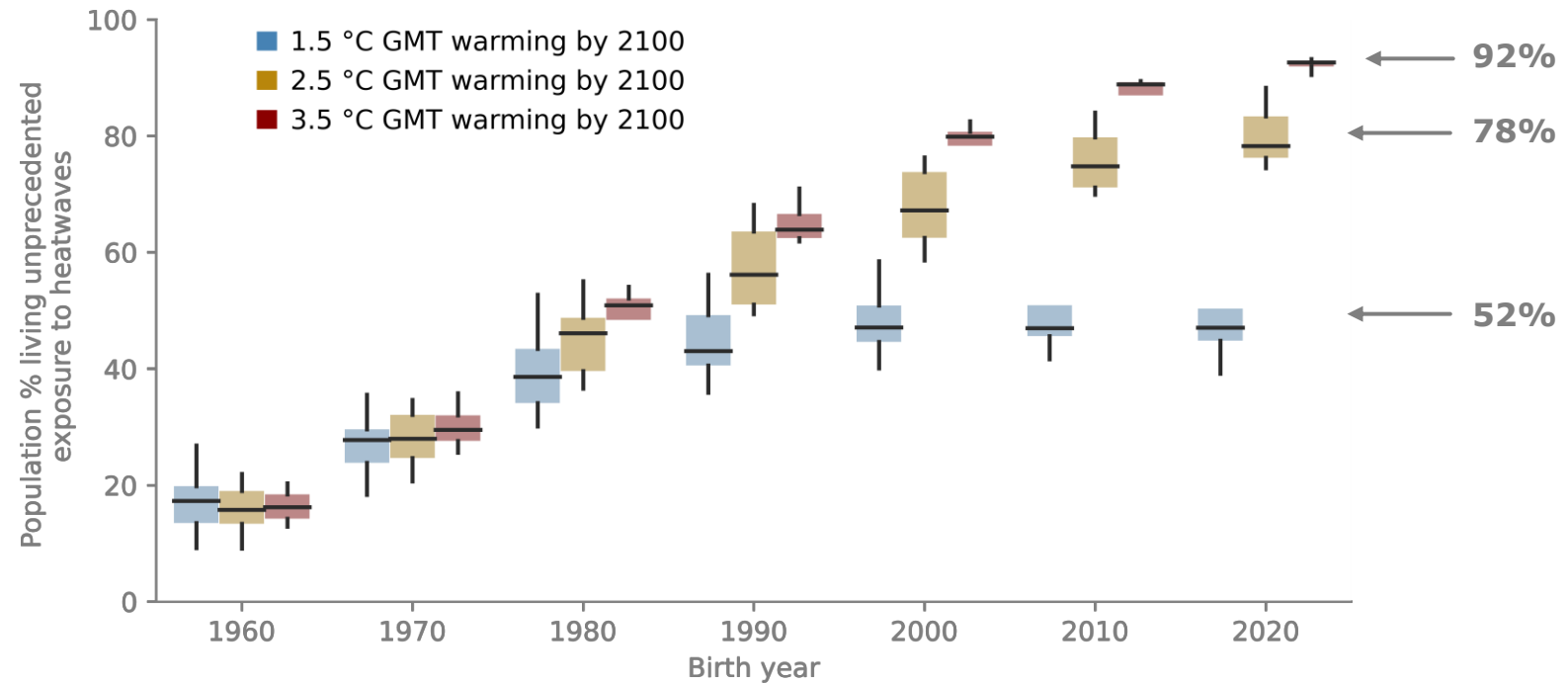
### c) The extent to which current and future generations will experience a hotter and different world depends on choices now and in the near-term



(IPCC, 2023 SYR SPM)

# With every increment of warming

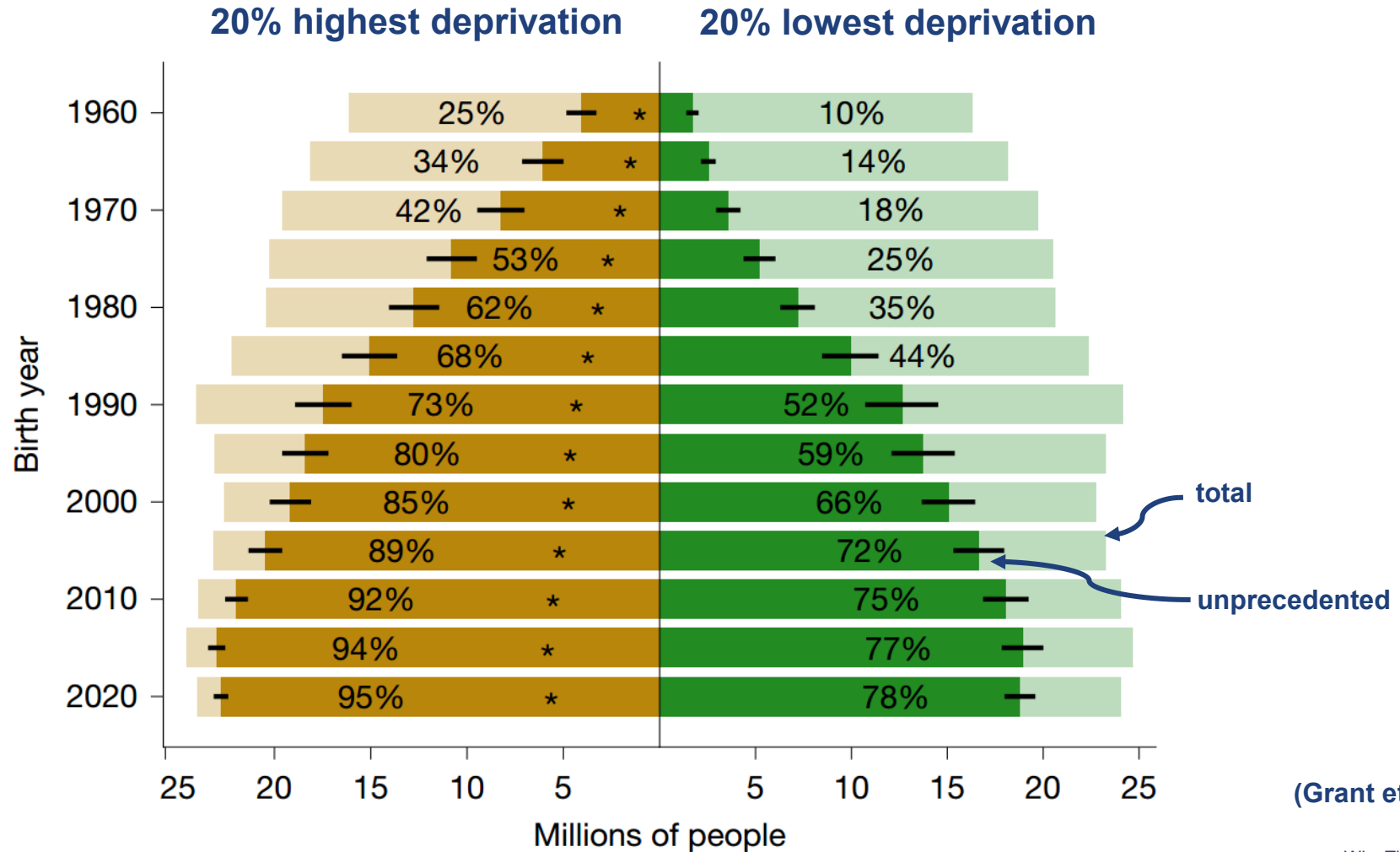
an increasing number of young people will experience an unprecedented number of extreme heatwaves



(Grant et al., 2025 Nature)

# Including climate change in the age pyramid

under a 2,7°C warming pathway



(Grant et al., 2025 Nature)

# This presentation

- Brief self-introduction
- Glacier volume
- Lifetime extreme event exposure
- Heat-related mortality



