

The background of the slide is a prehistoric cave wall covered in paintings of animals. A large black bull with prominent horns is the central focus, surrounded by other animals like horses and deer in various colors including ochre, red, and black. The text is overlaid on this background.

Dati e analisi statistiche fra montagne, Artico e cambiamento climatico

Antonello Provenzale
Istituto di Geoscienze e Georisorse del CNR
Fondazione di Ricerca CIMA

«Ma chi lo dice che il clima sta cambiando?
Cosa ne sanno gli scienziati? Io non ci credo!»

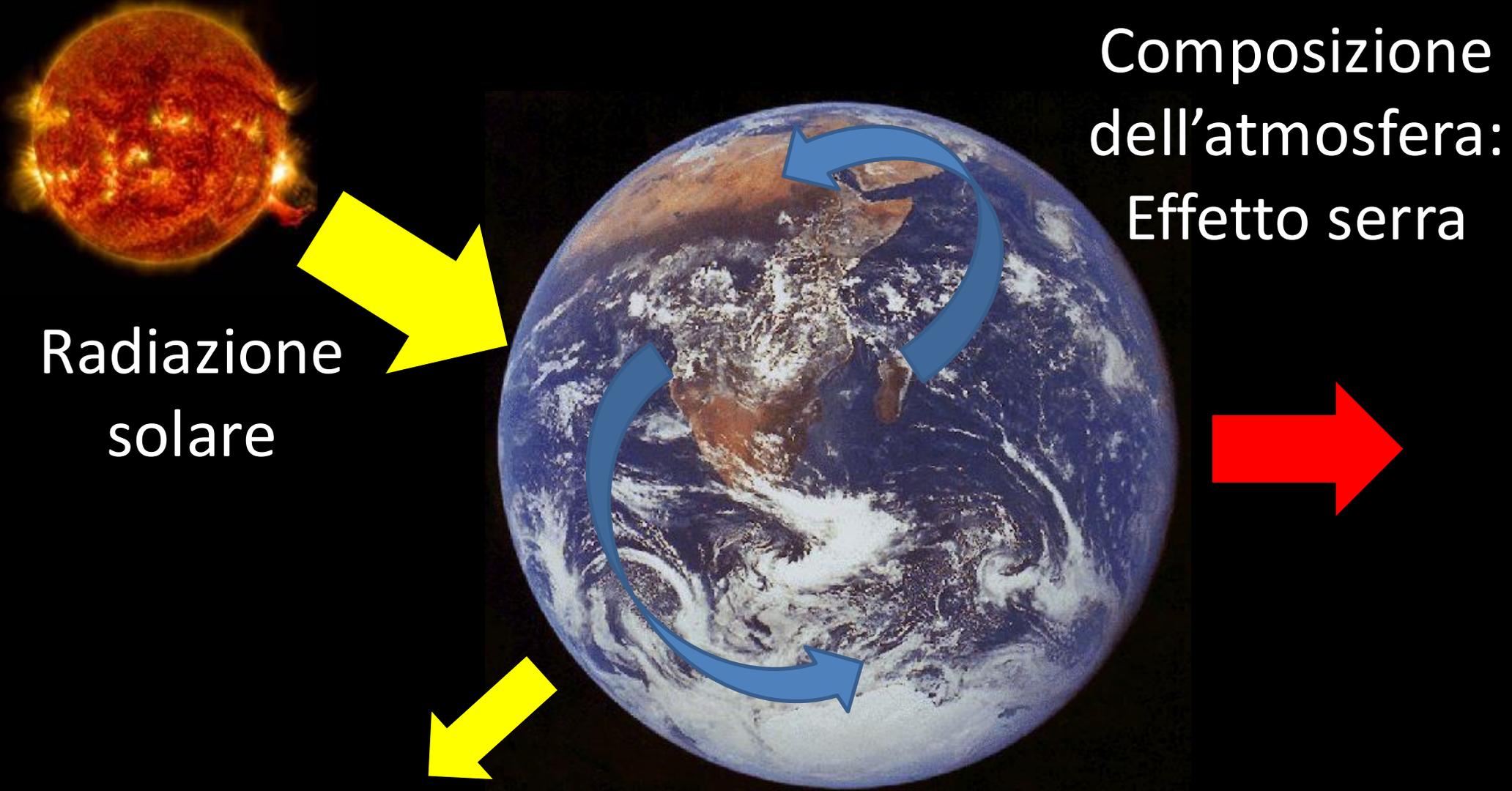
«Il clima sta cambiando
ma non è colpa degli esseri umani!»

«Ma figurati se una specie singola può cambiare il
clima!»

«Stiamo andando verso la fine del pianeta!
Dobbiamo salvarlo!»

«Non c'è più niente da fare...»

Il più semplice modello del clima



Radiazione
solare

Composizione
dell'atmosfera:
Effetto serra

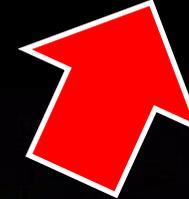
Caratteristiche della superficie
e delle nubi: Albedo

