« NaturAdapt, l'indispensable adaptation. »

An introduction to past and ongoing climate changes

by a glaciologist

Jean-Baptiste Bosson (CEN74, IUCN)

Asters Conservatoire d'espaces naturels Haute-Savoie

IUCN

Life

LIFE NATUR' ADAPT

My background

UNIL | Université de Lausanne
Institut des dynamiques de la surface terrestre

PhD on current evolution of alpine glaciers

Asters
Conservatoire d'espaces naturels Haute-Savoie

Scientific officer for the 9 Nature Reserves of Haute-Savoie (France)

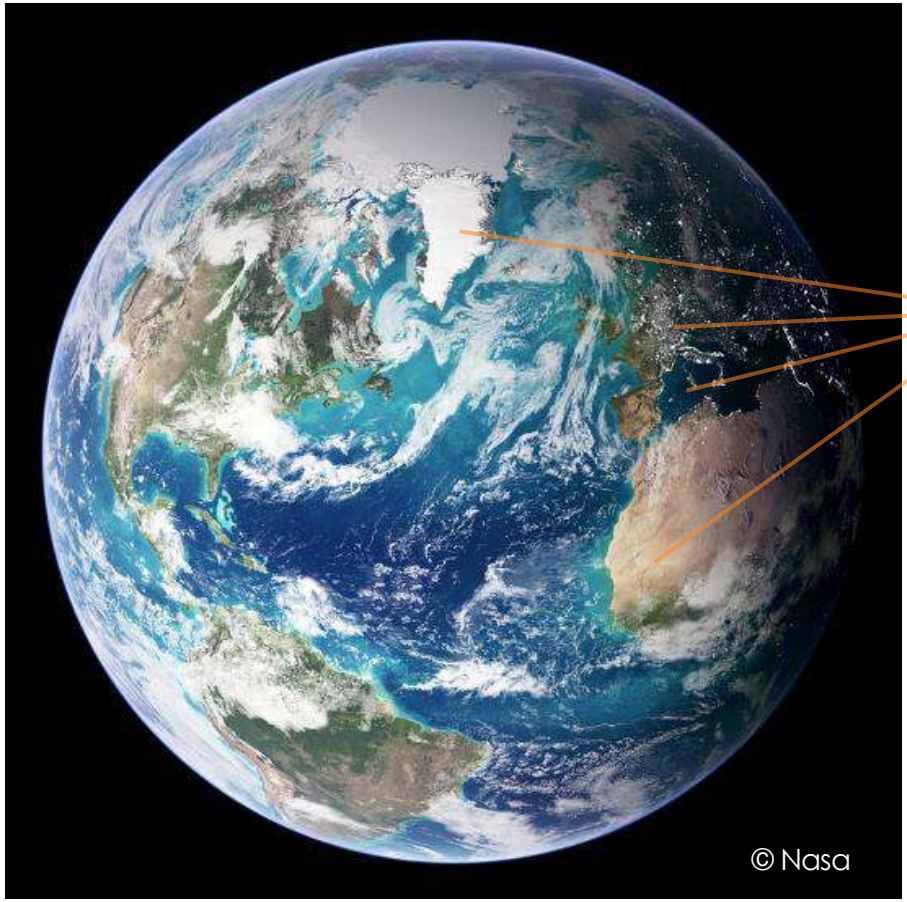
IUCN

World Heritage officer (research on World Heritage Glacier)

Webinar : an introduction to past and ongoing climate changes

1. Climate and glaciers : definition and relation
2. From recent (natural) climatic fluctuations on Earth…
3. … to climate change at the Anthropocene

1. **Climate** definition



Because of the permanent interactions between …

Earth's climate system

- **Atmosphere** (composition, fluxes…)
- **Hydrosphere** (ocean, current…)
- **Biosphere** (living organisms…)
- **Cryosphere** (ice sheets, glaciers, sea ice, permafrost…)
- **Lithosphere** (tectonic, relief, volcanism…)

Atmospheric conditions (temperature, precipitation, wind, etc.) **vary in time and space on Earth**

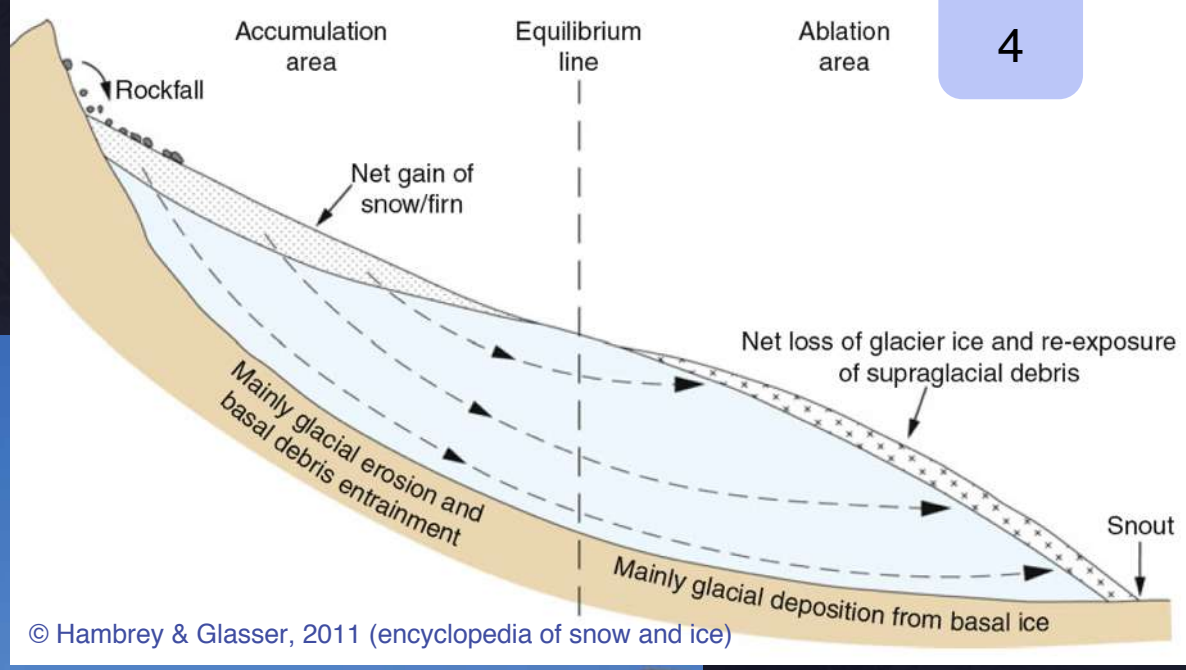
Weather : Short-term characterisation of these conditions for small surfaces

Climate : statistical distribution (means, ranges, normal on a 30 yr periods, etc.) of these conditions for a given region and period

→ allows a typology according to the main characteristics

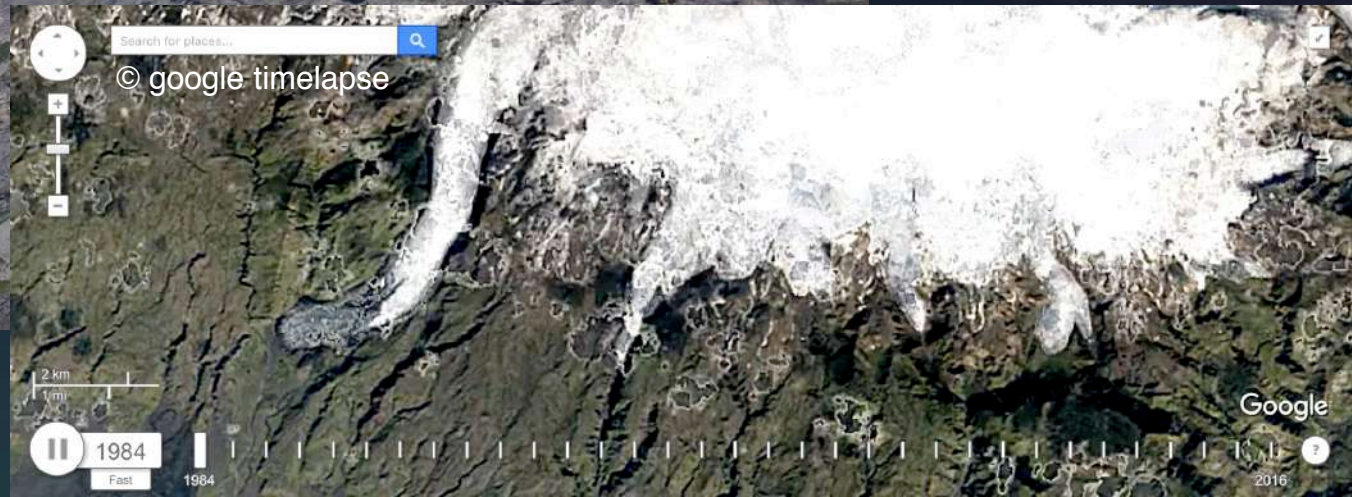
Glacier definition

A **glacier** is a mass of **sedimentary ice**, formed through snow compaction, which **flows downhill** under gravity