COLUMBIA UNIVERSITY  
IN THE CITY OF NEW YORK




## ARTICLE

<https://doi.org/10.1038/s41467-021-24487-w>

OPEN

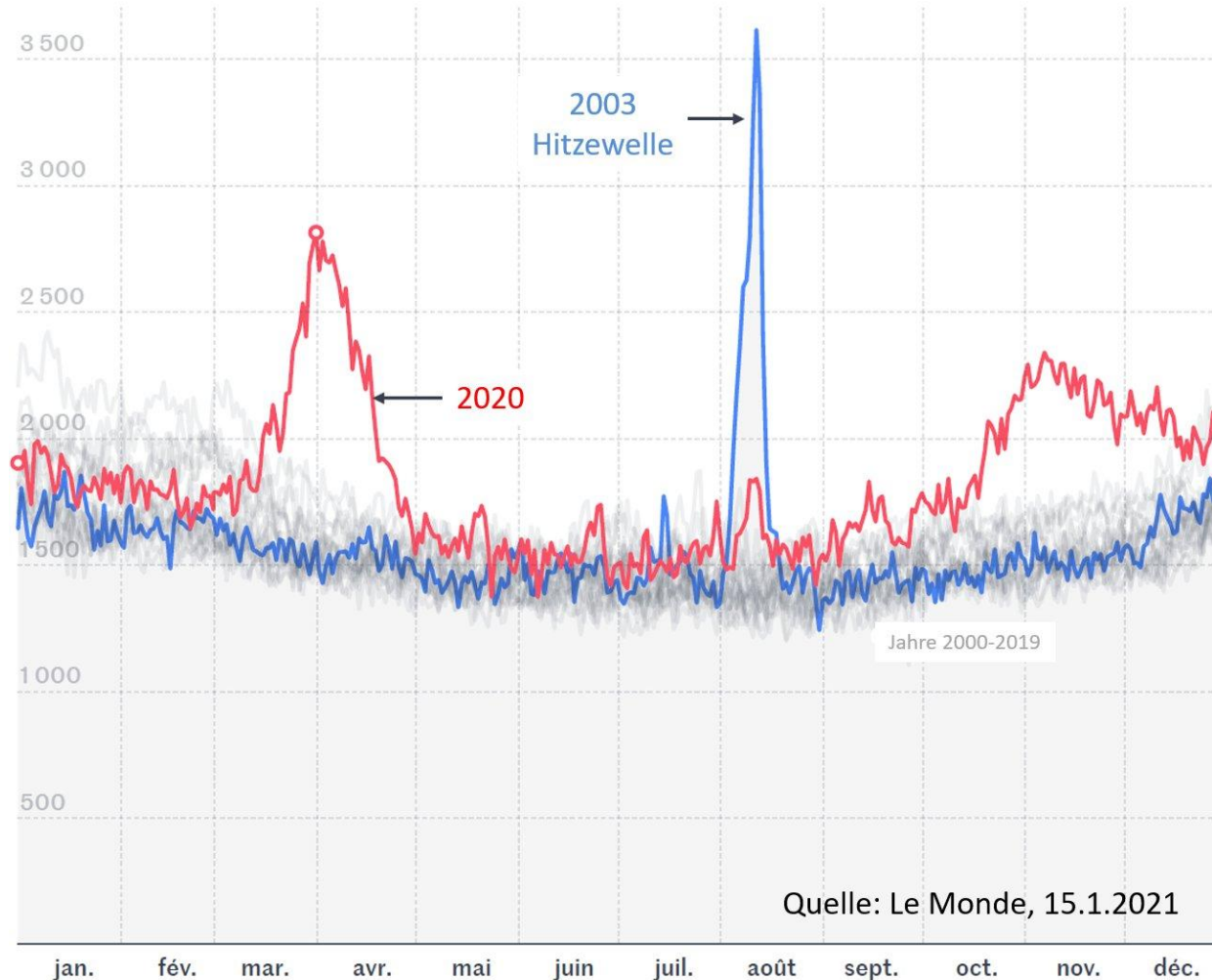
## The mortality cost of carbon

R. Daniel Bressler  <sup>1,2,3</sup>✉

Many studies project that climate change can cause a significant number of excess deaths. Yet, in integrated assessment models (IAMs) that determine the social cost of carbon (SCC) and prescribe optimal climate policy, human mortality impacts are limited and not updated to the latest scientific understanding. This study extends the DICE-2016 IAM to explicitly include temperature-related mortality impacts by estimating a climate-mortality damage function. We introduce a metric, the mortality cost of carbon (MCC), that estimates the number of deaths caused by the emissions of one additional metric ton of CO<sub>2</sub>. In the baseline emissions scenario, the 2020 MCC is  $2.26 \times 10^{-4}$  [low to high estimate  $-1.71 \times 10^{-4}$  to  $6.78 \times 10^{-4}$ ] excess deaths per metric ton of 2020 emissions. This implies that adding 4,434 metric tons of carbon dioxide in 2020—equivalent to the lifetime emissions of 3.5 average Americans—causes one excess death globally in expectation between 2020-2100. Incorporating mortality costs increases the 2020 SCC from \$37 to \$258 [–\$69 to \$545] per metric ton in the baseline emissions scenario. Optimal climate policy changes from gradual emissions reductions starting in 2050 to full decarbonization by 2050 when mortality is considered.

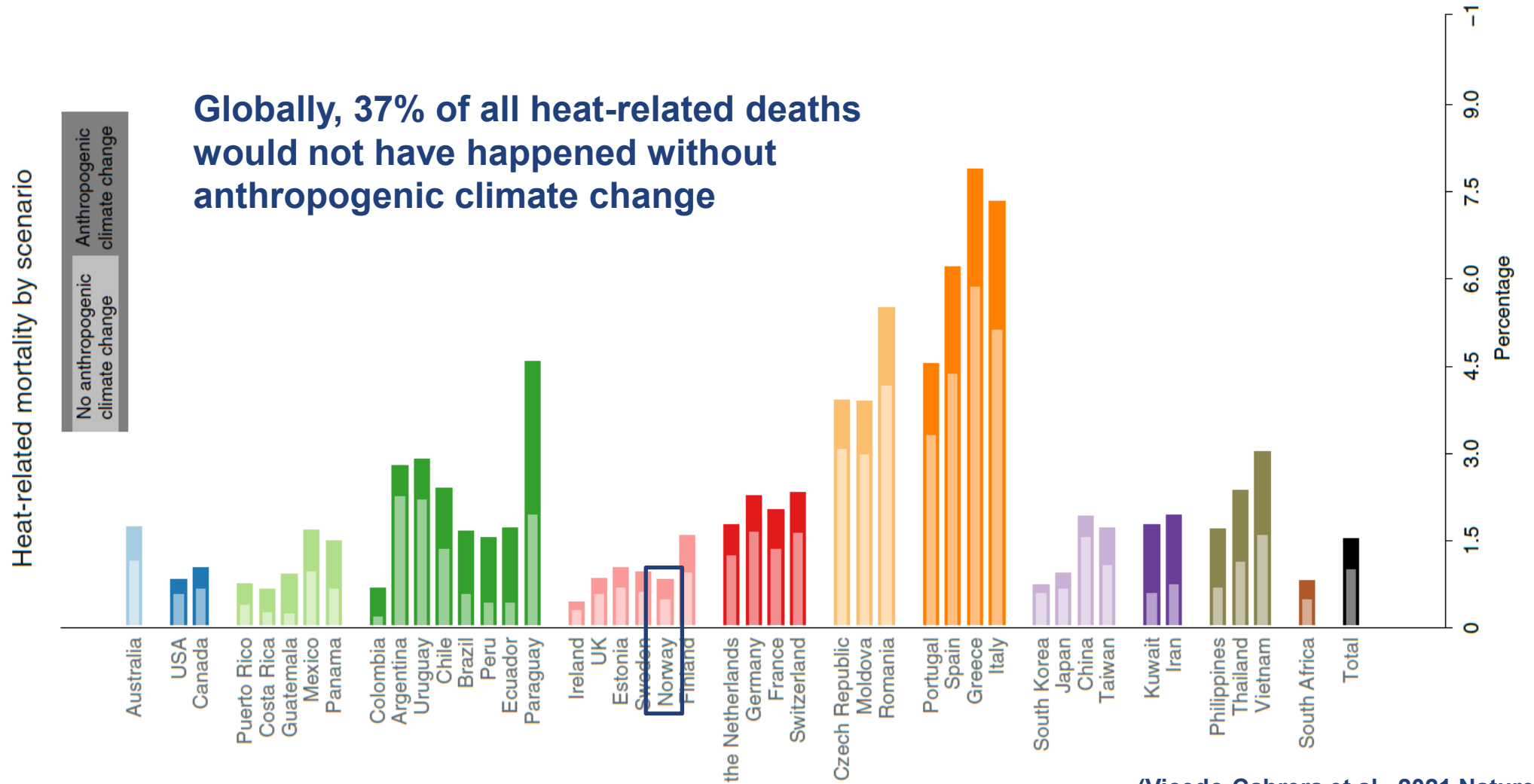
**(Bressler, 2021 Nature Comm.)**

# Human mortality: 2003 summer heat wave (France)



- “We estimate it is very likely (confidence level >90%) that human influence has at least doubled the risk of a heatwave exceeding this threshold magnitude” (Stott et al., 2004 Nature)
- “Out of the estimated ~315 and ~735 summer deaths attributed to the heatwave event in Greater London and Central Paris, respectively, 64 ( $\pm 3$ ) deaths were attributable to anthropogenic climate change in London, and 506 ( $\pm 51$ ) in Paris.” (Mitchell et al., 2016 Env. Res. Lett.)

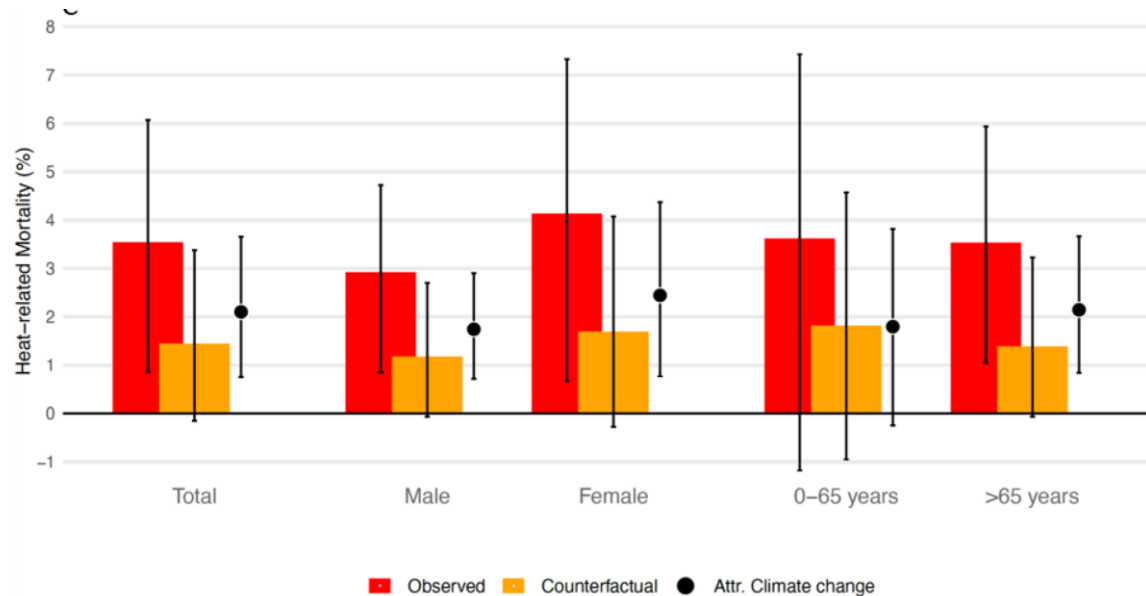
# Heat-related deaths, 1991-2018



(Vicedo-Cabrera et al., 2021 Nature Clim. Ch.)