Ruolo dell'atmosfera: l'effetto serra

Radiazione
solare



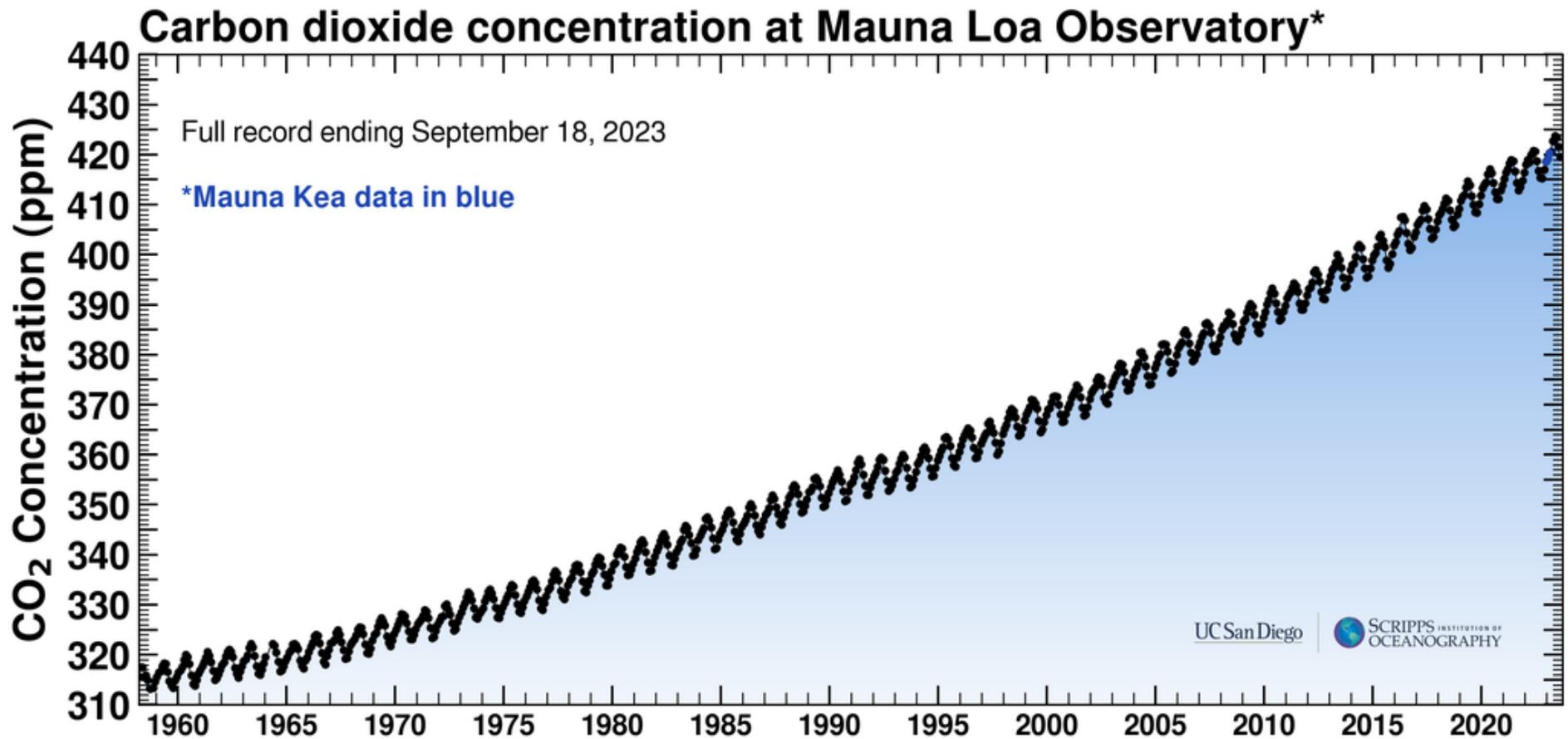
Radiazione IR
della Terra



CO₂
CH₄
H₂O

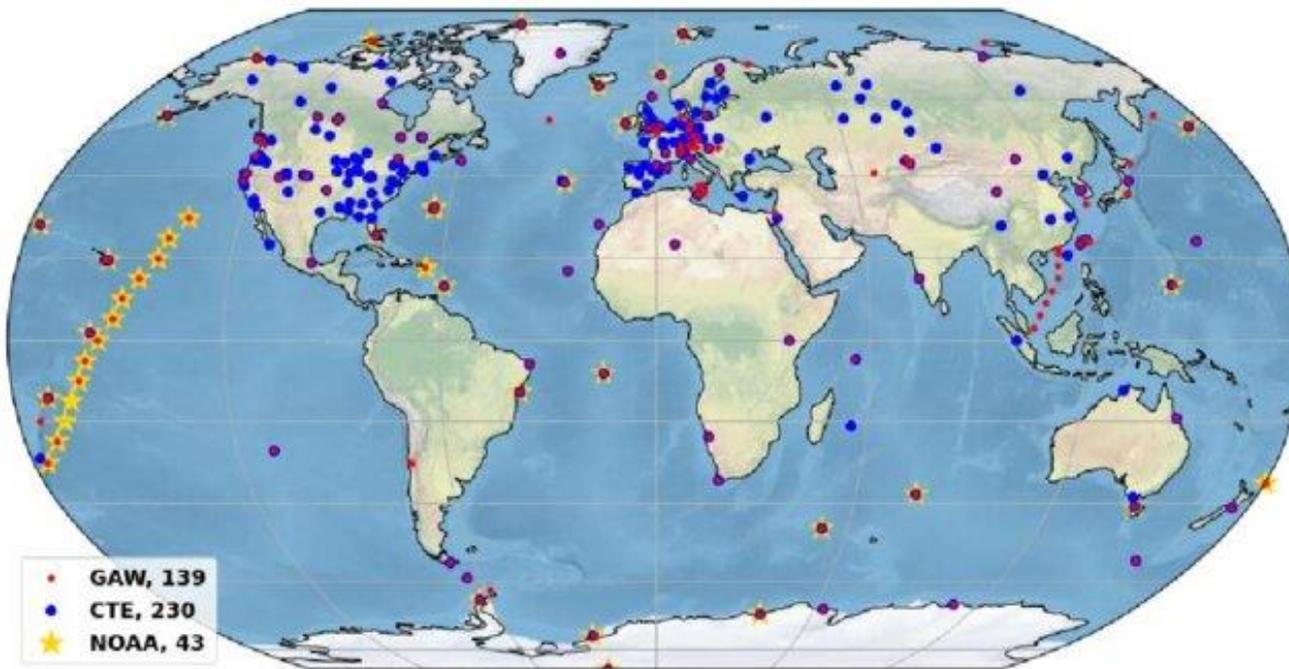
Grazie all'effetto serra, la temperatura media alla superficie del pianeta è di circa 15 °C e non di -18 °C