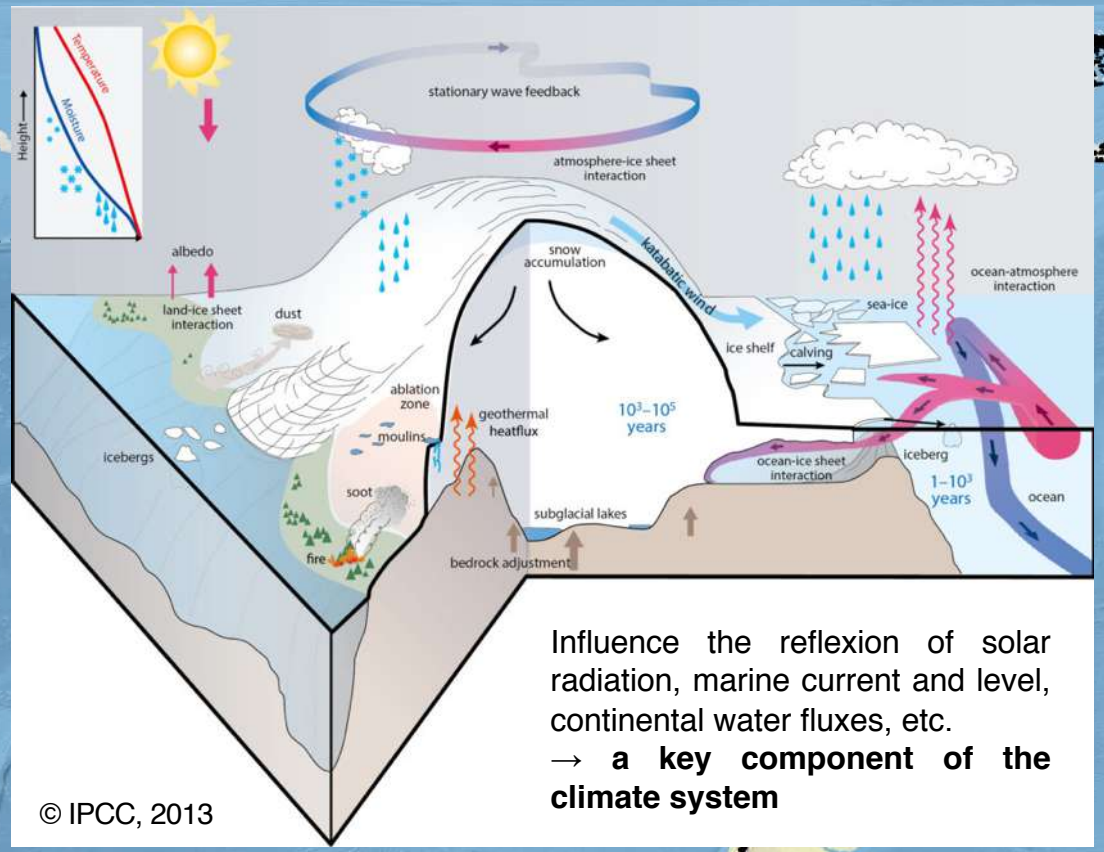


© Hambrey & Glasser, 2011 (encyclopedia of snow and ice)

Wildstrubelgletscher (Switzerland)



→ Very sensitive to climatic variations



© IPCC, 2013

Influence the reflexion of solar radiation, marine current and level, continental water fluxes, etc.
→ **a key component of the climate system**

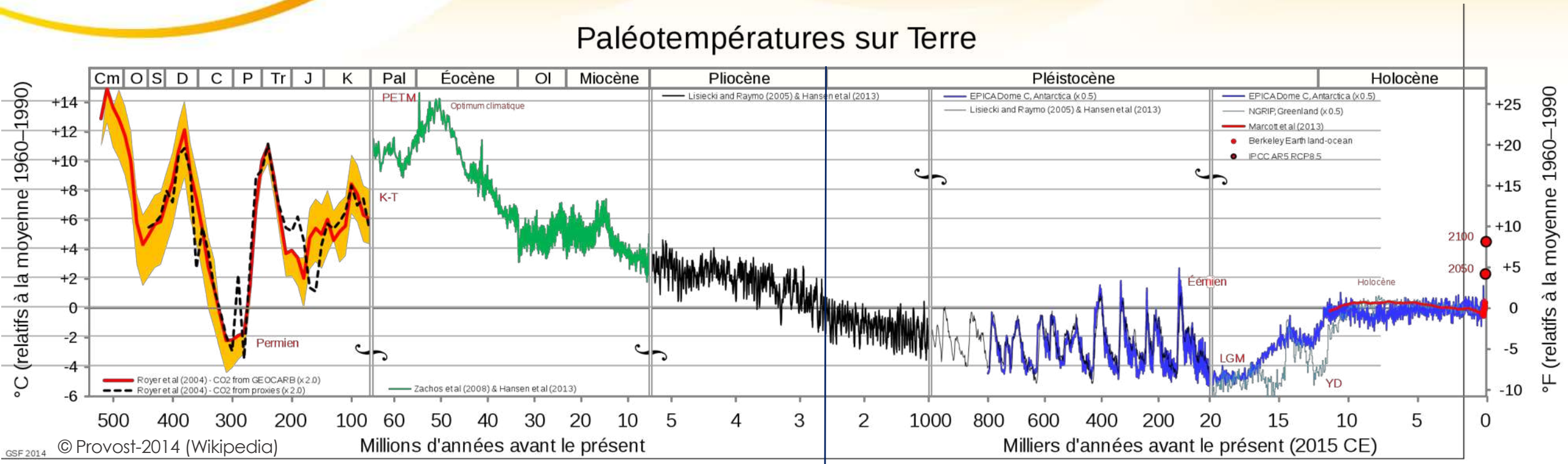
4000 glaciers
(0.3 mm SLE)

>210’000 glaciers :0.5 % vol (0.32 m SLE)

88.3% vol. (58.3 m SLE)

Glaciers and ice sheets = 10 % of land surface et 66 m SLE

2. Recent (natural) climatic fluctuations on Earth…



Ice cores = climate archives

Closing of Panama Isthmus / position of Antarctica
→ Formation of large ice sheets

Quaternary period (2.6 Myr – 2019)

→ Cycle of interglacials and glaciations (n ~20)