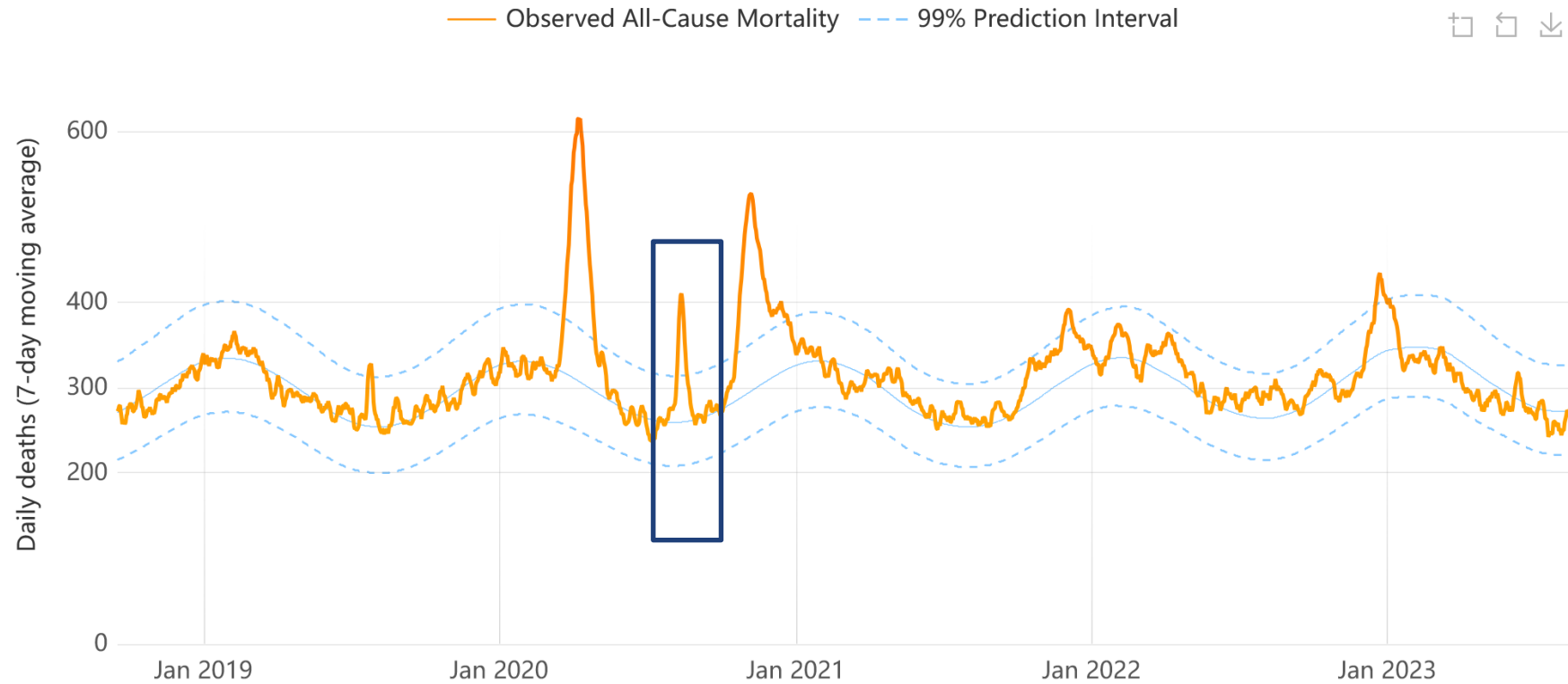
# The fraction in recent heatwaves is even higher

- Switzerland, summer 2022
  - “We estimate 623 deaths [151 - 1,068] due to heat between June-August 2022, corresponding to 3.5% of all-cause mortality.”
  - “More importantly, we find that 60% of this burden (370 deaths [133-644]) could have been avoided in absence of human-induced climate change.”



(Vicedo-Cabrera et al., 2023 *Env. Res. Lett.*)

# Belgium



**“in the absence of human-caused climate change, almost 70% of this burden could have been prevented” (Tran, 2024)**

# Risk of heat-related mortality is rising rapidly



(Lüthi et al., 2023 Nature Comm.)

# The mortality cost of Carbon

“4 434 metric tons of carbon dioxide in 2020 [...] causes one excess death globally in expectation between 2020-2100” \*

Results applied to this situation (best estimate):

0,01208 GT CO <sub>2</sub> eq (Tyrving)	→	<b>2 700</b>	people dying prematurely somewhere in the world between 2020-2100
0,10697 GT CO <sub>2</sub> eq (Breidablikk)	→	<b>24 100</b>	people dying prematurely somewhere in the world between 2020-2100
0,36500 GT CO <sub>2</sub> eq (Yggdrasil)	→	<b>82 300</b>	people dying prematurely somewhere in the world between 2020-2100
0,48405 GT CO <sub>2</sub> eq (Combined)	→	<b>109 100</b>	people dying prematurely somewhere in the world between 2020-2100

\* assuming an overall high-emission scenario

(Bressler, 2021 Nature Comm.)

# Climate change, extreme events, & climate victims

**Prof. Dr. Wim Thiery**

# Emission values – used as input

Emissions (MtCO<sub>2</sub>eq) used as input in the calculations

<i>Time period</i>	<u>Tyrving</u>	<u>Breidablikk</u>	Yggdrasil	Combined
<i>Total</i>	12.08	106.97	365	484.05
<i>2024</i>	0.435	10.14	-	-
<i>2025</i>	3.08	10.39	-	-
<i>2026</i>	1.697	8.66	-	-
<i>2027</i>	1.262	8.08	28.8	-
<i>2028</i>	-	-	42.4	-

# Heatwaves – total emissions

Number of children facing an additional **heatwave** due to the **total** emissions of

<i>Birth year</i>	<u>Tyrving</u>	<u>Breidablikk</u>	Yggdrasil	Combined
2020	7400	65700	224500	297700
2019	7200	63900	218100	289300
2018	7000	62100	211900	281100
2017	6800	60300	206000	273200
2016	6600	58600	200000	265300
2015	6400	56900	194200	257500
2014	6200	55100	188200	249500
2013	6000	53400	182200	241600
2012	5700	51300	175200	232300
2011	5500	49300	168200	223100
2010	5300	47300	161500	214300
<b>2010-2020</b>	<b>70100</b>	<b>623900</b>	<b>2130000</b>	<b>2824900</b>

# Droughts – total emissions

Number of children facing an additional **drought** due to the **total** emissions of

<i>Birth year</i>	<u>Tyrving</u>	<u>Breidablikk</u>	Yggdrasil	Combined
2020	200	2100	7200	9600
2019	200	2000	6900	9200
2018	200	1900	6600	8800
2017	200	1800	6400	8400
2016	200	1800	6100	8200
2015	100	1700	5900	7900
2014	100	1600	5700	7600
2013	100	1600	5500	7300
2012	100	1500	5200	6900
2011	100	1400	4900	6600
2010	100	1300	4700	6200
<b>2010-2020</b>	<b>1600</b>	<b>18700</b>	<b>65100</b>	<b>86700</b>

# Crop failures – total emissions

Number of children facing an additional **crop failure** due to the **total** emissions of

<i>Birth year</i>	<u>Tyrving</u>	<u>Breidablikk</u>	Yggdrasil	Combined
2020	200	1700	6000	8000
2019	100	1700	5900	7800
2018	100	1700	5800	7700
2017	100	1600	5600	7500
2016	100	1600	5500	7300
2015	100	1500	5400	7200
2014	100	1500	5300	7000
2013	100	1500	5100	6800
2012	100	1400	5000	6600
2011	100	1400	4800	6400
2010	100	1300	4700	6300
<b>2010-2020</b>	<b>1200</b>	<b>16900</b>	<b>59100</b>	<b>78600</b>

# Wildfires – total emissions

Number of children facing an additional **wildfire** due to the **total** emissions of

<i>Birth year</i>	<u>Tyrving</u>	<u>Breidablikk</u>	Yggdrasil	Combined
2020	0	600	2300	3000
2019	0	600	2200	3000
2018	0	600	2200	2900
2017	0	600	2100	2900
2016	0	600	2100	2800
2015	0	600	2000	2700
2014	0	600	2000	2700
2013	0	500	1900	2600
2012	0	500	1900	2500
2011	0	500	1800	2400
2010	0	500	1800	2300
<b>2010-2020</b>	<b>0</b>	<b>6200</b>	<b>22300</b>	<b>29800</b>

# Tropical cyclones – total emissions

Number of children facing an additional **tropical cyclone** due to the **total** emissions of

<i>Birth year</i>	<u>Tyrving</u>	<u>Breidablikk</u>	Yggdrasil	Combined
2020	0	600	2200	2900
2019	0	600	2100	2800
2018	0	600	2100	2800
2017	0	600	2000	2700
2016	0	500	2000	2600
2015	0	500	1900	2600
2014	0	500	1900	2500
2013	0	500	1800	2500
2012	0	500	1800	2300
2011	0	500	1700	2200
2010	0	400	1600	2200
<b>2010-2020</b>	<b>0</b>	<b>5800</b>	<b>21100</b>	<b>28100</b>

# River floods – total emissions

Number of children facing an additional **river flood** due to the **total** emissions of

<i>Birth year</i>	<u>Tyrving</u>	<u>Breidablikk</u>	Yggdrasil	Combined
2020	0	400	1600	2100
2019	0	400	1500	2000
2018	0	400	1500	2000
2017	0	400	1400	1900
2016	0	400	1400	1800
2015	0	300	1300	1700
2014	0	300	1300	1700
2013	0	300	1200	1600
2012	0	300	1200	1600
2011	0	300	1100	1500
2010	0	300	1100	1400
<b>2010-2020</b>	<b>0</b>	<b>3800</b>	<b>14600</b>	<b>19300</b>

# Heat-related mortality – total emissions

Regarding question 3; The following table provides the number of heat-related deaths expected worldwide until 2100 due to the total emissions of Tyrving, Breidablikk, Yggdrasil, and all three combined.