Charles Keeling e la curva della CO₂

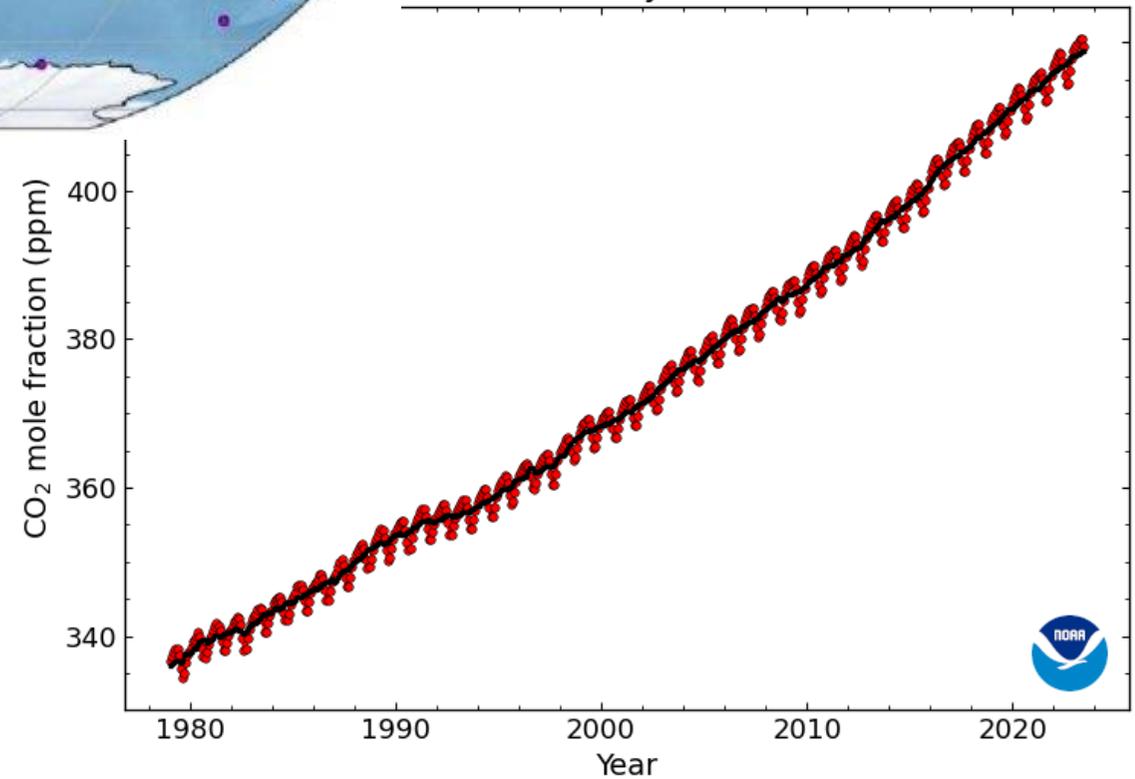


<https://keelingcurve.ucsd.edu/>

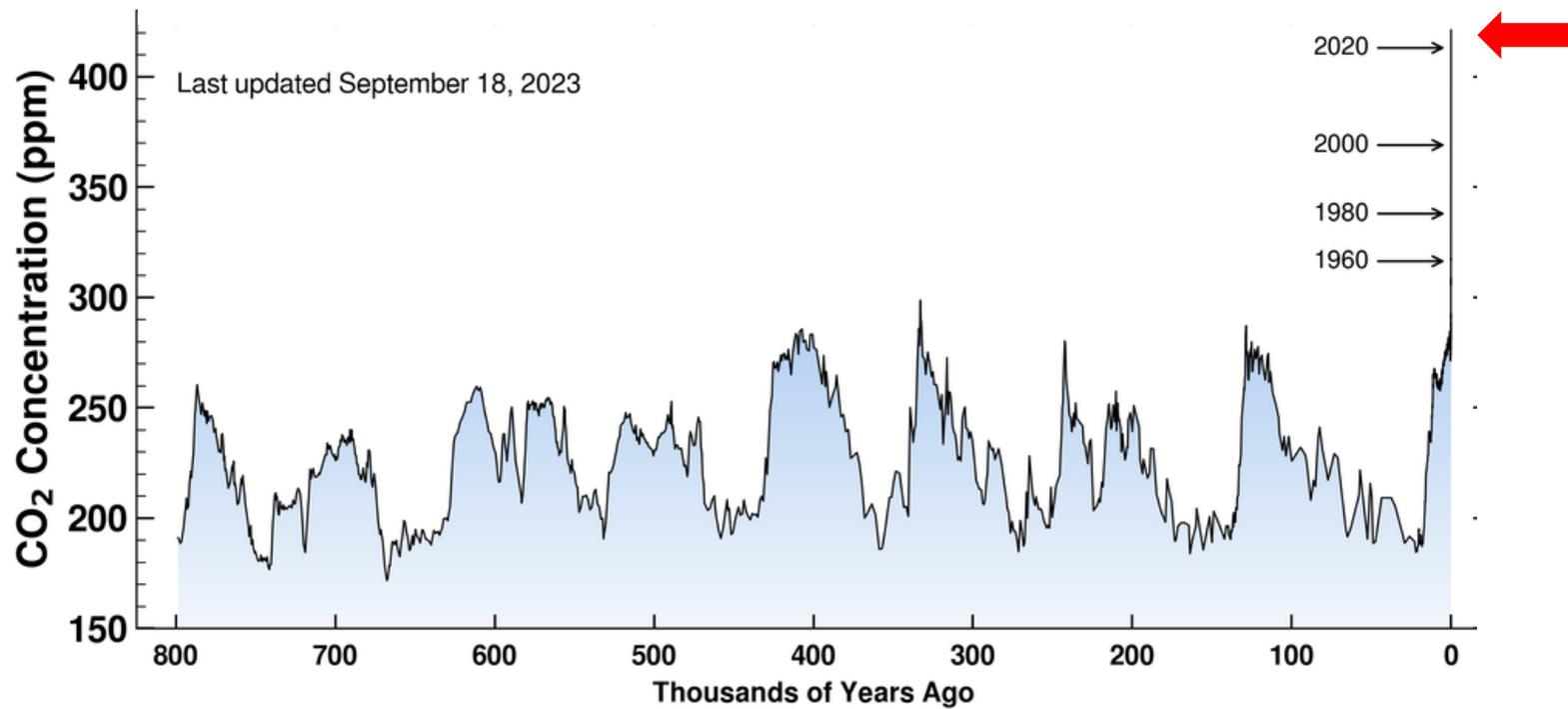
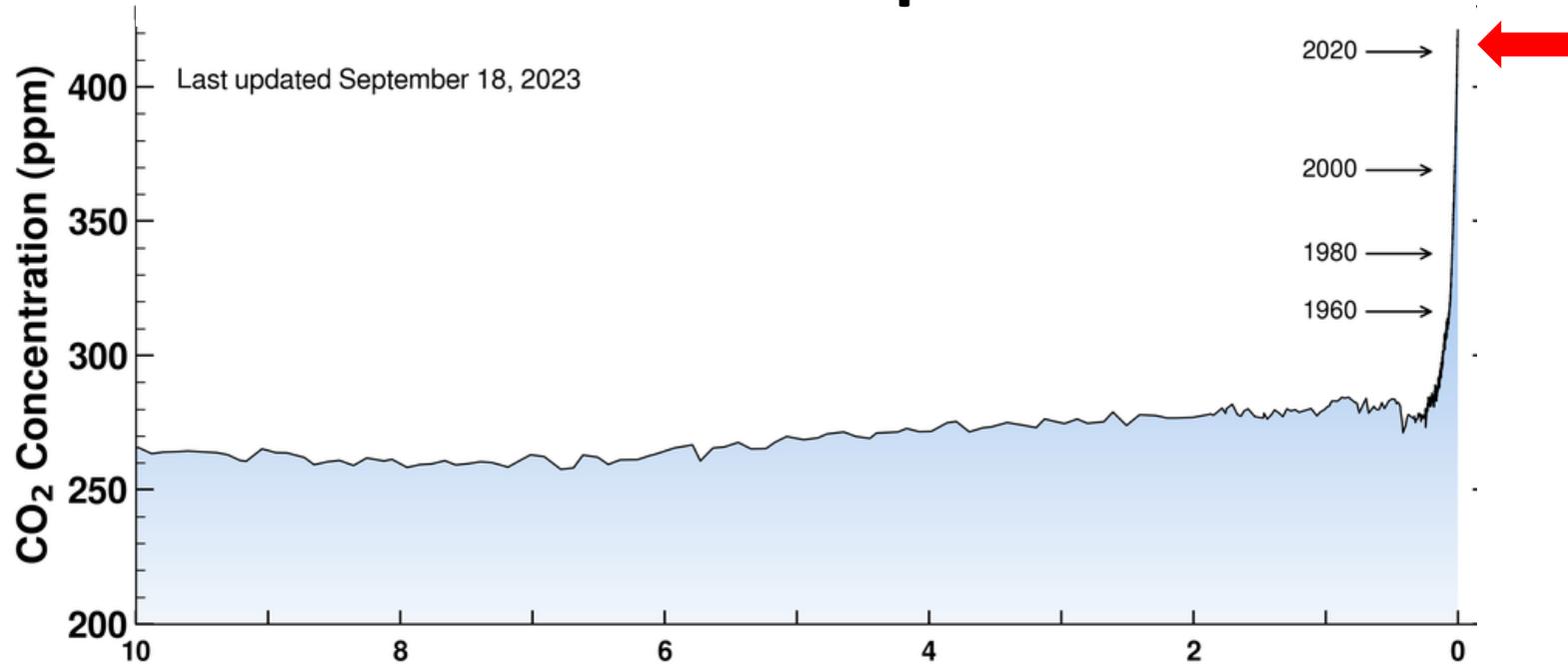
La rete globale di osservazioni della CO₂



Global Monthly Mean CO₂



Confronto con il passato



I progetti «EPICA» e «Beyond EPICA»