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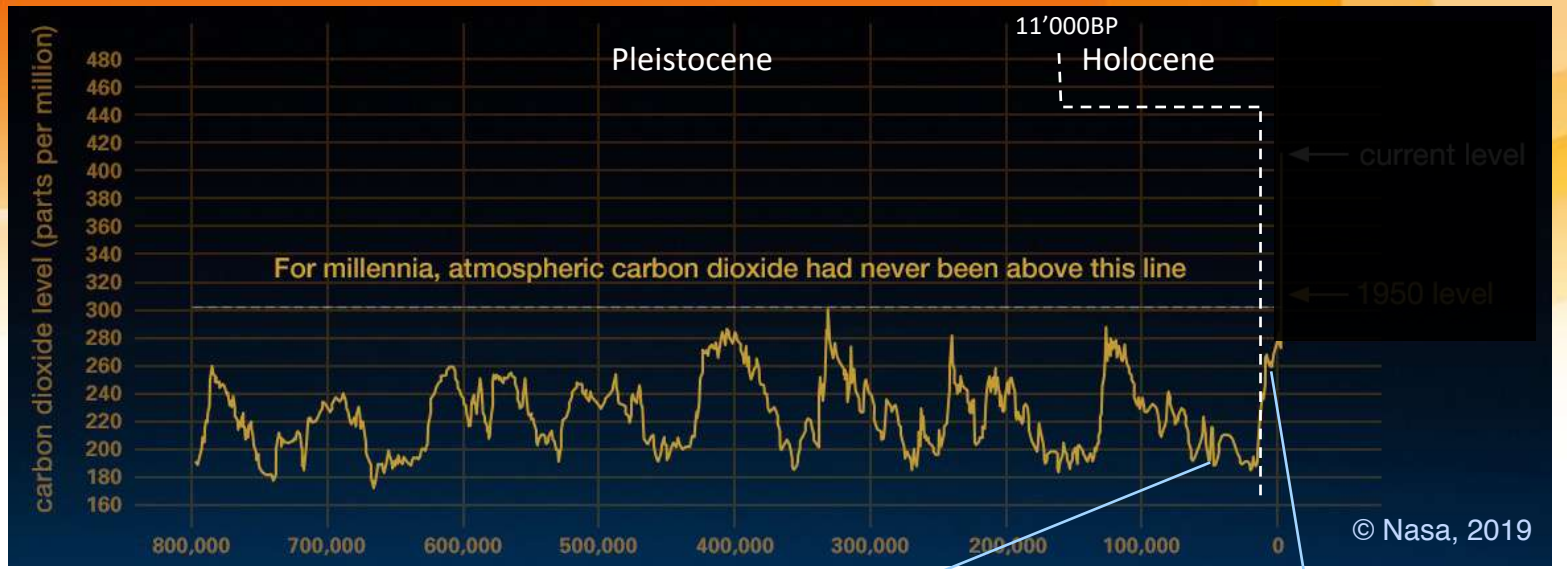
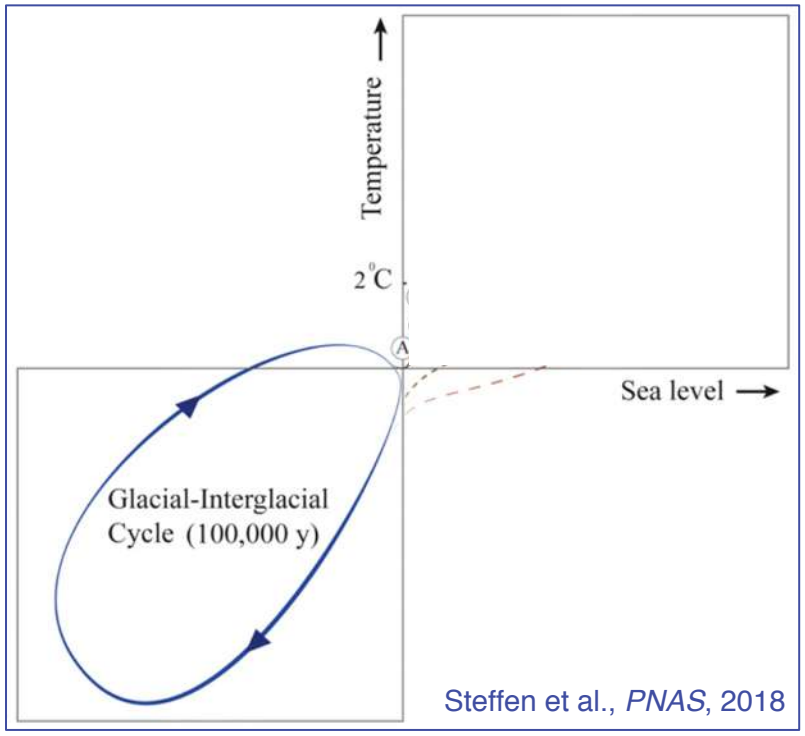
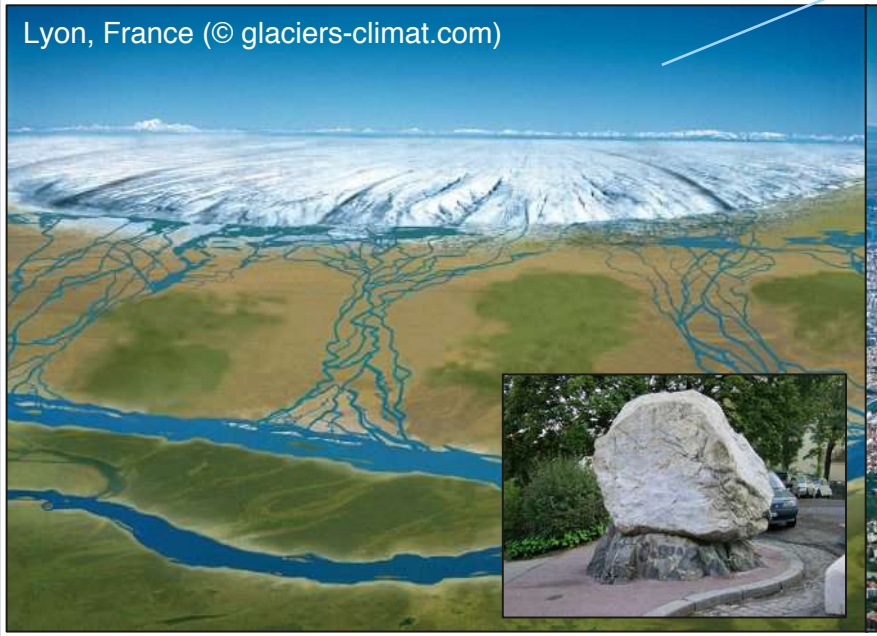
Quaternary (2.6 Myr – 2019)

Glacial – Interglacial cycle due to **variation of Earth's orbit and inclination**, of solar activity, …







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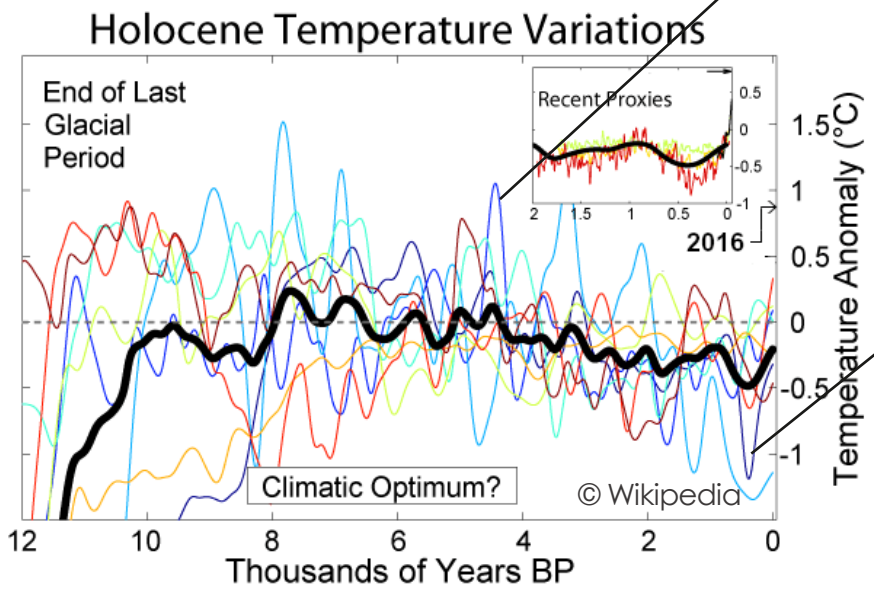
Holocene (Interglacial since 11'000 years)

Warm and cold pulses (+/- 1°C globally)
(due to variations of orbit, solar activity, volcanism..)