	Number of heat-related deaths until 2100 due to the total emissions of			
	<u>Tyrving</u>	<u>Breidablikk</u>	<u>Yggdrasil</u>	<b>Combined</b>
<i>Additional heat-related deaths until 2100</i>	2700	24100	82300	109100

The results<sup>3</sup> imply that

- 2 700 heat-related deaths are expected worldwide until 2100 due to the total emissions of Tyrving.
- 24 100 heat-related deaths are expected worldwide until 2100 due to the total emissions of Breidablikk.
- 82 300 heat-related deaths are expected worldwide until 2100 due to the total emissions of Yggdrasil.
- 109 100 heat-related deaths are expected worldwide until 2100 due to the total emissions of Tyrving, Breidablikk, and Yggdrasil combined.

# annual emissions

**Regarding question 5;** The following table provides the number of children born in a particular birth year worldwide expected to face one additional heatwave, drought, wildfire, tropical cyclone, crop failure, or river flood due to the emissions of Tyrving and Breidablikk in the calendar years 2024, 2025, 2026 and 2027, and Yggdrasil in the calendar years 2027 and 2028. Note that for each value of 0 in the tables below, the method in fact returned a number between 1 and 99, which was subsequently rounded downwards to 0.

# Heatwaves – annual emissions

Number of children facing an additional **heatwave** due to the **annual** emissions of

<i>Birth year</i>	<del>Tyrving</del> 2024	<del>Tyrving</del> 2025	<del>Tyrving</del> 2026	<del>Tyrving</del> 2027	<del>Breidablikk</del> 2024	<del>Breidablikk</del> 2025	<del>Breidablikk</del> 2026	<del>Breidablikk</del> 2027	<del>Yggdrasil</del> 2027	<del>Yggdrasil</del> 2028
2020	200	1800	1000	700	6200	6300	5300	4900	17700	26000
2019	200	1800	1000	700	6000	6200	5100	4800	17200	25300
2018	200	1700	900	700	5800	6000	5000	4600	16700	24600
2017	200	1700	900	700	5700	5800	4800	4500	16200	23900
2016	200	1600	900	600	5500	5600	4700	4400	15700	23200
2015	200	1600	900	600	5300	5500	4600	4200	15300	22500
2014	200	1500	800	600	5200	5300	4400	4100	14800	21800
2013	200	1500	800	600	5000	5100	4300	4000	14300	21100
2012	200	1400	800	600	4800	4900	4100	3800	13800	20300
2011	200	1400	700	500	4600	4700	3900	3700	13200	19500
2010	100	1300	700	500	4400	4600	3800	3500	12700	18700
<b>2010-2020</b>	<b>2100</b>	<b>17300</b>	<b>9400</b>	<b>6800</b>	<b>58500</b>	<b>60000</b>	<b>50000</b>	<b>46500</b>	<b>167600</b>	<b>246900</b>

# Droughts – annual emissions

Number of children facing an additional **drought** due to the **annual** emissions of

<i>Birth year</i>	<u>Tyrving</u>	<u>Tyrving</u>	<u>Tyrving</u>	<u>Tyrving</u>	<u>Breidablikk</u>	<u>Breidablikk</u>	<u>Breidablikk</u>	<u>Breidablikk</u>	<u>Yggdrasil</u>	<u>Yggdrasil</u>
	2024	2025	2026	2027	2024	2025	2026	2027	2027	2028
2020	0	0	0	0	200	200	100	100	500	800
2019	0	0	0	0	100	100	100	100	500	800
2018	0	0	0	0	100	100	100	100	500	700
2017	0	0	0	0	100	100	100	100	500	700
2016	0	0	0	0	100	100	100	100	400	700
2015	0	0	0	0	100	100	100	100	400	600
2014	0	0	0	0	100	100	100	100	400	600
2013	0	0	0	0	100	100	100	100	400	600
2012	0	0	0	0	100	100	100	100	400	600
2011	0	0	0	0	100	100	100	100	300	500
2010	0	0	0	0	100	100	100	100	300	500
<b>2010-2020</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>1200</b>	<b>1200</b>	<b>1100</b>	<b>1100</b>	<b>4600</b>	<b>7100</b>

# Crop failures – annual emissions

Number of children facing an additional **crop failure** due to the **annual** emissions of

<i>Birth year</i>	<u>Tyrving</u>	<u>Tyrving</u>	<u>Tyrving</u>	<u>Tyrving</u>	<u>Breidablikk</u>	<u>Breidablikk</u>	<u>Breidablikk</u>	<u>Breidablikk</u>	<u>Yggdrasil</u>	<u>Yggdrasil</u>
	2024	2025	2026	2027	2024	2025	2026	2027	2027	2028
2020	0	0	0	0	100	100	100	100	400	700
2019	0	0	0	0	100	100	100	100	400	600
2018	0	0	0	0	100	100	100	100	400	600
2017	0	0	0	0	100	100	100	100	400	600
2016	0	0	0	0	100	100	100	100	400	600
2015	0	0	0	0	100	100	100	100	400	600
2014	0	0	0	0	100	100	100	100	400	600
2013	0	0	0	0	100	100	100	100	400	600
2012	0	0	0	0	100	100	100	100	300	500
2011	0	0	0	0	100	100	100	100	300	500
2010	0	0	0	0	100	100	100	100	300	500
<b>2010-2020</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>1100</b>	<b>1100</b>	<b>1100</b>	<b>1100</b>	<b>4100</b>	<b>6400</b>

# Wildfires – annual emissions

Number of children facing an additional **wildfire** due to the **annual** emissions of

<i>Birth year</i>	<del>Tyrving</del> 2024	<del>Tyrving</del> 2025	<del>Tyrving</del> 2026	<del>Tyrving</del> 2027	<del>Breidablikk</del> 2024	<del>Breidablikk</del> 2025	<del>Breidablikk</del> 2026	<del>Breidablikk</del> 2027	Yggdrasil 2027	<del>Yggdrasil</del> 2028
2020	0	0	0	0	0	0	0	0	100	200
2019	0	0	0	0	0	0	0	0	100	200
2018	0	0	0	0	0	0	0	0	100	200
2017	0	0	0	0	0	0	0	0	100	200
2016	0	0	0	0	0	0	0	0	100	200
2015	0	0	0	0	0	0	0	0	100	200
2014	0	0	0	0	0	0	0	0	100	200
2013	0	0	0	0	0	0	0	0	100	200
2012	0	0	0	0	0	0	0	0	100	200
2011	0	0	0	0	0	0	0	0	100	200
2010	0	0	0	0	0	0	0	0	100	200
<b>2010-2020</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>1100</b>	<b>2200</b>

# Tropical cyclones – annual emissions

Number of children facing an additional **tropical cyclone** due to the **annual** emissions of

<i>Birth year</i>	<u>Tyrving</u> 2024	<u>Tyrving</u> 2025	<u>Tyrving</u> 2026	<u>Tyrving</u> 2027	<u>Breidablikk</u> 2024	<u>Breidablikk</u> 2025	<u>Breidablikk</u> 2026	<u>Breidablikk</u> 2027	<u>Yggdrasil</u> 2027	<u>Yggdrasil</u> 2028
	2020	0	0	0	0	0	0	0	0	100
2019	0	0	0	0	0	0	0	0	100	200
2018	0	0	0	0	0	0	0	0	100	200
2017	0	0	0	0	0	0	0	0	100	200
2016	0	0	0	0	0	0	0	0	100	200
2015	0	0	0	0	0	0	0	0	100	200
2014	0	0	0	0	0	0	0	0	100	200
2013	0	0	0	0	0	0	0	0	100	200
2012	0	0	0	0	0	0	0	0	100	200
2011	0	0	0	0	0	0	0	0	100	200
2010	0	0	0	0	0	0	0	0	100	100
<b>2010-2020</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>1100</b>	<b>2100</b>

# River floods – annual emissions

Number of children facing an additional **river flood** due to the **annual** emissions of

	<u>Tyrving</u> 2024	<u>Tyrving</u> 2025	<u>Tyrving</u> 2026	<u>Tyrving</u> 2027	<u>Breidablikk</u> 2024	<u>Breidablikk</u> 2025	<u>Breidablikk</u> 2026	<u>Breidablikk</u> 2027	<u>Yggdrasil</u> 2027	<u>Yggdrasil</u> 2028
<b>Birth year</b>										
2020	0	0	0	0	0	0	0	0	100	100
2019	0	0	0	0	0	0	0	0	100	100
2018	0	0	0	0	0	0	0	0	100	100
2017	0	0	0	0	0	0	0	0	100	100
2016	0	0	0	0	0	0	0	0	100	100
2015	0	0	0	0	0	0	0	0	100	100
2014	0	0	0	0	0	0	0	0	100	100
2013	0	0	0	0	0	0	0	0	0	100
2012	0	0	0	0	0	0	0	0	0	100
2011	0	0	0	0	0	0	0	0	0	100
2010	0	0	0	0	0	0	0	0	0	100
<b>2010-2020</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>700</b>	<b>1100</b>

# Lifetime extreme event exposure – annual emissions

The results imply, for example, that

- 6 200 children born in the year 2020 are expected to face one additional heatwave in their lifetime due to the emissions of Breidablikk in the year 2024.
- 5 100 children born in the years 2010 to 2020 are expected to face one additional drought in their lifetime due to the emissions of Yggdrasil in the year 2027.