Carotaggio nel ghiaccio per 2800 metri



Isotopi dell'ossigeno e bolle d'aria

^{18}O , ^{17}O , ^{16}O

^{16}O : 8 protoni e 8 neutroni

H, D = ^2H

H : 1 protone

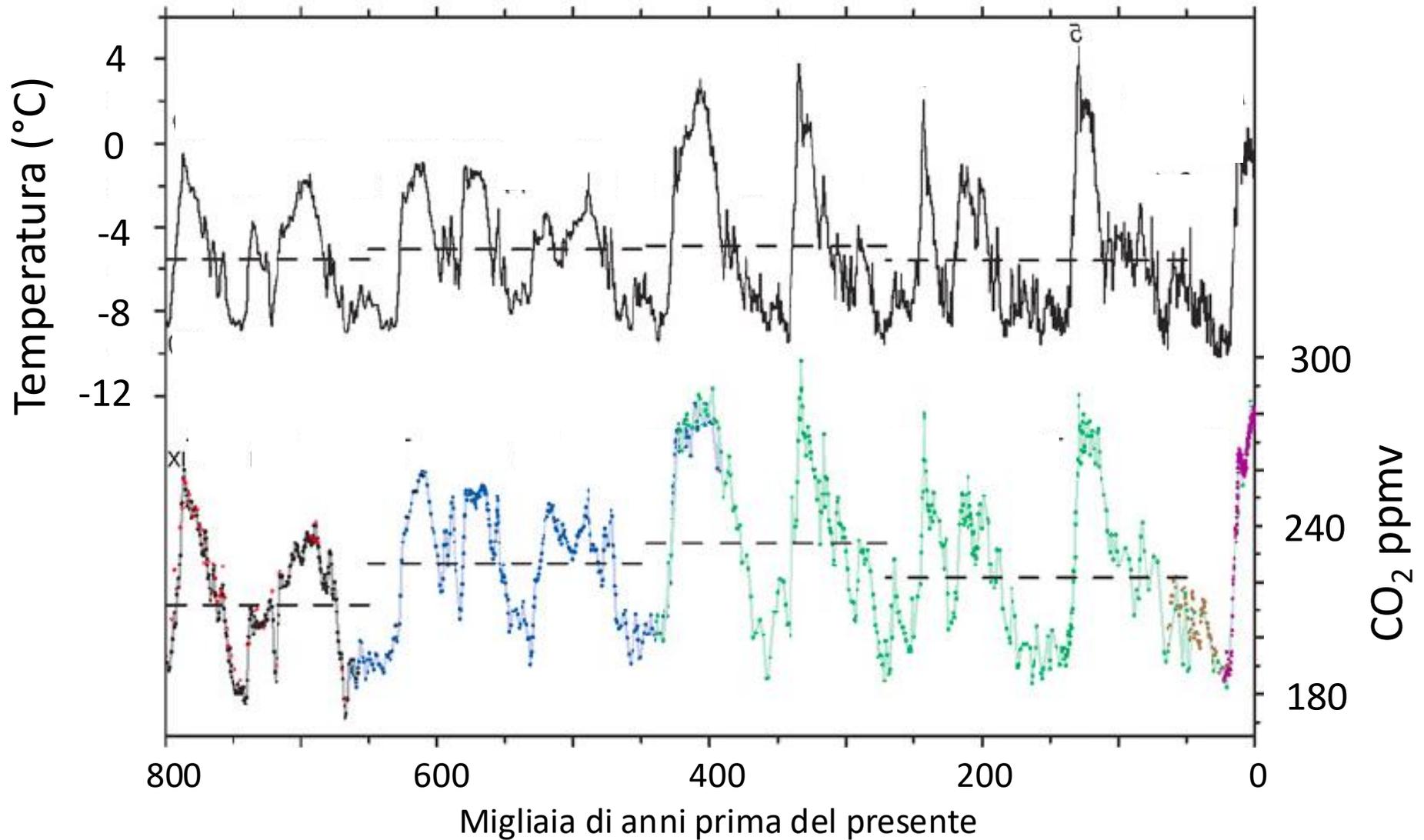
D : 1 protone e 1 neutrone

H_2O : due atomi di H e un atomo di O



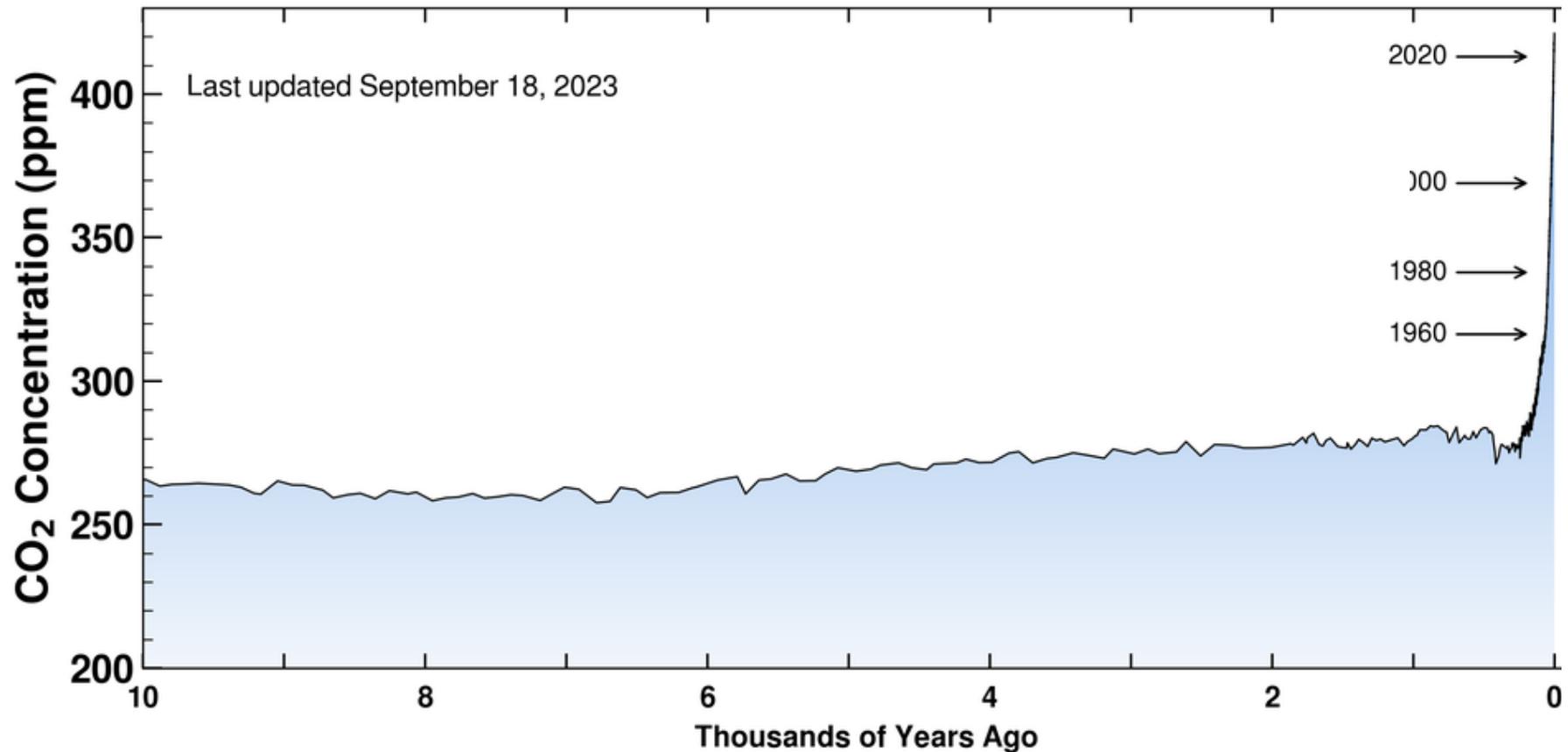
CO_2 : intrappolata nelle bolle d'aria nel ghiaccio

EPICA: gli ultimi 800 mila anni

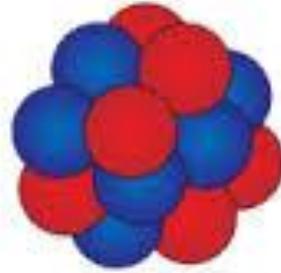


da Luthi et al., Nature 2008

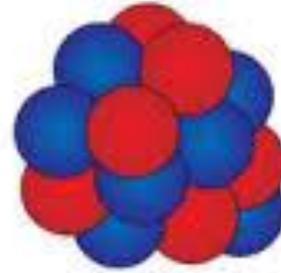
Ma come facciamo a sapere che la crescita della CO₂ atmosferica negli ultimi cento anni è di origine antropica?