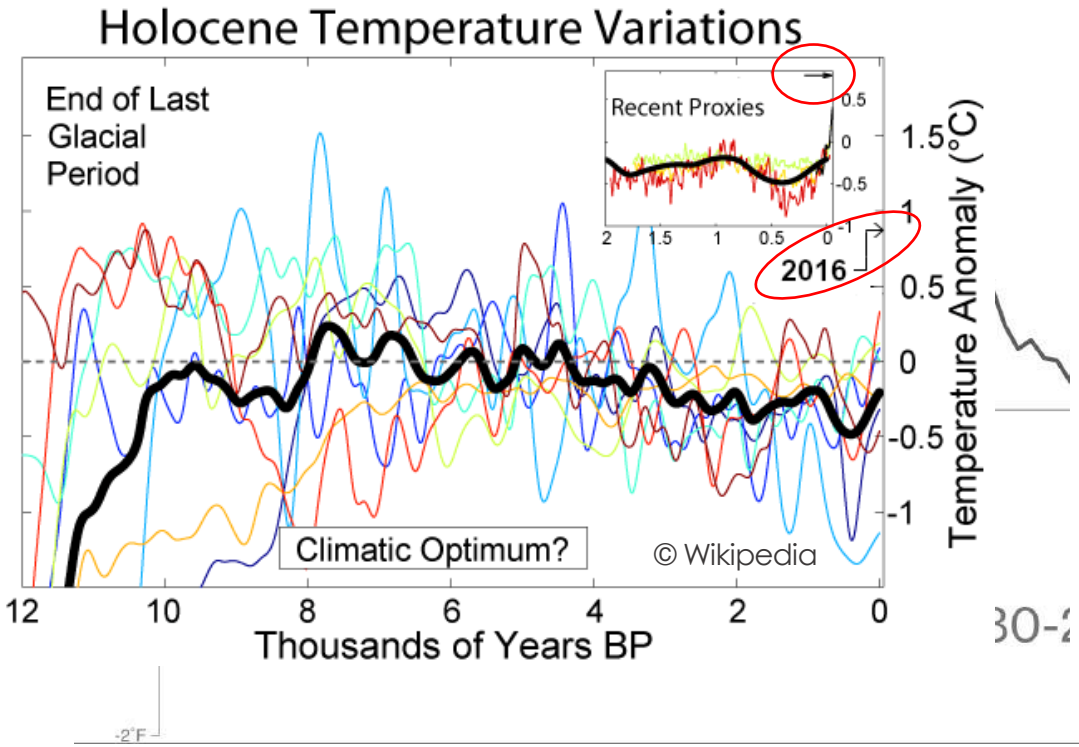
Nature Reserve of Les Contamines Montjoie (Mont-Blanc, France)

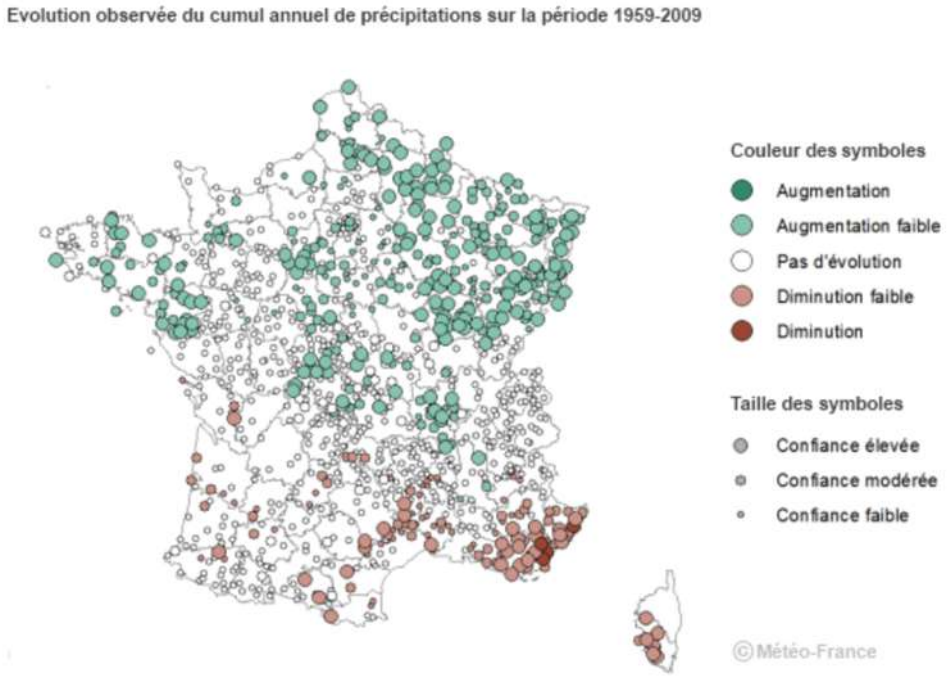
3. Ongoing climate change

1900-2019: Global warming (air, earth, ocean, extremely rapid at the geological timescale), modification of precipitations, of the frequency and magnitude of extreme events (cyclones, droughts, …)…

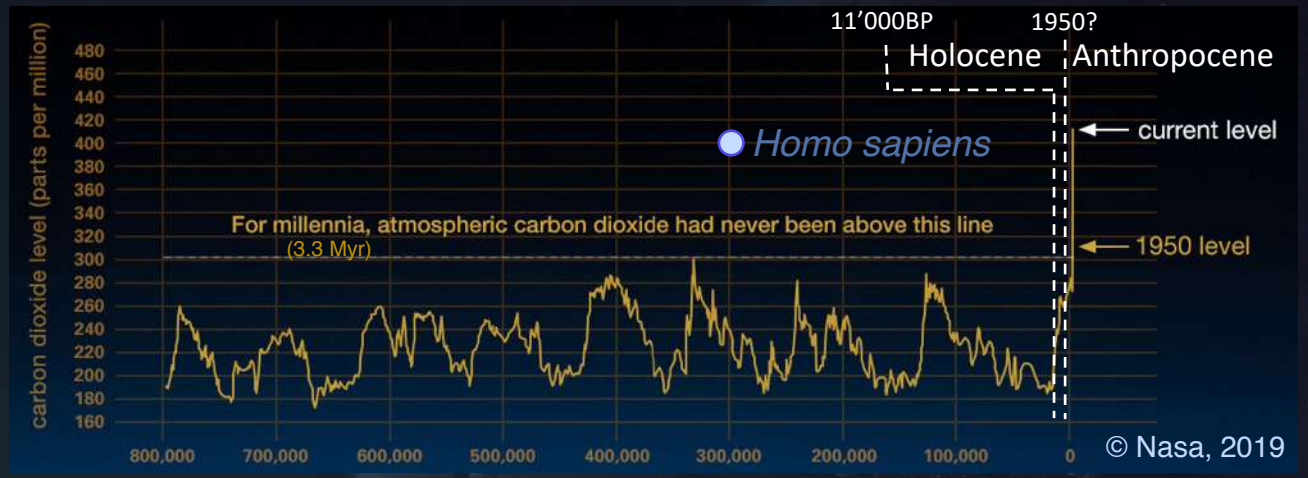
→ **Important and global climate change**

Origin?





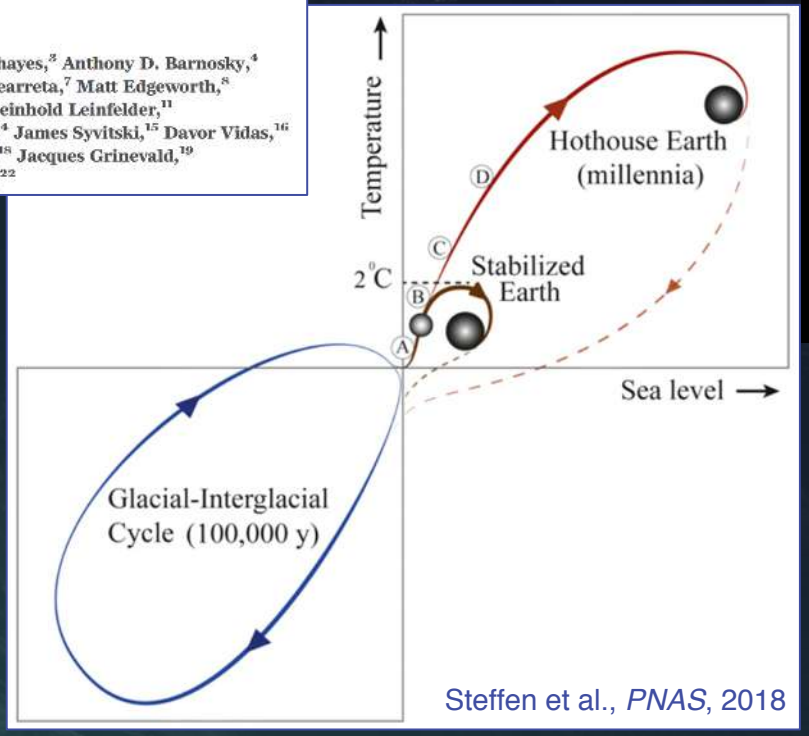
Data and Modelling : Nasa (© Bloomberg 2015)