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- 
- 6 900 children born in the years 2010 to 2020 are expected to face one additional crop failure in their lifetime due to the emissions of Yggdrasil in the year 2028.

# Glacier Mass Loss – annual emissions (part 1)

Glacier mass loss in m<sup>3</sup> due to the annual emissions of

<i>Region</i>	<u>Tyrving</u> <b>2024</b>	<u>Tyrving</u> <b>2025</b>	<u>Tyrving</u> <b>2026</b>	<u>Tyrving</u> <b>2027</b>	<u>Breidablikk</u> <b>2024</b>
<i>Arctic Canada South</i>	122000	869000	478000	356000	2861000
<i>Western Canada &amp; US</i>	20000	143000	79000	58000	473000
<i>Scandinavia</i>	6000	42000	23000	17000	141000
<i>Russian Arctic</i>	468000	3320000	1829000	1360000	10931000
<i>Iceland</i>	149000	1058000	583000	433000	3485000
<i>Greenland Periphery</i>	485000	3434000	1892000	1407000	11306000
<i>Central Europe</i>	3000	25000	14000	10000	84000
<i>North Asia</i>	3000	26000	14000	10000	86000
<i>South Asia East</i>	23000	168000	92000	68000	553000
<i>Svalbard &amp; Jan Mayen</i>	335000	2374000	1308000	972000	7815000
<i>Southern Andes</i>	139000	987000	543000	404000	3249000
<i>Alaska</i>	691000	4894000	2697000	2005000	16115000
<i>Sub &amp; Antarctic Islands</i>	1496000	10597000	5838000	4342000	34887000
<i>Arctic Canada North</i>	1269000	8985000	4950000	3681000	29581000
<i>Low Latitudes</i>	4000	31000	17000	12000	102000
<i>Caucasus &amp; Middle East</i>	2000	18000	9000	7000	59000
<i>New Zealand</i>	3000	23000	12000	9000	76000
<i>Central Asia</i>	176000	1252000	690000	513000	4123000
<i>South Asia West</i>	179000	1272000	701000	521000	4190000
<b>Global</b>	<b>5850000</b>	<b>41426000</b>	<b>22825000</b>	<b>16974000</b>	<b>136385000</b>

# Glacier Mass Loss – annual emissions (part 2)

Glacier mass loss in m<sup>3</sup> due to the annual emissions of

<i>Region</i>	<u>Breidablikk</u> 2025	<u>Breidablikk</u> 2026	<u>Breidablikk</u> 2027	Yggdrasil 2027	<u>Yggdrasil</u> 2028
<i>Arctic Canada South</i>	2932000	2443000	2280000	8127000	11965000
<i>Western Canada &amp; US</i>	484000	404000	377000	1343000	1978000
<i>Scandinavia</i>	144000	120000	112000	400000	589000
<i>Russian Arctic</i>	11201000	9336000	8710000	31048000	45710000
<i>Iceland</i>	3571000	2976000	2777000	9898000	14572000
<i>Greenland Periphery</i>	11585000	9656000	9009000	32114000	47278000
<i>Central Europe</i>	86000	72000	67000	239000	352000
<i>North Asia</i>	88000	73000	68000	245000	361000
<i>South Asia East</i>	566000	472000	440000	1570000	2312000
<i>Svalbard &amp; Jan Mayen</i>	8008000	6675000	6227000	22198000	32681000
<i>Southern Andes</i>	3329000	2775000	2589000	9229000	13588000
<i>Alaska</i>	16512000	13763000	12841000	45771000	67385000
<i>Sub &amp; Antarctic Islands</i>	35747000	29795000	27799000	99088000	145880000
<i>Arctic Canada North</i>	30310000	25263000	23571000	84017000	123693000
<i>Low Latitudes</i>	105000	87000	81000	291000	429000
<i>Caucasus &amp; Middle East</i>	61000	50000	47000	169000	249000
<i>New Zealand</i>	78000	65000	60000	216000	318000
<i>Central Asia</i>	4224000	3521000	3285000	11710000	17240000
<i>South Asia West</i>	4293000	3578000	3339000	11902000	17522000
<b>Global</b>	<b>139747000</b>	<b>116478000</b>	<b>108677000</b>	<b>387365000</b>	<b>570288000</b>

# Glacier Mass Loss – annual emissions

The results imply, for example, that

- Scandinavian glaciers will lose 42 000 m<sup>3</sup> due to the 2025 emissions of Tyrving.
- Scandinavian glaciers will lose 141 000 m<sup>3</sup> due to the 2024 emissions of Breidablikk.
- Scandinavian glaciers will lose 589 000 m<sup>3</sup> due to the 2028 emissions of Yggdrasil.
- Glaciers worldwide will lose 41 426 000 m<sup>3</sup> due to the 2025 emissions of Tyrving.
- Glaciers worldwide will lose 136 385 000 m<sup>3</sup> due to the 2024 emissions of Breidablikk.
- Glaciers worldwide will lose 570 288 000 m<sup>3</sup> due to the 2028 emissions of Yggdrasil.

# Heat-related mortality – annual emissions

Number of **heat-related deaths until 2100** due to the **annual** emissions of

	<u>Tyrving</u> 2024	<u>Tyrving</u> 2025	<u>Tyrving</u> 2026	<u>Tyrving</u> 2027	<u>Breidabli.</u> 2024	<u>Breidabli.</u> 2025	<u>Breidabli.</u> 2026	<u>Breidabli.</u> 2027	<u>Yggdrasil</u> 2027	<u>Yggdrasil</u> 2028
<i>Additional heat-related mortality until 2100</i>	0	600	300	200	2200	2300	1900	1800	6400	9500

The results imply that

- 98 heat-related deaths are expected worldwide until 2100 due to the emissions of Tyrving in 2024 (note that 98 was rounded down to 0 in the table).
- 694 heat-related deaths are expected worldwide until 2100 due to the emissions of Tyrving in 2025 (note that 694 was rounded down to 600 in the table).
- 300 heat-related deaths are expected worldwide until 2100 due to the emissions of Tyrving in 2026.
- 200 heat-related deaths are expected worldwide until 2100 due to the emissions of Tyrving in 2027.
- 2200 heat-related deaths are expected worldwide until 2100 due to the emissions of Breidablikk in 2024.
- 2300 heat-related deaths are expected worldwide until 2100 due to the emissions of Breidablikk in 2025.
- 1900 heat-related deaths are expected worldwide until 2100 due to the emissions of Breidablikk in 2026.
- 1800 heat-related deaths are expected worldwide until 2100 due to the emissions of Breidablikk in 2027.
- 6400 heat-related deaths are expected worldwide until 2100 due to the emissions of Yggdrasil in 2027.
- 9500 heat-related deaths are expected worldwide until 2100 due to the emissions of Yggdrasil in 2028.

## question 6

- **Regarding question 6;** In recent decades, climate science has evolved to a level at which climate impact assessments for individual fossil fuel projects have become possible. The *de facto* proof for this ability is the current report, in which such a risk assessment is actually performed (see our responses to questions 1-5). The risk assessment is based on a framework which I, a research professor in Climate Science, developed based on the laws of physics and chemistry, and using parameter values established in IPCC reports and leading international scientific journals (*Science, Nature, Nature Communications*).
- Furthermore, I am aware of at least two independent scientific frameworks that allow for similar types of risk assessment. The first framework is developed at ETH Zurich, and allows to translate emissions to spatially-resolved warming and extreme hot year occurrences (Beusch et al., 2022). The second framework has been recently developed at Stanford University, and translates the emissions of 1 ton of CO<sub>2</sub> to a set of 16 climate change indicators (Semken et al., forthcoming). Note that the latter explicitly assesses the effects of a single ton of CO<sub>2</sub>, whereas the current report assesses emissions on the order of 0.5 to 500 million tonnes of CO<sub>2</sub>, that is, four to eight order of magnitude above the threshold of detectable impacts identified by the Stanford University study.
- Beusch, L., et al. (2022). Responsibility of major emitters for country-level warming and extreme hot years. *Communications Earth & Environment*, 3(1), 7. [\[pdf\]](#)
- This framework is finalised and the paper will soon be submitted for publication to a scientific journal.