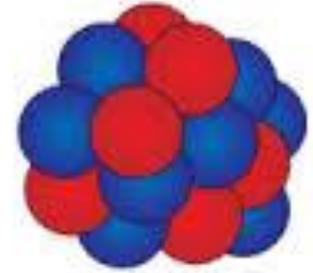
Composizione isotopica della CO₂



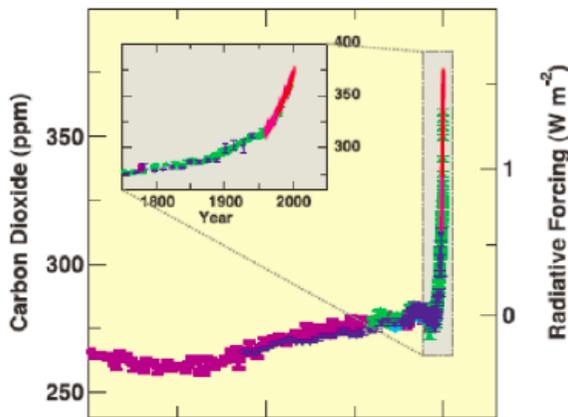
Carbon-12
98.9%
6 protons
6 neutrons



Carbon-13
1.1%
6 protons
7 neutrons



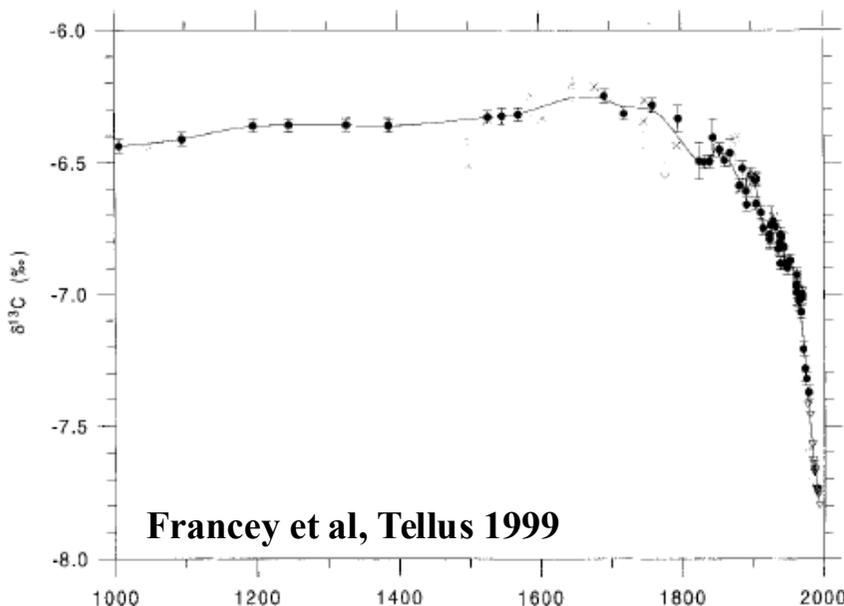
Carbon-14
<0.1%
6 protons
8 neutrons



$^{13}\text{C}/^{12}\text{C}$ piante < $^{13}\text{C}/^{12}\text{C}$ atmosfera

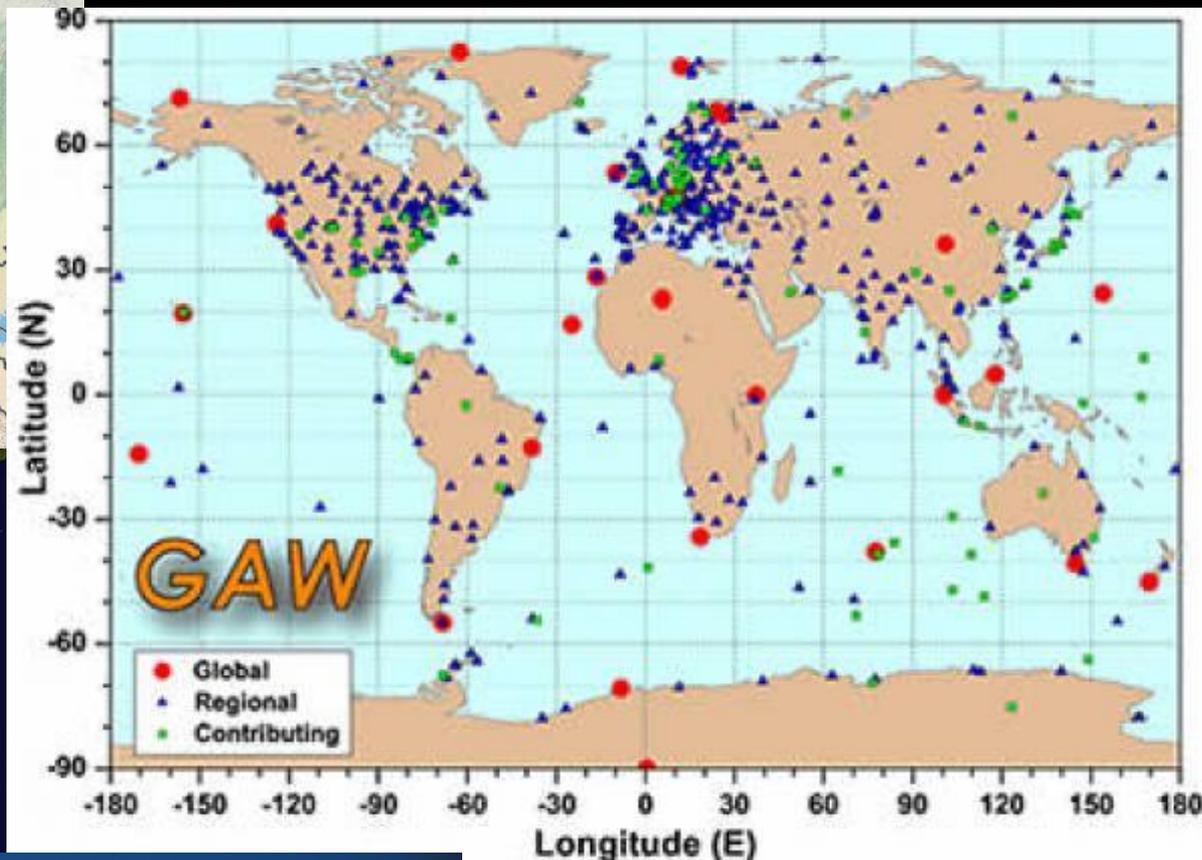
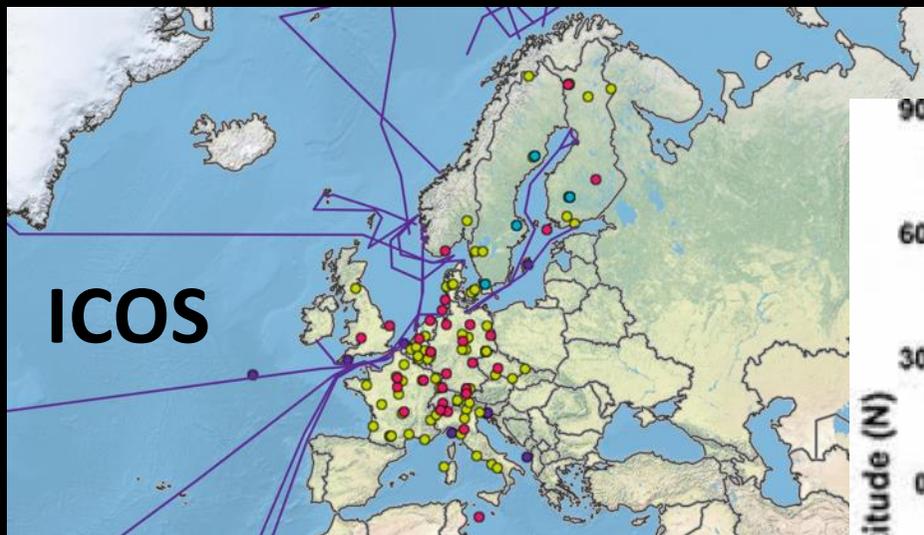
$^{13}\text{C}/^{12}\text{C}$ petrolio \approx $^{13}\text{C}/^{12}\text{C}$ piante

$^{13}\text{C}/^{12}\text{C}$ della CO₂ < $^{13}\text{C}/^{12}\text{C}$ atmosfera