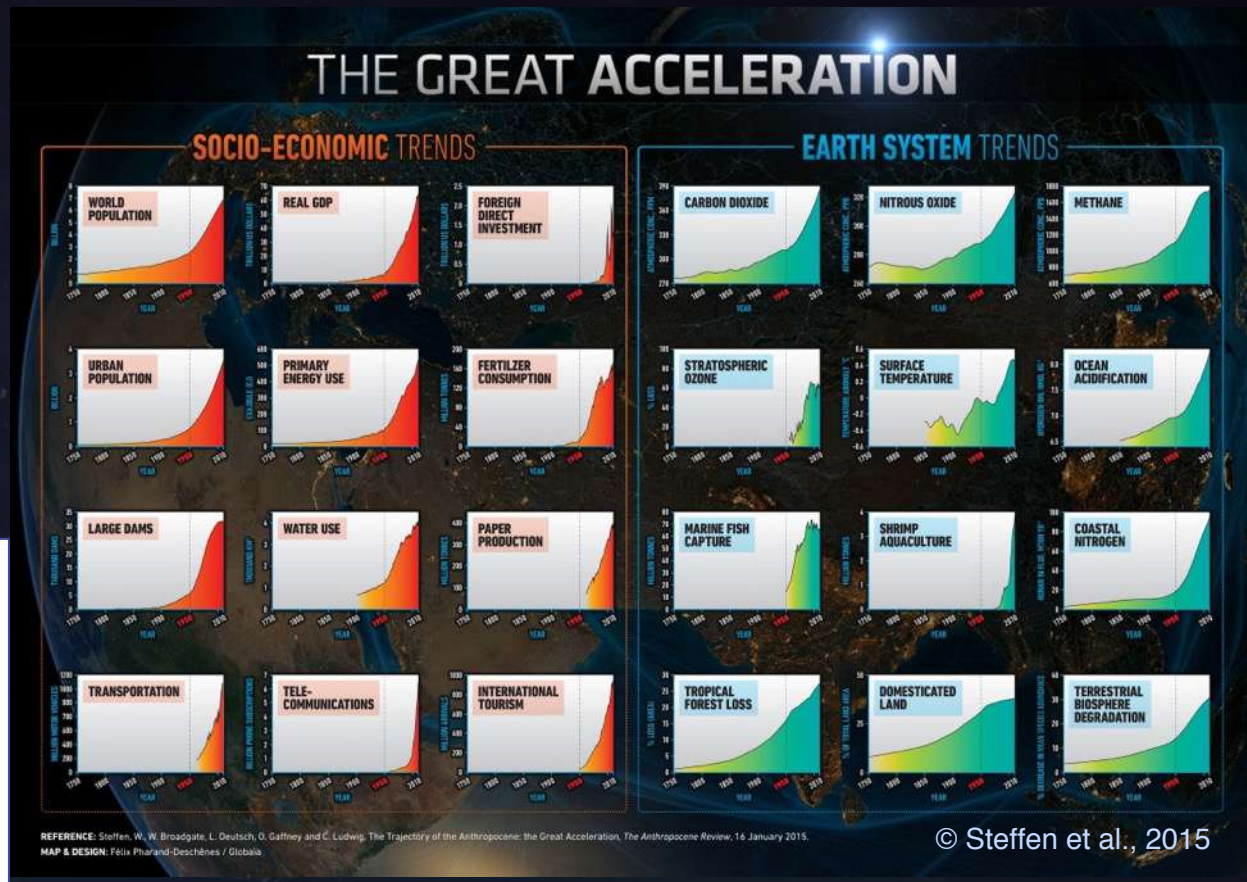
The Anthropocene is functionally and stratigraphically distinct from the Holocene

Colin N. Waters,[1*] Jan Zalasiewicz,[2] Colin Summerhayes,[3] Anthony D. Barnosky,[4] Clément Poirier,[5] Agnieszka Gałuszka,[6] Alejandro Cearreta,[7] Matt Edgeworth,[8] Erle C. Ellis,[9] Michael Ellis,[1] Catherine Jeandel,[10] Reinhold Leinfelder,[11] J. R. McNeill,[12] Daniel deB. Richter,[13] Will Steffen,[14] James Syvitski,[15] Davor Vidas,[16] Michael Wagreich,[17] Mark Williams,[2] An Zhisheng,[18] Jacques Grinevald,[19] Eric Odada,[20] Naomi Oreskes,[21] Alexander P. Wolfe[22]

Waters et al., *Science*, 2016



Steffen et al., *PNAS*, 2018



© Steffen et al., 2015

Modification of atmosphere's composition (greenhouse gas, ozone, …), biodiversity, land surface…

→ deep modification of the Earth and its climatic system

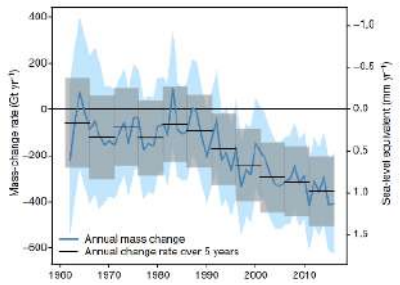
Glaciers and ice sheets at the Anthropocene

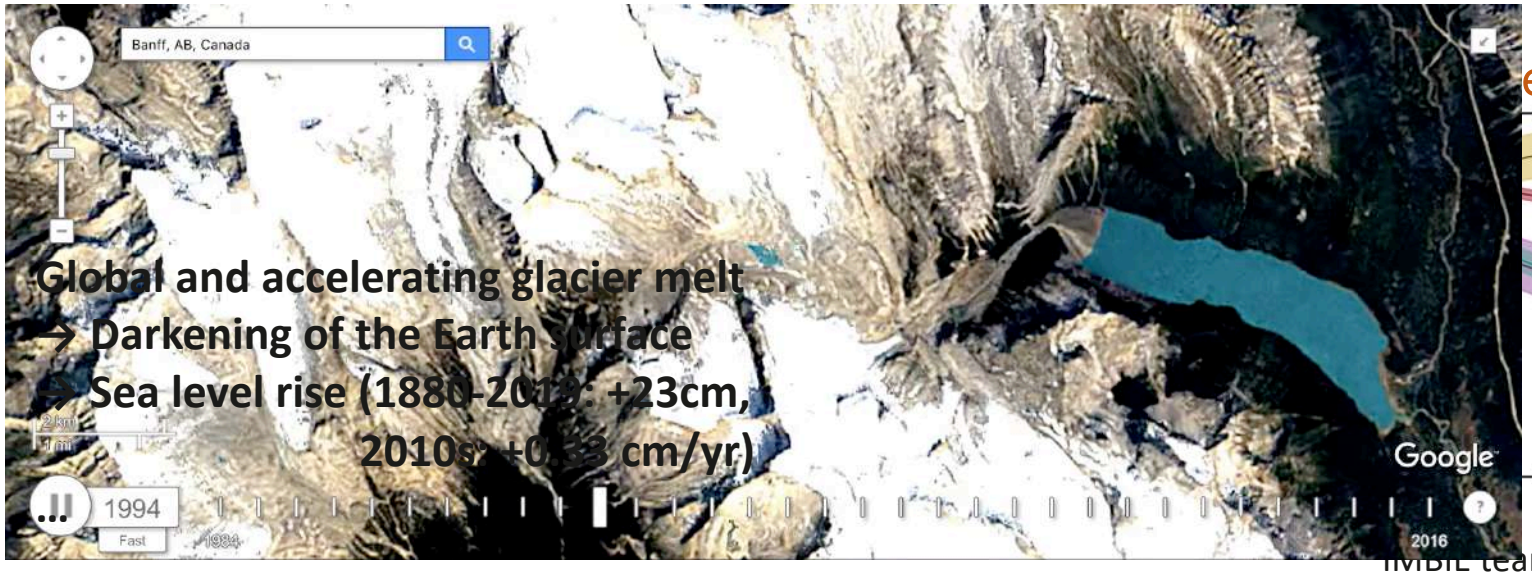
Glaciers

nature
International journal of science
https://doi.org/10.1038/s41586-019-1071-0

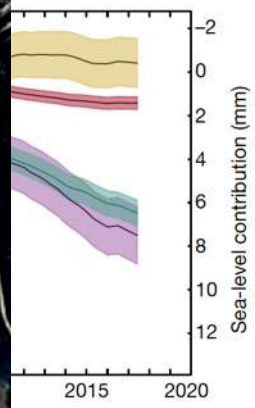
Global glacier mass changes and their contributions to sea-level rise from 1961 to 2016