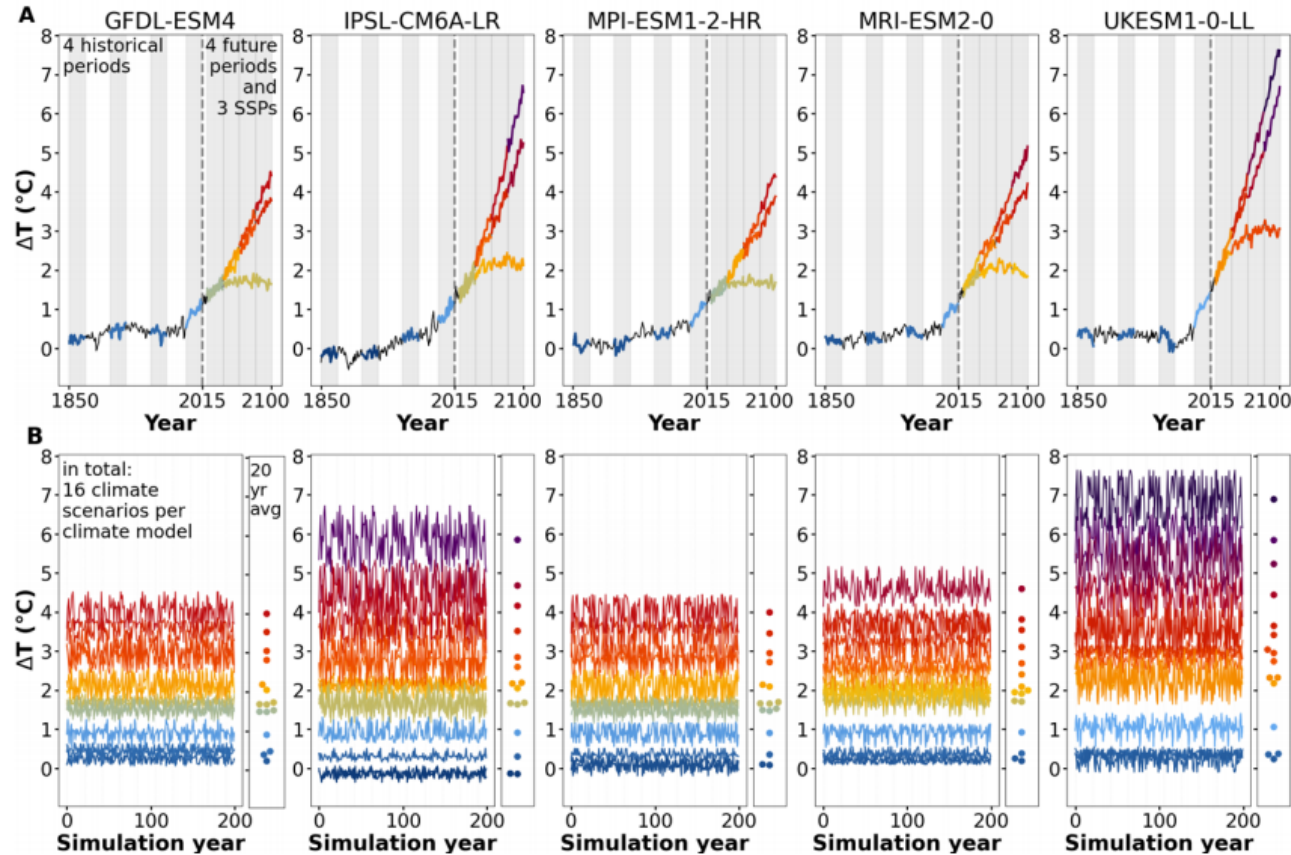
# methods

- **Discussion and Methods;** As also mentioned during my testimony of 30 November 2023, the numbers shown here represent the *best estimate*, that is, the central number expected given the employed scientific information. The actual number could be lower, but could equally well be higher, depending on the imprecision of the numbers that were used as input in the calculations.
- 
- These input values include, for question 1 and 2: the total greenhouse gas emission estimates for Tyrving, Breidablikk and Yggdrasil (see first table), the transient climate response to cumulative emissions (TCRE; 0,45°C per 1000 Gt CO<sub>2</sub>eq), the birth cohort size for 2010-2020 birth cohorts (obtained from the Wittgenstein Center), the sensitivity of lifetime heatwave, drought, crop failure, wildfire, tropical cyclone, and river flood exposure to global mean temperature rise (derived from Thiery et al., 2021 *Science*). The results were obtained by first multiplying the respective emission values with the TCRE to obtain the global warming linked to the emissions. This value was then multiplied with the change in lifetime extreme event exposure per degree of warming for the respective climate extremes, to obtain the number of climate extremes additionally experienced by the average birth cohort member. Finally, this value was multiplied with the cohort size for the respective birth years to obtain the number of members from a birth cohort experiencing one additional climate extreme. The final results were rounded to the nearest lower hundred for every individual birth cohort.
- 
- For question 3, the input values include: the total greenhouse gas emission estimates for Tyrving, Breidablikk and Yggdrasil (see first table) and the mortality cost of carbon (1 extra heat-related death until 2100 per 4434 t CO<sub>2</sub>eq; Bressler, 2021 *Nature Communications*). The results were obtained by multiplying the emission values with the mortality cost of carbon. The results were rounded to the nearest lower hundred.
- 
- For question 4, the input values include the total greenhouse gas emission estimates for Tyrving, Breidablikk and Yggdrasil (see first table), the transient climate response to cumulative emissions (TCRE; 0,45°C per 1000 Gt CO<sub>2</sub>eq), and the sensitivity of equilibrium change in regional and global glacier mass to global mean temperature rise (derived from Zekollari et al., 2025 *Science*). The results were obtained by first converting the glacier mass loss (Gt per tenth of a degree of warming) to glacier volume loss (m<sup>2</sup> per degree of warming) assuming a density value of 0,920 kg dm<sup>-3</sup> (which renders out estimate conservative as we disregard the fraction of snow which has a lower density). Next, the respective emission values were multiplied with the TCRE to obtain the global warming linked to the emissions. Finally, this value was multiplied with the change in glacier volume loss per degree of warming for the respective regions and the world. The results were rounded to the nearest lower thousand.
- 
- For question 5, the input values include the same inputs as in the previous questions, except for the greenhouse gas emission estimates for Tyrving, Breidablikk and Yggdrasil, where we use annual instead of total values (see first table). The calculation were performed analogous to the ones of questions 1-4.
- Thiery, W., et al., op. cit.
- Bressler, R. D. (2021). The mortality cost of carbon. **Nature communications**, 12(1), 4467. [[pdf](#)]
- Thiery, W., et al., op. cit.

## About the author

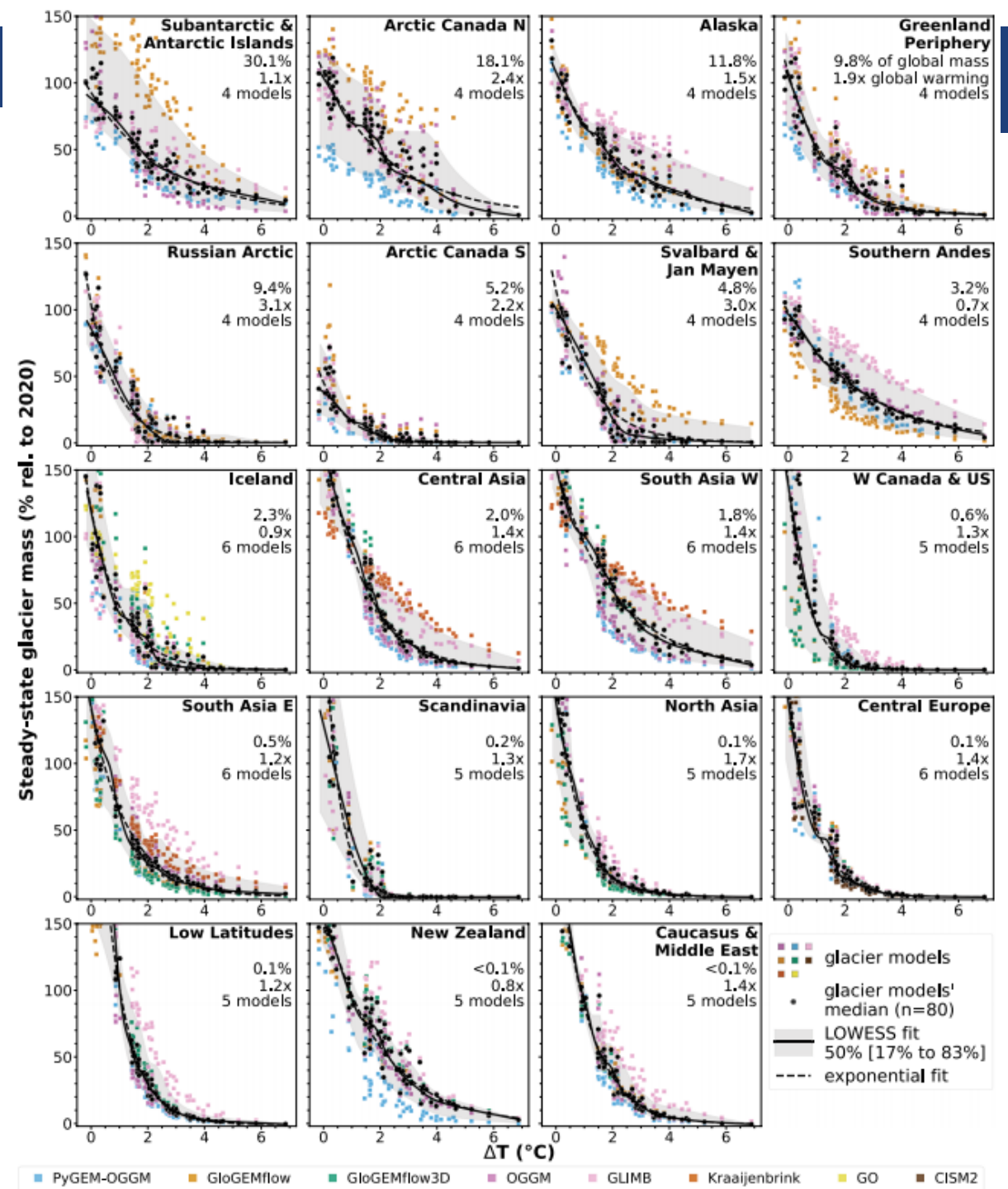
- **Prof. Dr. Wim Thiery** is a climate scientist focused on modelling extreme events in a changing climate. After obtaining MScs at KU Leuven in Philosophy (2008) and Terrestrial Ecosystems and Global Change (2011), he was an FWO PhD fellow investigating the interaction between climate and the African Great Lakes with a regional climate model (2011–2015). From 2015 to 2018, he was a Postdoctoral Fellow at ETH Zurich, where he investigated the historical and future impacts of irrigation on climate extremes at the global scale. In 2017 (age 29), he was appointed as research professor at the Vrije Universiteit Brussel, where he established the bclimate Group. With over 1000 media contributions since 2014, he is one of Belgium’s leading climate science communicators. During his research, he undertook research exchanges to Montréal, Berlin, and Zurich, and conducted field campaigns to Uganda, Rwanda, and DR Congo to install automatic weather stations on Lake Kivu and Lake Victoria. Thiery is contributing author of the IPCC Special Report on Climate Change and Land (2019) and the Sixth Assessment Report (2021). His expertise includes climate change, climate extremes, regional and global climate modelling, global-scale climate impact modelling, impact attribution, land-atmosphere interactions, land management, storm early warnings, and energy meteorology. Overall, he (co-)authored 136 peer-reviewed scientific articles, including 27 in the flagship Science and Nature-Family journals. In 2017, Forbes magazine elected him as a member of the “Forbes 30 under 30 Europe”, bringing together “the brightest young entrepreneurs, innovators and game changers in Europe”. Prof. Thiery is currently leading a 2 Million European research grant awarded by the European Research Council (ERC Consolidator Grant) on impact attribution. In 2023, he received one of the Arne Richter Awards for Outstanding Early Career Scientists from the European Geosciences Union. This is *de facto* the highest scientific recognition an early career researcher in climate science can receive in Europe. In 2024, he received the Scientific Award Climate Research, awarded by the Research Foundation – Flanders (FWO). In 2024, he received the price Laureate of the Royal Flemish Academy of Belgium for Science and the Arts (KVAB - Class Natural Sciences). Since 2023, he is recognised by Stanford University as a member of the top 2% of scientists worldwide across all scientific disciplines.
- **Full CV** can be found [here](#).
- **Full publication list** can be found [here](#).