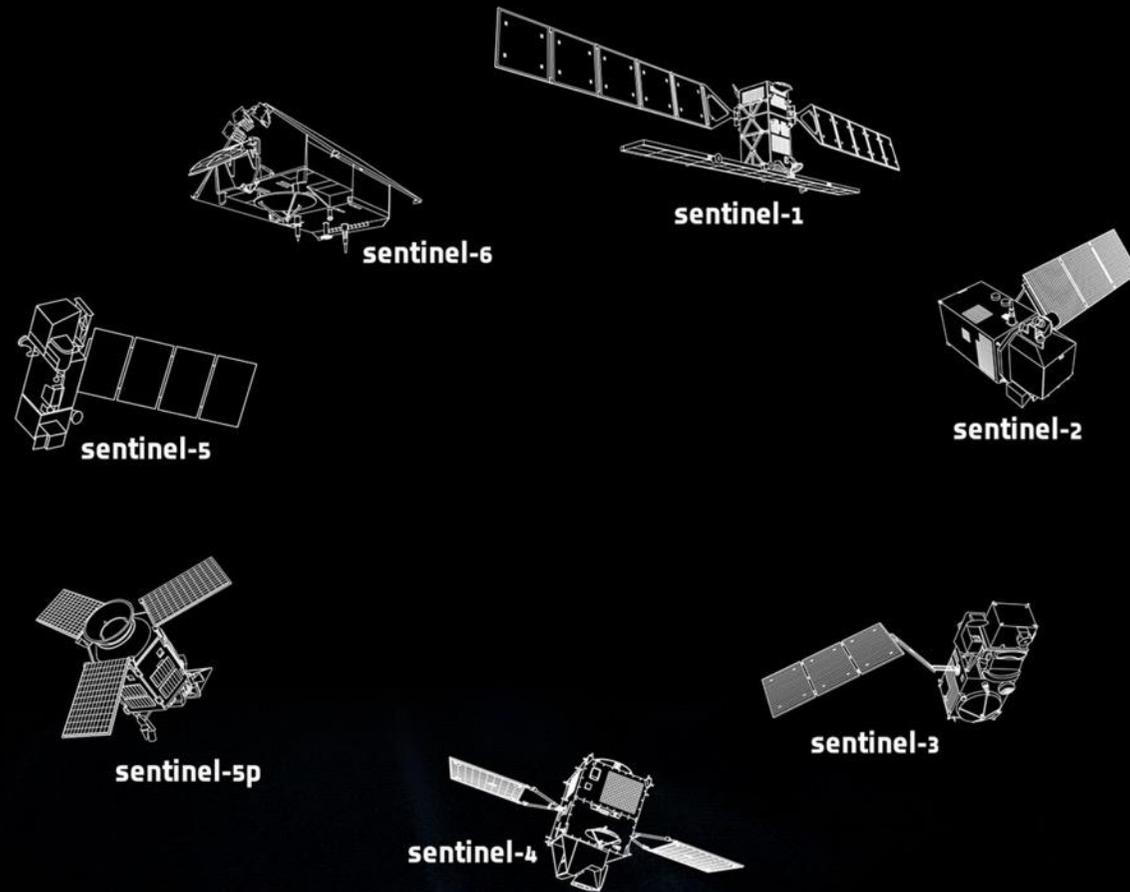


Composizione isotopica della CO₂ atmosferica da anelli degli alberi, coralli, carotaggi glaciali

Global Atmosphere Watch



Il ruolo cruciale dei dati osservativi



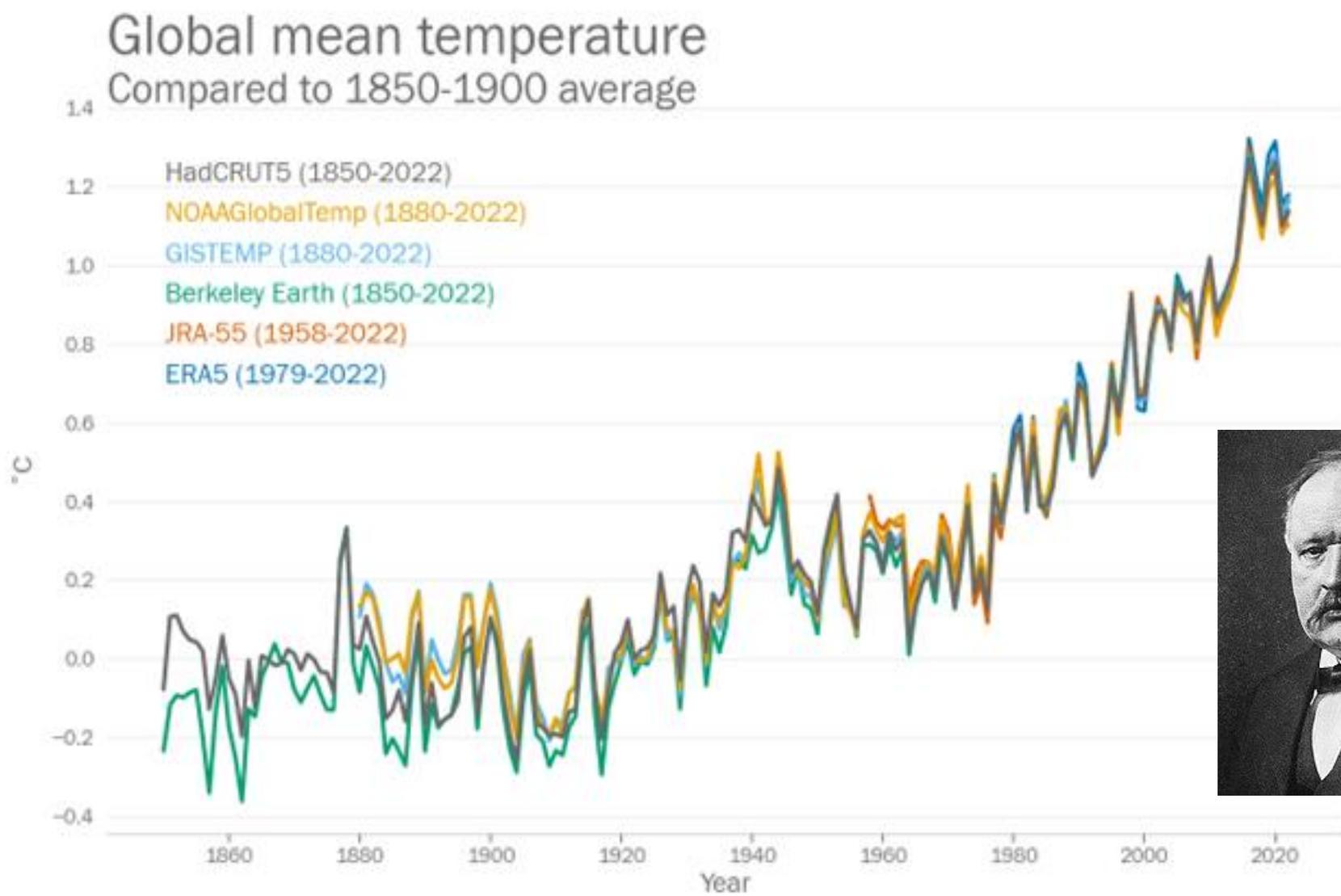
**Il Sistema Terra dallo spazio:
le «European Sentinels»**