M. Zemp[1]*, M. Huss[2,3], E. Thibert[4], N. Eckert[4], R. McNabb[5], J. Huber[1], M. Barandun[3], H. Machguth[1,3], S. U. Nussbaumer[1,3], I. Gärtner-Roer[1], L. Thomson[6], F. Paul[1], F. Maussion[7], S. Kutuzov[8] & J. G. Cogley[9,10]



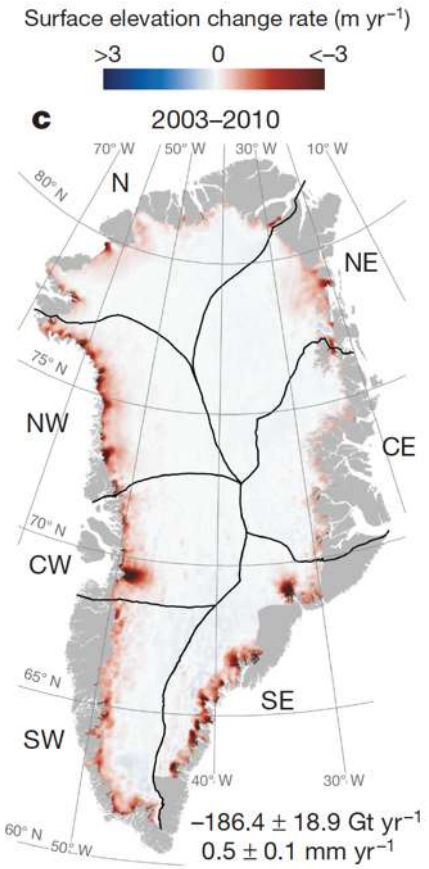


Global and accelerating glacier melt
→ Darkening of the Earth surface
→ Sea level rise (1880-2018: +23cm, 2010s: +0.33 cm/yr)



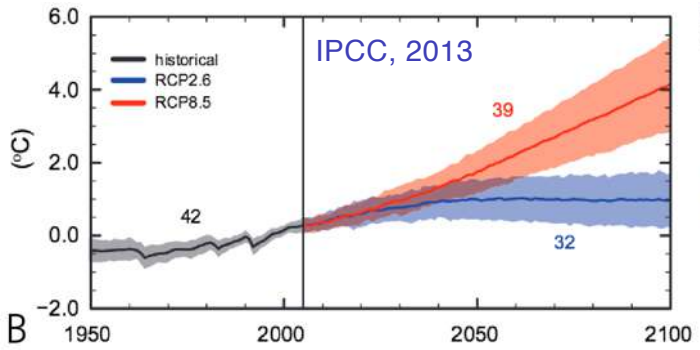
IMBIE team, *Nature,* 2018

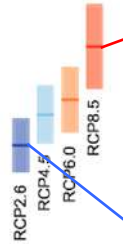
Greenland ice sheet



Kjeldsen et al., *Nature,* 2015

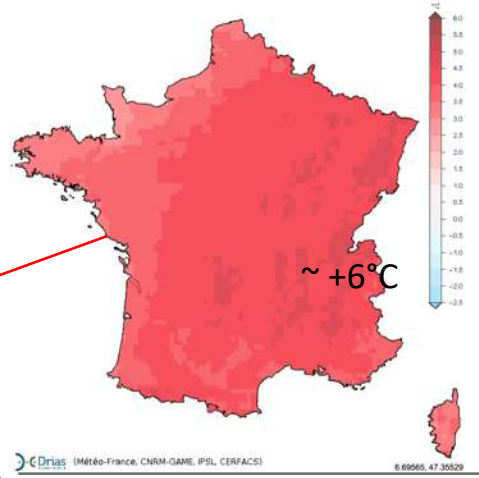
Global projections | 1900-2100: +1.5/2°C → +5°C
according to greenhouse gas emissions

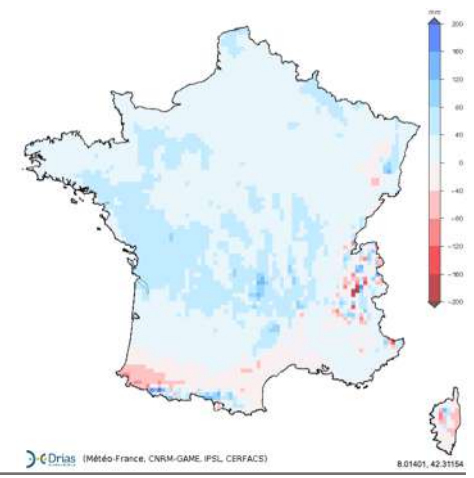


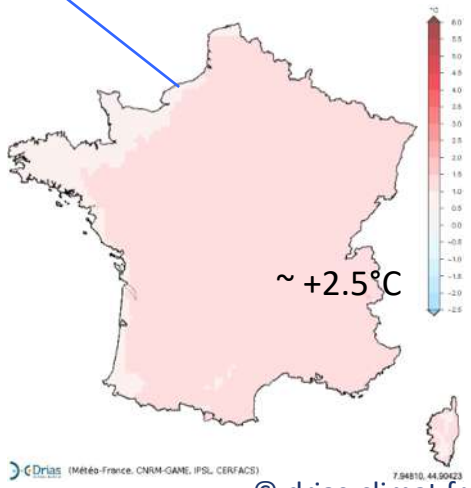


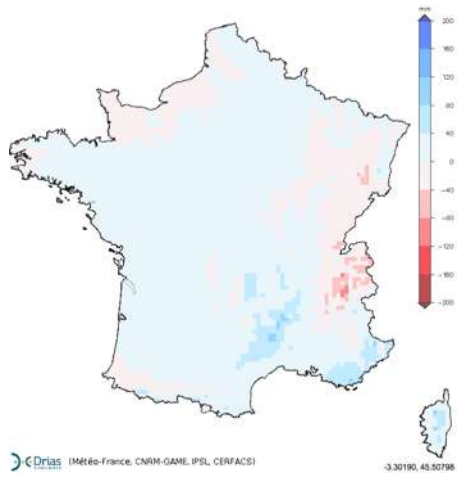
Annual temperature in 2100

Winter precipitations in 2100









Natural Greenhouse effect : 155 W/m^2 (preindustrial level)
→ Additional anthropogenic forcing in 2100 (2.6-8.5 W/m^2)
Representative Concentration Pathways (RCP) proposed by considering social and environmental trends/possibilities

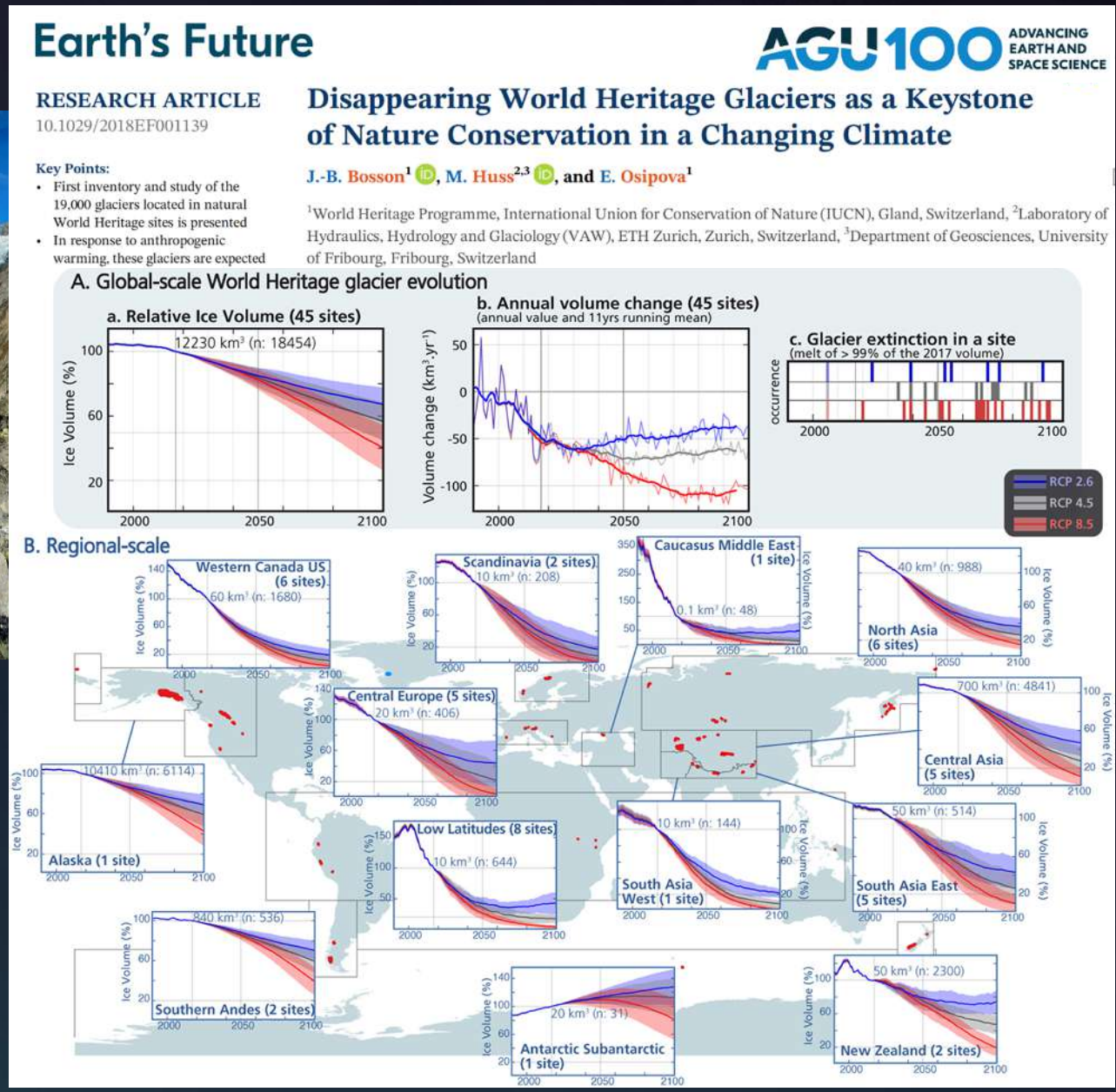
Glaciers, a keystone of nature conservation in a changing climate ?