# GlacierMIP3 simulation set-up



**Fig. S 1. Overview of air temperature forcing for the 80 constant-climate scenarios. (A)** Global mean annual near-surface air temperatures above pre-industrial ( $\Delta T$ ) between 1850 and 2100 for the five ISIMIP3b climate models, and after 2015 for three SSPs (SSP1-2.6, SSP2-4.5 and SSP5-8.5). 20-year historical (1851-1870, 1901-1920, 1951-1970, 1995-2014) and future (2021-2040, 2041-2060, 2061-2080, 2081-2100) periods were used to extract the climate forcing for the glacier models. **(B)** Derived climate scenarios used to force the glacier models, shown for the first 200 simulation years (left subpanels with lines), together with mean  $\Delta T$  (right subpanels with dots).

# GlacierMIP3 regional sensitivities



# GlacierMIP3 regional sensitivities

A Mass	Mass 2020 (Gt)	Committed glacier mass loss at $\Delta T$ (% rel. to 2020)						Sensitivity (% per 0.1°C rel. to 2020) 1.5–3.0°C	Response timescale (years) 1.5±0.2°C
		1.2°C	1.5°C	2.0°C	2.7°C	3.0°C	4.0°C		
Arctic Canada S	7212	85 [ 83–94]	87 [ 83–96]	95 [90– 98]	99 [ 96–100]	99 [ 96–100]	100 [ 98–100]	0.8 [0.4–1.0]	241 [190– 573]
W Canada & US	795	74 [ 43–93]	81 [ 61–94]	93 [79– 99]	98 [ 92– 99]	99 [ 94–100]	100 [ 98–100]	1.2 [0.4–1.6]	57 [ 44– 109]
Scandinavia	237	66 [ 24–85]	82 [ 51–93]	100 [83–100]	100 [100–100]	100 [100–100]	100 [100–100]	1.2 [0.8–1.5]	166 [102– 235]
Russian Arctic	12965	65 [ 46–80]	75 [ 57–89]	88 [72– 99]	99 [ 86–100]	100 [ 90–100]	100 [ 94–100]	1.7 [1.5–2.1]	445 [321– 902]
Iceland	3194	61 [ 39–73]	65 [ 40–80]	77 [49– 91]	96 [ 82– 99]	97 [ 83–100]	99 [ 92–100]	2.2 [1.4–2.6]	316 [207– 640]
Greenland Periphery	13410	58 [ 42–72]	63 [ 44–75]	68 [53– 79]	86 [ 70– 93]	89 [ 73– 96]	95 [ 87– 99]	1.7 [1.3–2.2]	373 [260– 656]
Central Europe	85	56 [ 52–61]	65 [ 56–75]	86 [79– 91]	93 [ 90– 95]	95 [ 93– 97]	99 [ 98– 99]	2.0 [1.5–2.0]	42 [ 29– 64]
North Asia	109	56 [ 46–72]	70 [ 58–79]	86 [79– 91]	93 [ 89– 95]	94 [ 91– 96]	98 [ 96– 98]	1.6 [1.2–2.0]	47 [ 38– 114]
South Asia E	656	49 [ 18–63]	63 [ 34–74]	74 [56– 85]	84 [ 62– 91]	88 [ 68– 93]	93 [ 79– 97]	1.7 [1.4–2.1]	47 [ 32– 72]
Svalbard & Jan Mayen	6566	46 [ 25–61]	59 [ 34–73]	82 [51– 96]	94 [ 63–100]	95 [ 70–100]	98 [ 79–100]	2.4 [2.1–2.4]	318 [208– 629]
Southern Andes	4368	39 [ 21–57]	45 [ 25–61]	50 [29– 73]	64 [ 39– 81]	68 [ 45– 84]	79 [ 57– 91]	1.5 [1.3–1.6]	86 [ 61– 111]
Alaska	16246	37 [ 30–51]	41 [ 31–58]	58 [34– 69]	69 [ 44– 79]	71 [ 47– 82]	80 [ 56– 90]	2.0 [1.3–2.1]	104 [ 74– 173]
Sub- & Antarctic Islands	41377	36 [ -21–52]	44 [ -12–59]	56 [ 4– 70]	67 [ 24– 81]	70 [ 31– 85]	77 [ 54– 91]	1.7 [1.4–2.5]	828 [224–1322]
Arctic Canada N	24851	33 [ -1–67]	35 [ 4–70]	47 [18– 71]	69 [ 37– 83]	71 [ 37– 83]	82 [ 47– 95]	2.4 [1.8–2.3]	644 [356– 735]
Low Latitudes	69	23 [ -8–37]	46 [ 13–62]	68 [47– 78]	87 [ 71– 90]	91 [ 81– 93]	96 [ 93– 98]	3.0 [2.1–3.7]	23 [ 14– 30]
Caucasus & Middle East	43	23 [ 15–35]	45 [ 18–56]	59 [43– 72]	82 [ 68– 87]	87 [ 76– 90]	95 [ 87– 96]	2.8 [2.3–2.7]	30 [ 26– 56]
New Zealand	53	15 [ 2–39]	24 [ 6–45]	34 [14– 55]	61 [ 46– 77]	67 [ 52– 80]	82 [ 76– 92]	2.9 [2.7–2.9]	36 [ 28– 45]
Central Asia	2771	12 [ 3–32]	35 [ 18–54]	57 [34– 73]	77 [ 48– 86]	80 [ 52– 89]	91 [ 70– 96]	3.0 [2.2–3.2]	103 [ 72– 138]
South Asia W	2485	5 [ 0–30]	17 [ 10–51]	38 [24– 67]	59 [ 36– 79]	68 [ 40– 84]	80 [ 54– 91]	3.4 [2.0–3.6]	139 [100– 175]
Global	137491	39 [ 15–55]	47 [ 20–64]	63 [43– 76]	76 [ 54– 82]	77 [ 60– 85]	86 [ 74– 93]	2.0 [1.6–2.4]	463 [216– 805]

B SLE	Committed glacier mass loss at $\Delta T$ (mm SLE rel. to 2020)						Sensitivity (mm SLE per 0.1°C rel. to 2020) 1.5–3.0°C
	1.2°C	1.5°C	2.0°C	2.7°C	3.0°C	4.0°C	
Global (below sea-level correction applied)	113 [43–204]	138 [59–237]	190 [128–279]	230 [159–302]	236 [178–313]	263 [218–342]	6.5 [4.6–8.9]
Global (no below sea-level correction)	144 [54–204]	174 [74–237]	234 [160–279]	279 [199–302]	286 [223–313]	316 [272–342]	7.5 [5.7–8.9]

**Table S 1. Global and regional committed glacier mass losses at different warming levels, sensitivity to global mean temperature change, and response timescales. (A)** Mass losses are shown in percent, and **(B)** globally also in sea-level equivalent (SLE), relative to the masses in 2020. Median values are provided, with the likely range (17<sup>th</sup> and 83<sup>rd</sup> percentile) in brackets, calculated from LOWESS fits (see Methods). Regions in (A) are ordered by decreasing regional relative mass loss at 1.2°C. Colors highlight the mass losses in five 20 % bins between 0 to 100%.