Enter search words



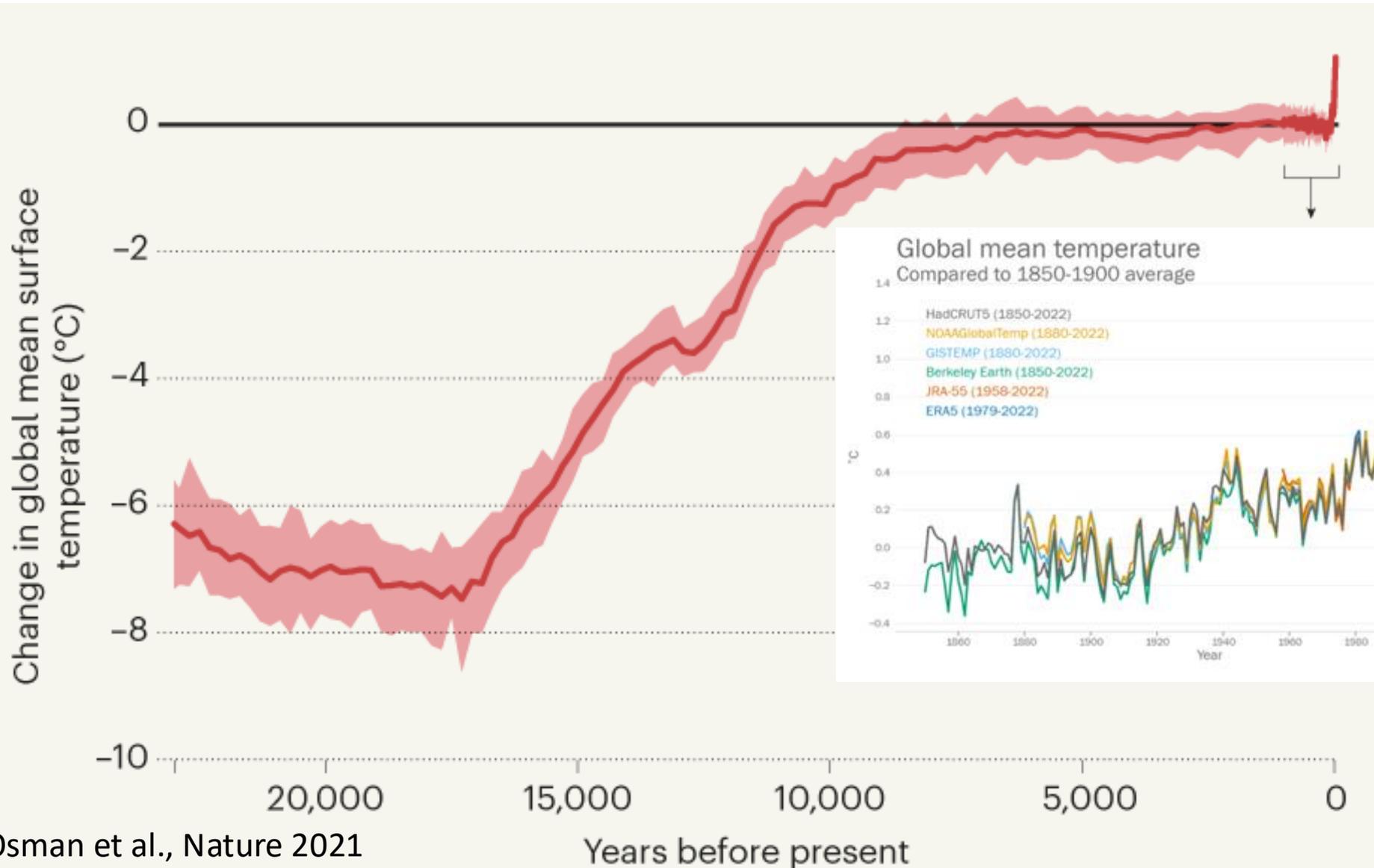
ADVANCED SEARCH ▾

Conseguenza della crescita della concentrazione di CO₂: aumento globale delle temperature



WMO, <https://public.wmo.int/en/media/press-release/eight-warmest-years-record-witness-upsurge-climate-change-impacts>