Future response of glaciers?

- **Major and unprecedented global glacier melt** :
  -25/-50% of global glacier volume by 2100
  Glacier extinction in some regions
- Toward a new equilibrium vs. an irreversible disappearance

→ Major influence of greenhouse gas emissions
(and thus human activities at very short-term)

19039 glaciers in 46 natural World Heritage sites



Earth's Future

RESEARCH ARTICLE
10.1029/2018EF001139

Disappearing World Heritage Glaciers as a Keystone of Nature Conservation in a Changing Climate

J.-B. Bosson[1], M. Huss[2,3], and E. Osipova[1]

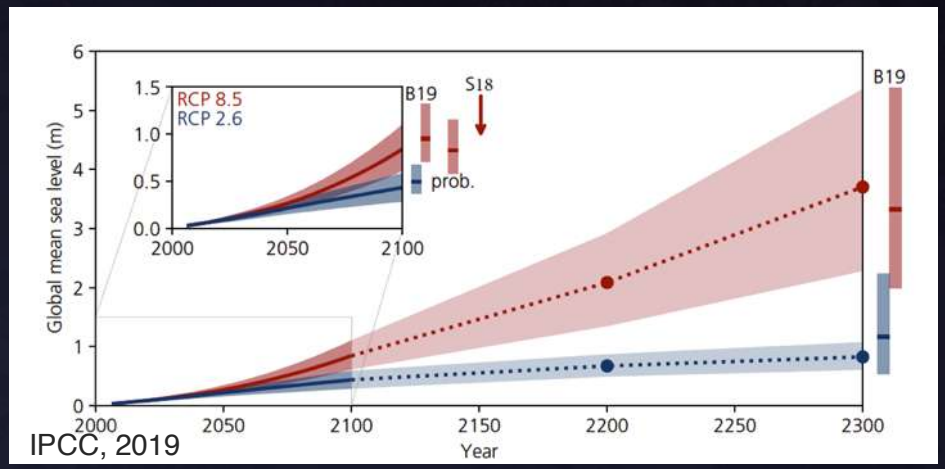
[1]World Heritage Programme, International Union for Conservation of Nature (IUCN), Gland, Switzerland, [2]Laboratory of Hydraulics, Hydrology and Glaciology (VAW), ETH Zurich, Zurich, Switzerland, [3]Department of Geosciences, University of Fribourg, Fribourg, Switzerland

Key Points:
- First inventory and study of the 19,000 glaciers located in natural World Heritage sites is presented
- In response to anthropogenic warming, these glaciers are expected

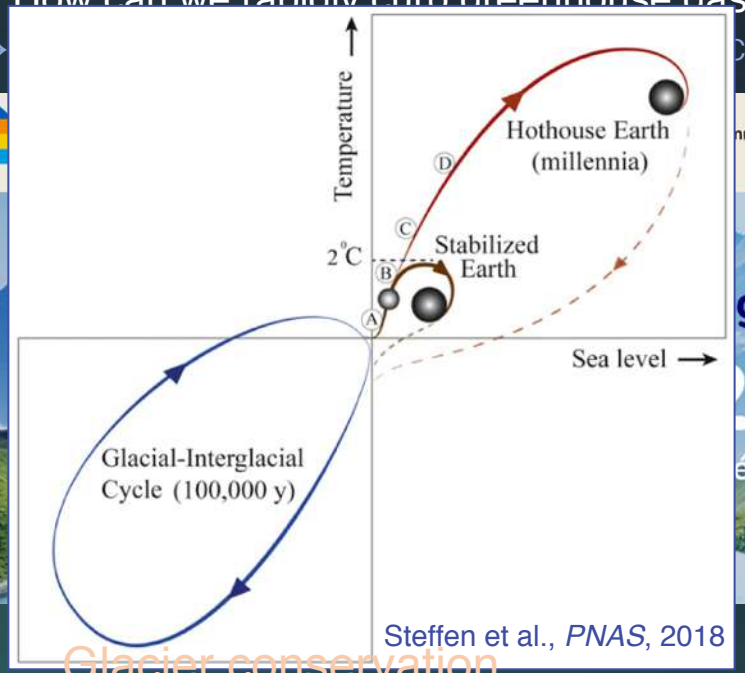
1. Why do we have to protect/save the glaciers?
→ key component of global Earth's ecosystems where Humanity lives (glaciers ≈ *keystone species*)

2. How do we protect/conserve the glaciers?
→ limitation of greenhouse gas emissions (glaciers ≈ *umbrella species)*

3. How can we rapidly curb greenhouse gas emissions?
→ ...celerate climate change



IPCC, 2019



Steffen et al., *PNAS*, 2018

Rhone Glacier (Swtzerland, © Jurg Alean)

Glacier conservation
→ **key objective and leverage to face CC**

A key period...