## Note on glaciers

- These results are based on a study published in 2025 in *Science* in which Zekollari, Schuster and colleagues calculated the long-term equilibration of global glacier mass under different global warming levels. They found that the >200,000 glaciers around the globe (excluding the Greenland and Antarctic ice sheet) will globally lose 2.0% of their mass per tenth of a degree of warming occurring in the +1.5°C to +3.0°C warming range. More specifically, every +0.1°C in warming results in a loss of 2749Gt of ice, which is roughly equivalent to filling 900 million Olympic swimming pools with meltwater from glaciers. At the regional scale, the sensitivity varies between 0.8% to 3.4% mass loss per tenth of a degree warming (still in the +1.5°C to +3.0°C warming range; see Table S1 in Zekollari, Schuster et al., 2025). Note that these regional and global warming sensitivities used in this report are conservative for the current situation, since this sensitivity decreases towards higher warming levels as there is less ice left to melt (i.e., at the present-day warming level of +1.2°C for the period 2014-2023 vs. 1850-1900, the sensitivity is higher than 2.0% loss per 0.1°C warming; see Fig. 1b in Zekollari, Schuster et al., 2025). The sensitivity per region and globally is a consensus estimate derived from internationally coordinated simulations performed with 8 glacier evolution models, of which four run globally and four only in selected regions. These global glacier models were forced with 80 different climate scenarios representing long-term climate change and associated glacier stabilisation at different levels of global warming.
- Zekollari, H., Schuster, et al. (2025). Glacier preservation doubled by limiting warming to 1.5°C versus 2.7°C. ***Science***, 388(6750), 979-983. [[pdf](#)]

# The global carbon budget 2013-2022;

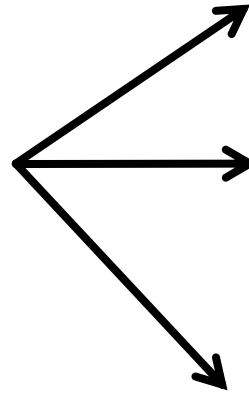
sources = sinks



88%  
35.3 GtCO<sub>2</sub>/yr



12%  
4.7 GtCO<sub>2</sub>/yr



47%  
18.9 GtCO<sub>2</sub>/yr



31%  
12.3 GtCO<sub>2</sub>/yr



26%  
10.4 GtCO<sub>2</sub>/yr



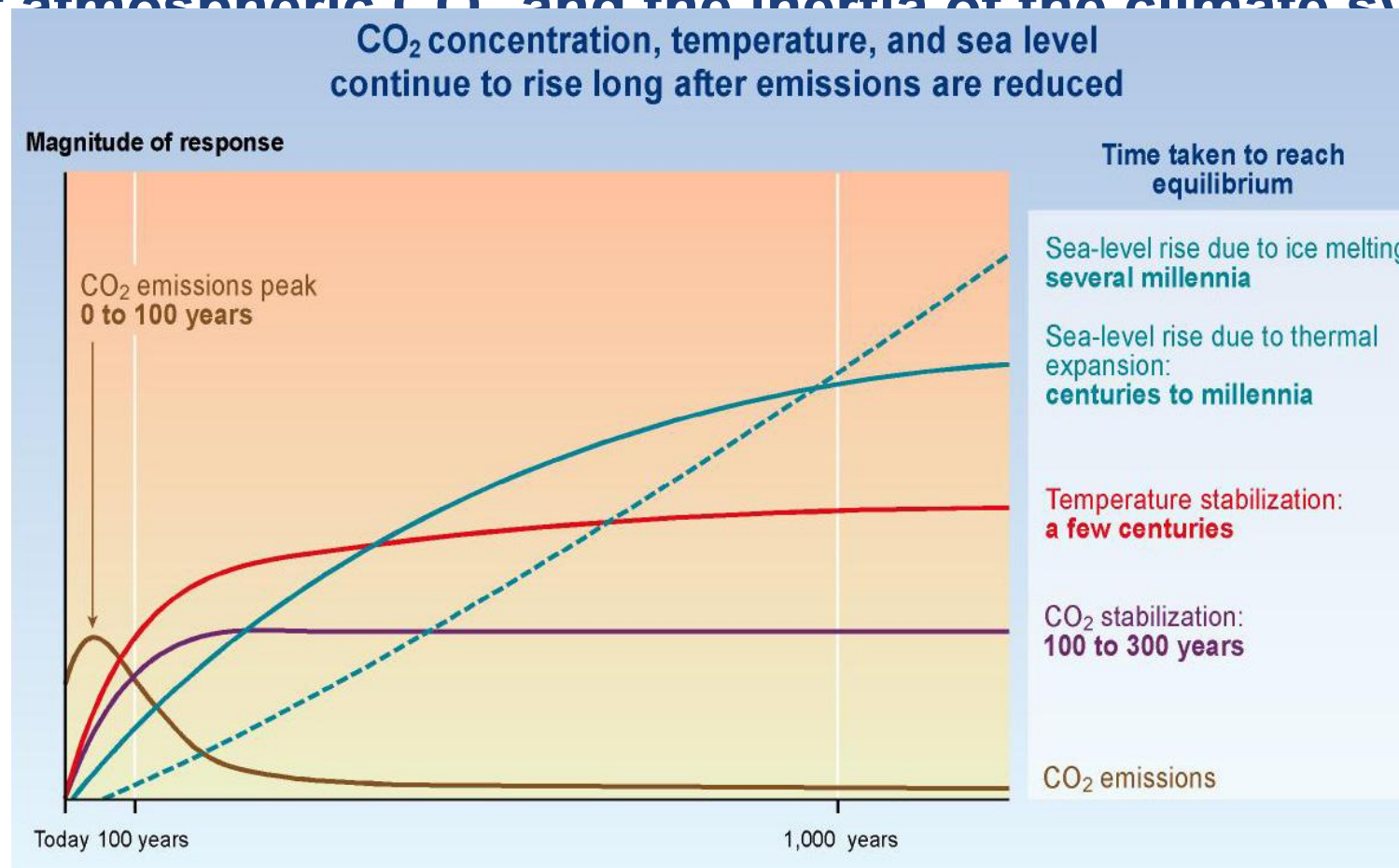
Q5: Guess the fractions?

1 PgCO<sub>2</sub> = 1 GtCO<sub>2</sub> = 10<sup>15</sup> gCO<sub>2</sub>  
Budget imbalance: 6% or 2.1 GtCO<sub>2</sub>/yr

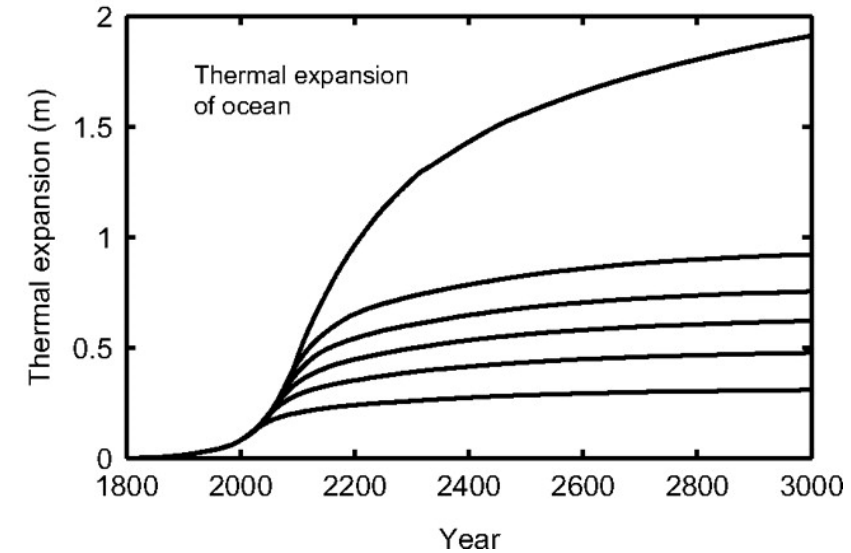
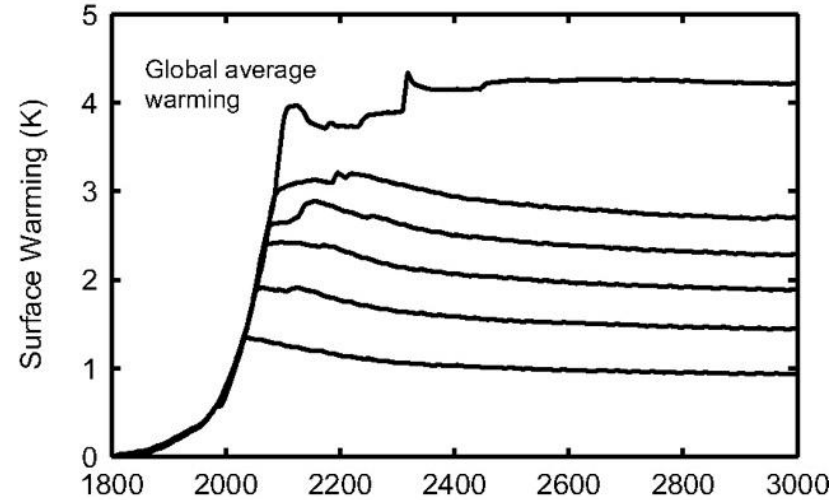
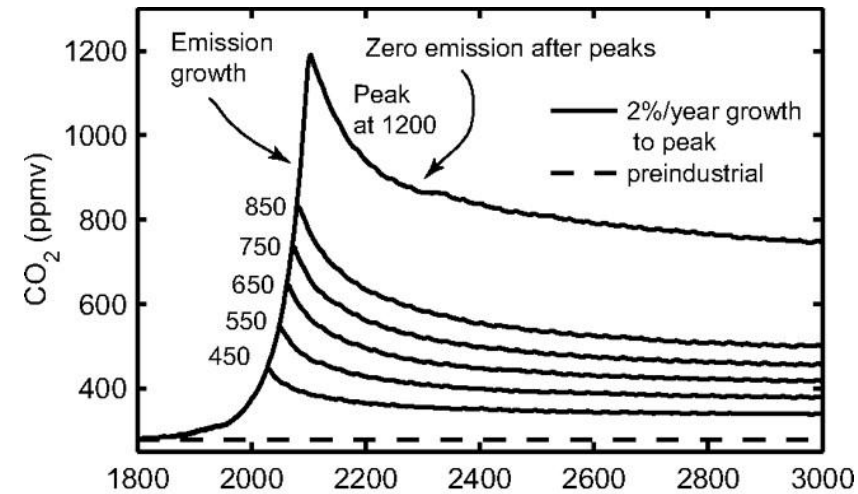
(Global Carbon Budget, 2023)

# The longer-term poison

long lifetime of atmospheric CO<sub>2</sub> and the inertia of the climate system



# Climate changes are effectively irreversible for >1000 years after emissions stop



- CO<sub>2</sub> has a long life-time in the atmosphere
- Diminishing radiative forcing counteracted by lagged oceanic heat uptake

(Solomon et al., 2009  
PNAS)

## 80-90% of fossil fuel extraction is used for energy production

- International Energy Agency. in *The Future of Petrochemicals: Towards a More Sustainable Chemical Industry*, 11–27 (IEA, 2018).