2017 *Viewpoint*

World Scientists' Warning to Humanity: A Second Notice

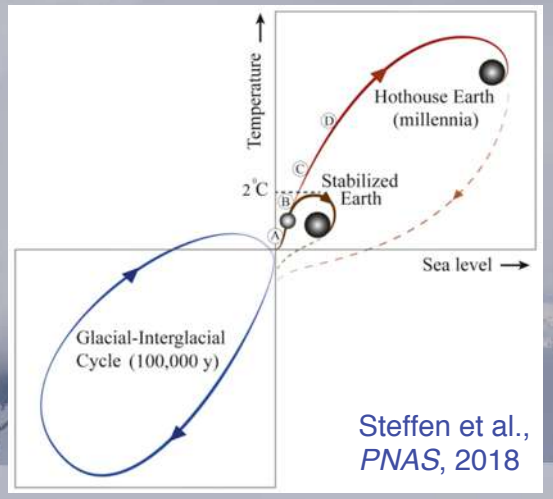
WILLIAM J. RIPPLE, MAHMOUD I. MAHM

2019 *Viewpoint*

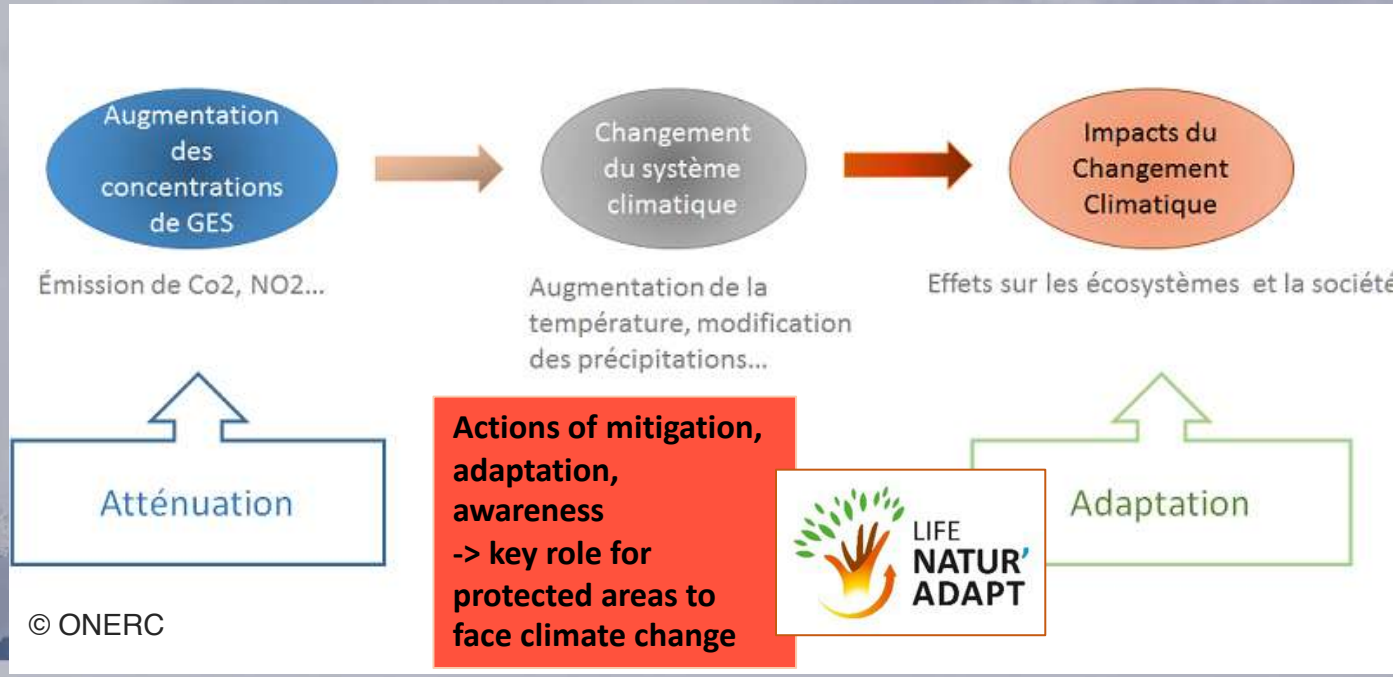
World Scientists' Warning of a Climate Emergency

WILLIAM J. RIPPLE, CHRISTOPHER WOLF, THOMAS M. NEWSOME, PHOEBE BARNARD, WILLIAM R. MOOMAW, AND 11,258 SCIENTIST SIGNATORIES FROM 153 COUNTRIES (LIST IN SUPPLEMENTAL FILE S1)

Humans are on a collision course with the natural world
→ **destruction of the Earth, our only Home**
There is an **emergency to change the trajectory of human societies** and to find a sustainable alternative to the «business as usual» model



Steffen et al., *PNAS*, 2018



Take home messages

- **(Climate) Change = norm at the geological timescale** (the Earth has already been colder and warmer than today)
- **Current climate change is particular because**:
  - **Mainly anthropogenic** (modification of energy exchanges within the climate system)
  - (among cascading consequences) **global warming has an important magnitude and velocity** (unprecedented velocity since at least 11’000 years, highest carbon level in the atmosphere since 3.3 Myr)
- **Already major consequences** (glacier decline, coral bleaching, sea level rise, climatic migrants, etc.)
- **According to human activities in the near future, toward a new climatic *equilibrium*** in the next centuries (close to the *natural* trajectory of the Earth system) or **Hothouse Earth** (global warming of several °C and triggering of irreversible processes (cross and lock the Earth beyond planetary thresholds)). Humanity has never faced this extreme situation (→ unprecedented environmental and social consequences)

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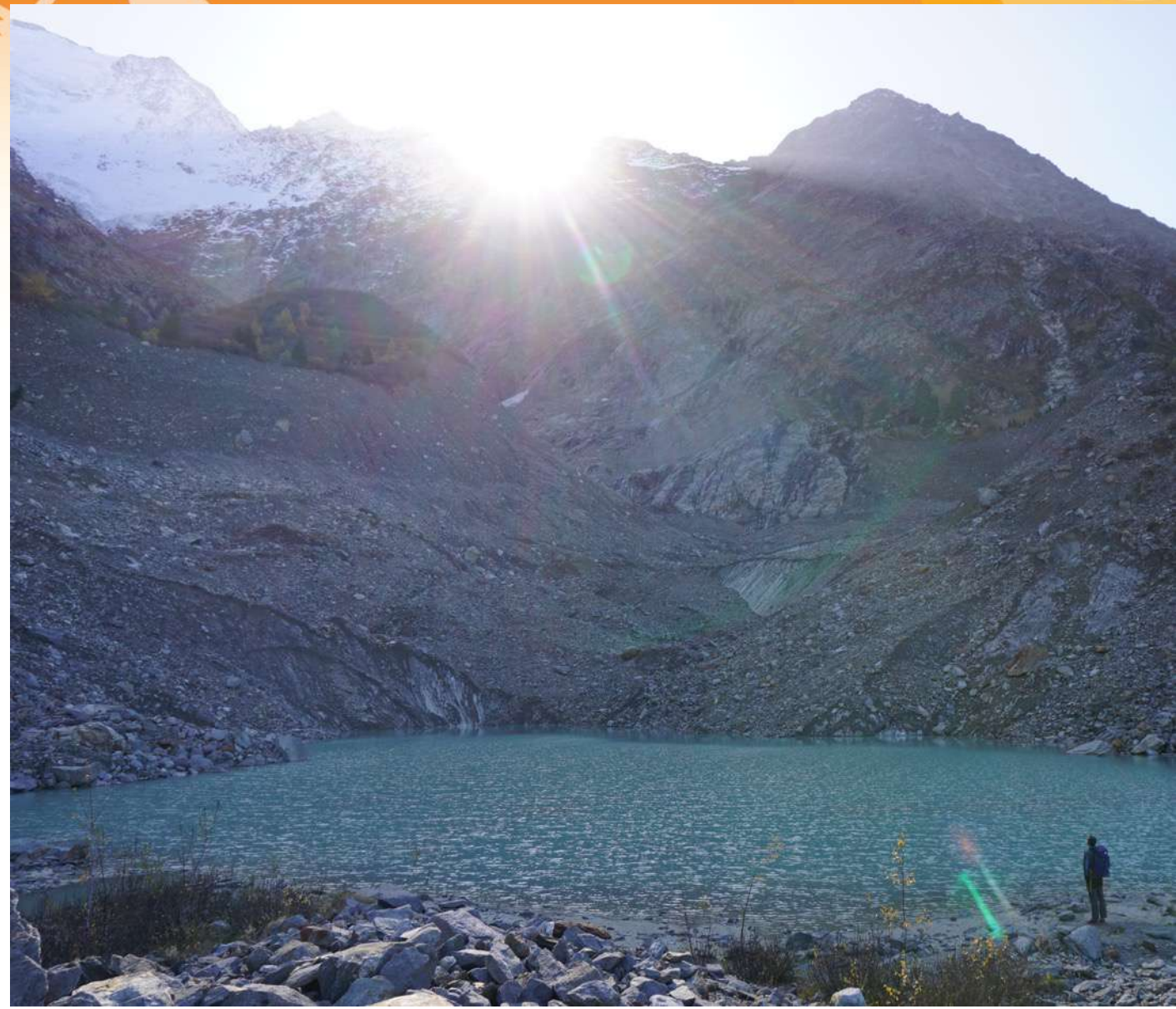
Thanks for your attention

Questions : jb.bosson@asters.asso.fr



Coordinateur du projet

Réserves Naturelles de France

Contact : naturadapt-rnf@espaces-naturels.fr 03.80.48.91.00

Partenaires engagés dans le projet

EUROPARC FEDERATION · UMS Patrimoine Naturel · Tela Botanica · LPO · AGIR pour la BIODIVERSITÉ · Asters Conservatoire d'espaces naturels Haute-Savoie · Réserves Naturelles CATALANES · Parc naturel régional du Morvan · Parc naturel régional des Volcans d'Auvergne · Petite Camargue Alsacienne

Financeurs du projet

Life · Ministère de la Transition écologique et solidaire · AGENCE FRANÇAISE POUR LA BIODIVERSITÉ – Ministère de l'Environnement

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