CO₂ e crescita delle temperature



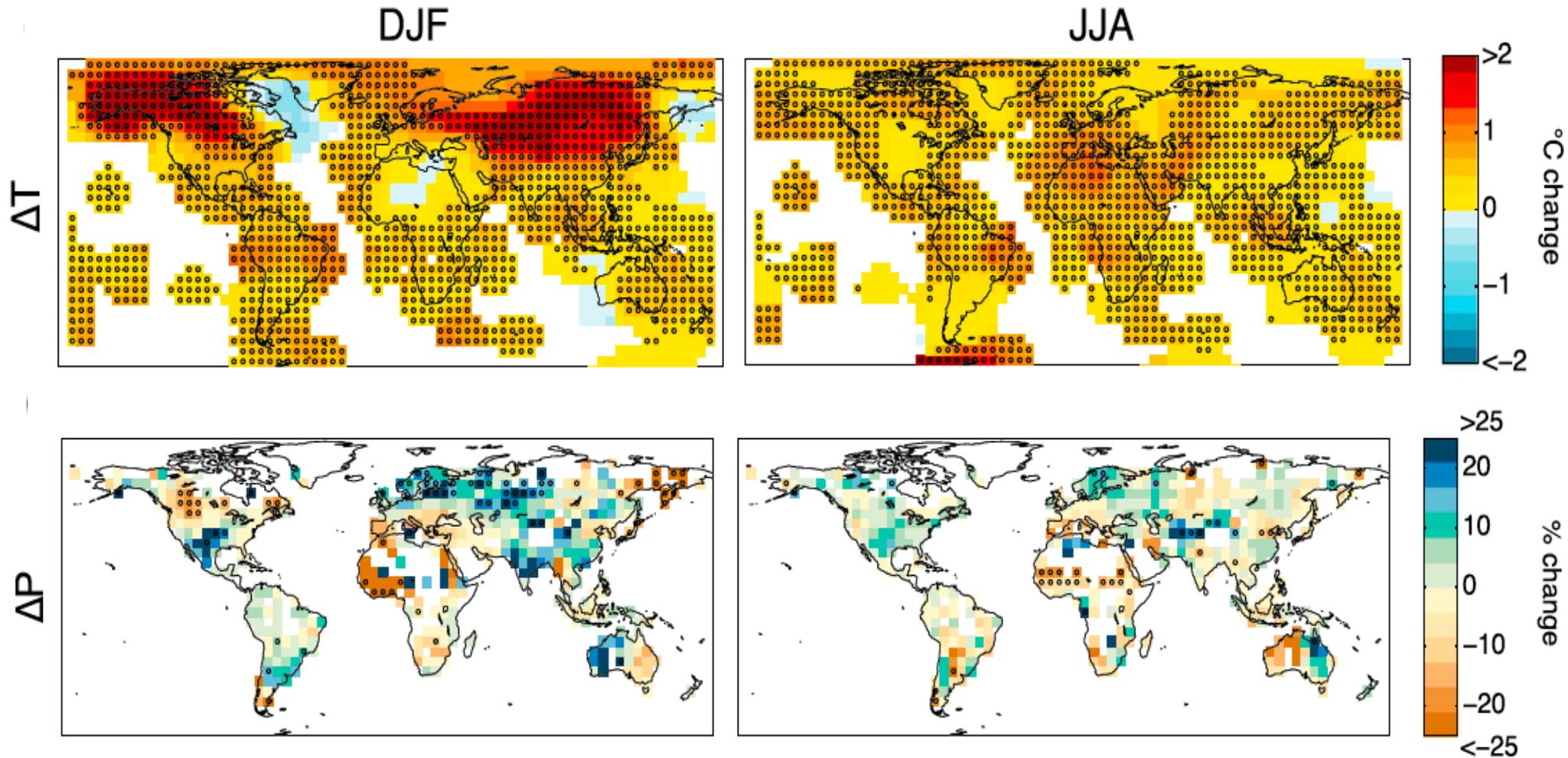
Osman et al., Nature 2021

Marcott e Shakun, Nature 2021

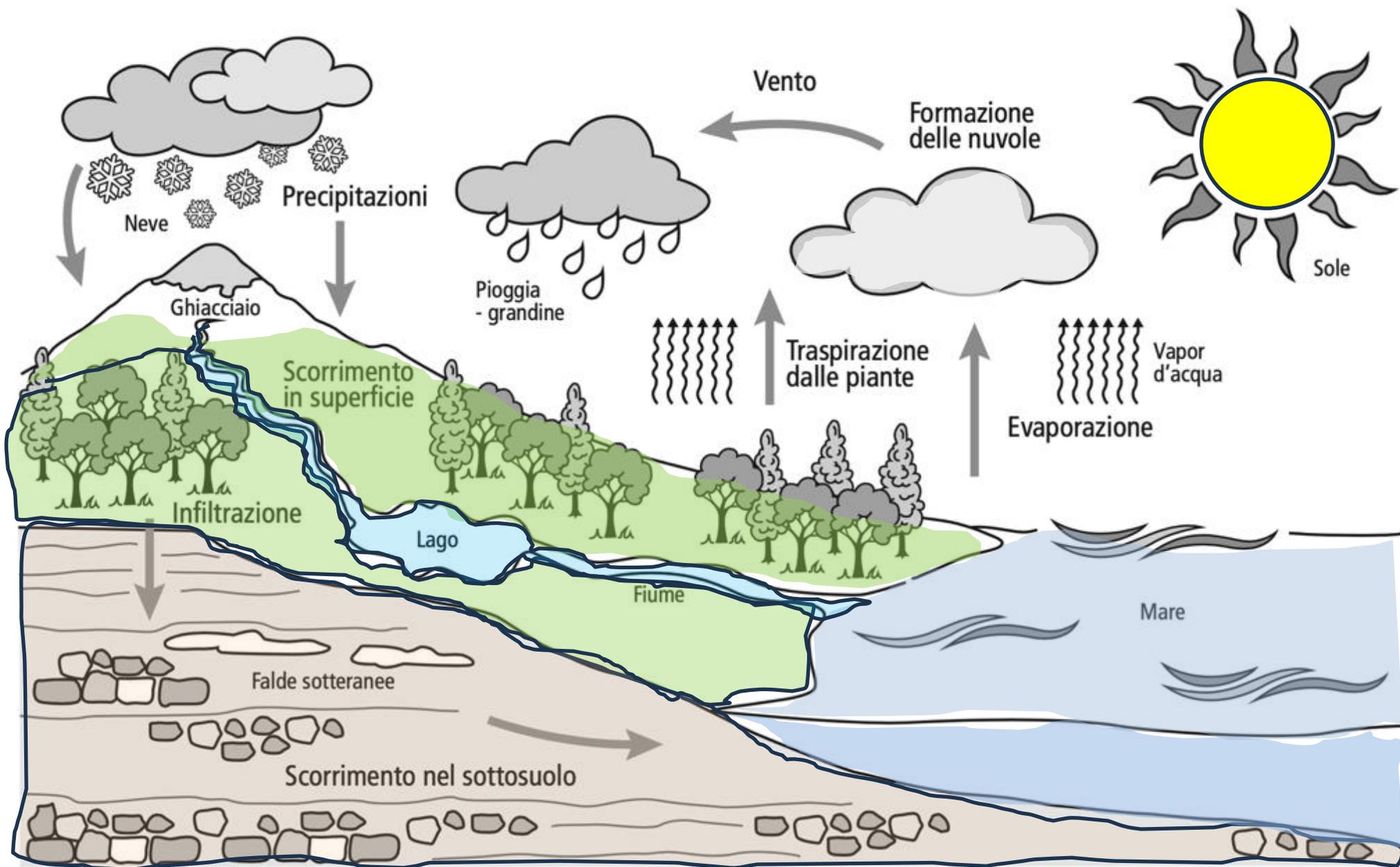
©nature

WMO,
<https://public.wmo.int/en/media/press-release/eight-warmest-years-record-witness-upsurge-climate-change-impacts>

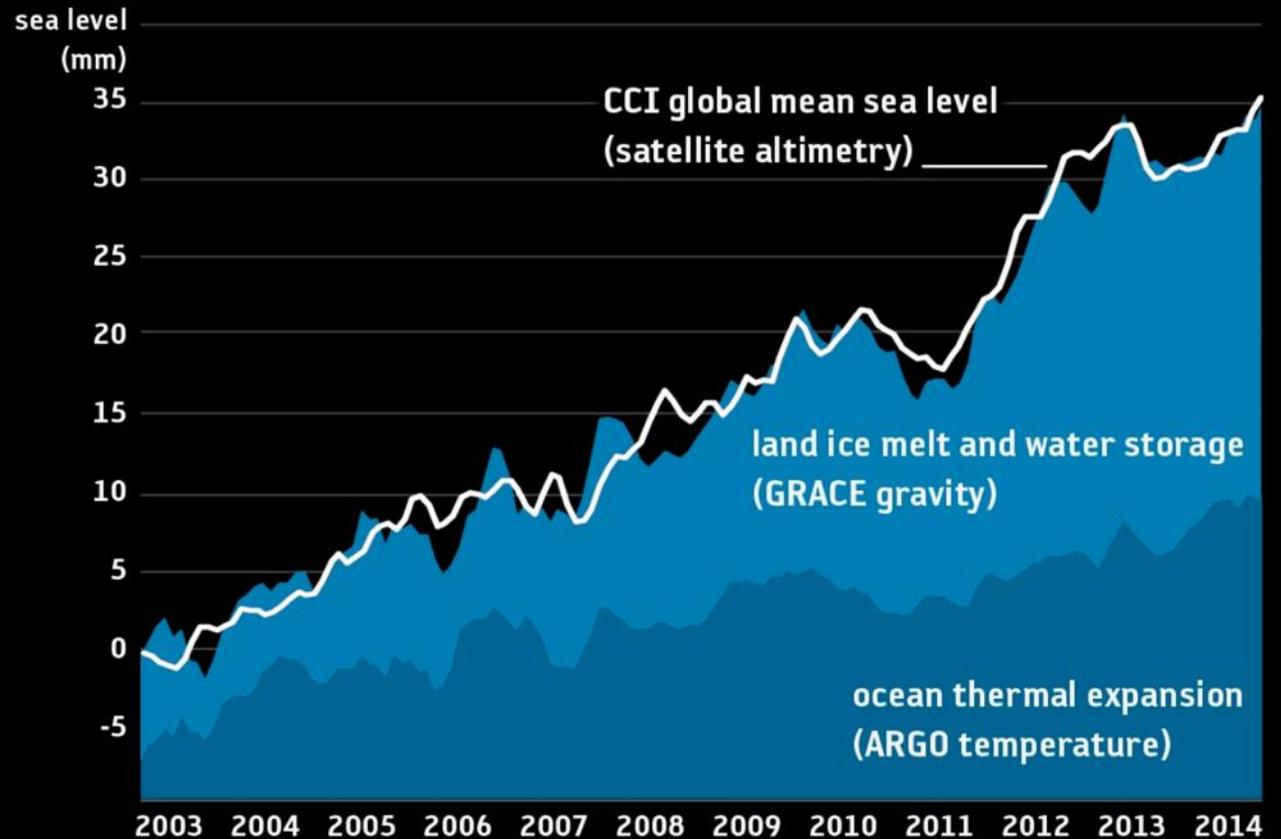
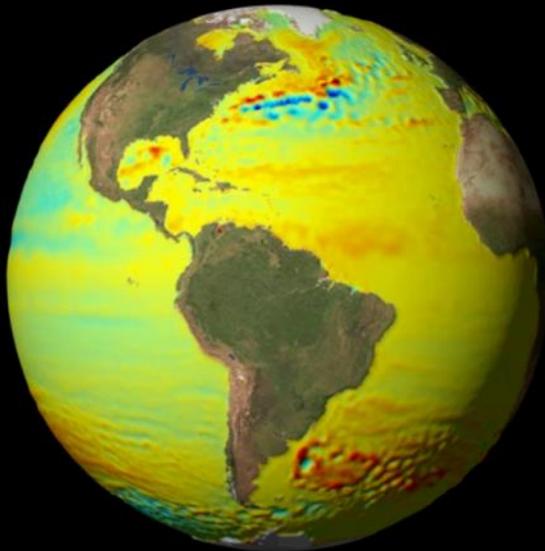
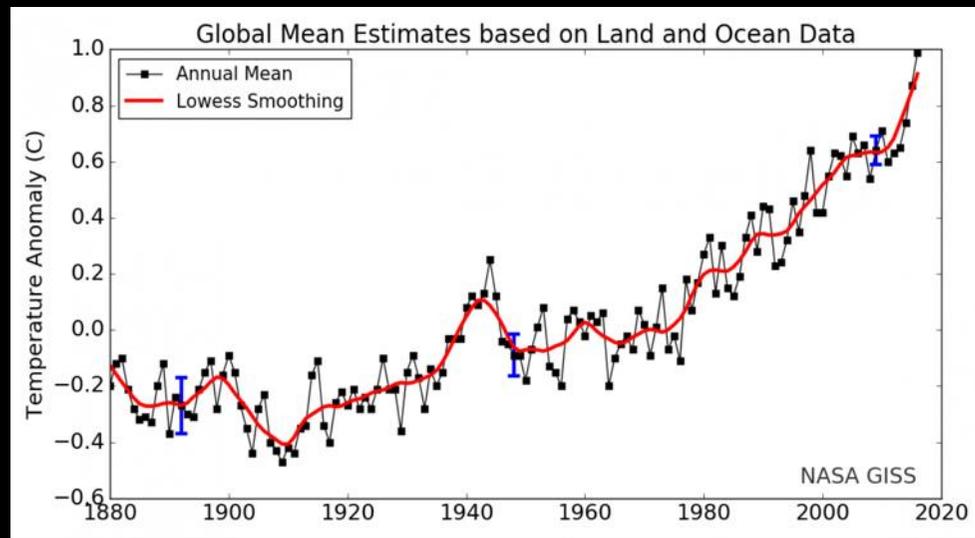
Il cambiamento climatico non è omogeneo nel tempo e nello spazio (1981-2010 vs 1951-1980)



Clima e ciclo dell'acqua



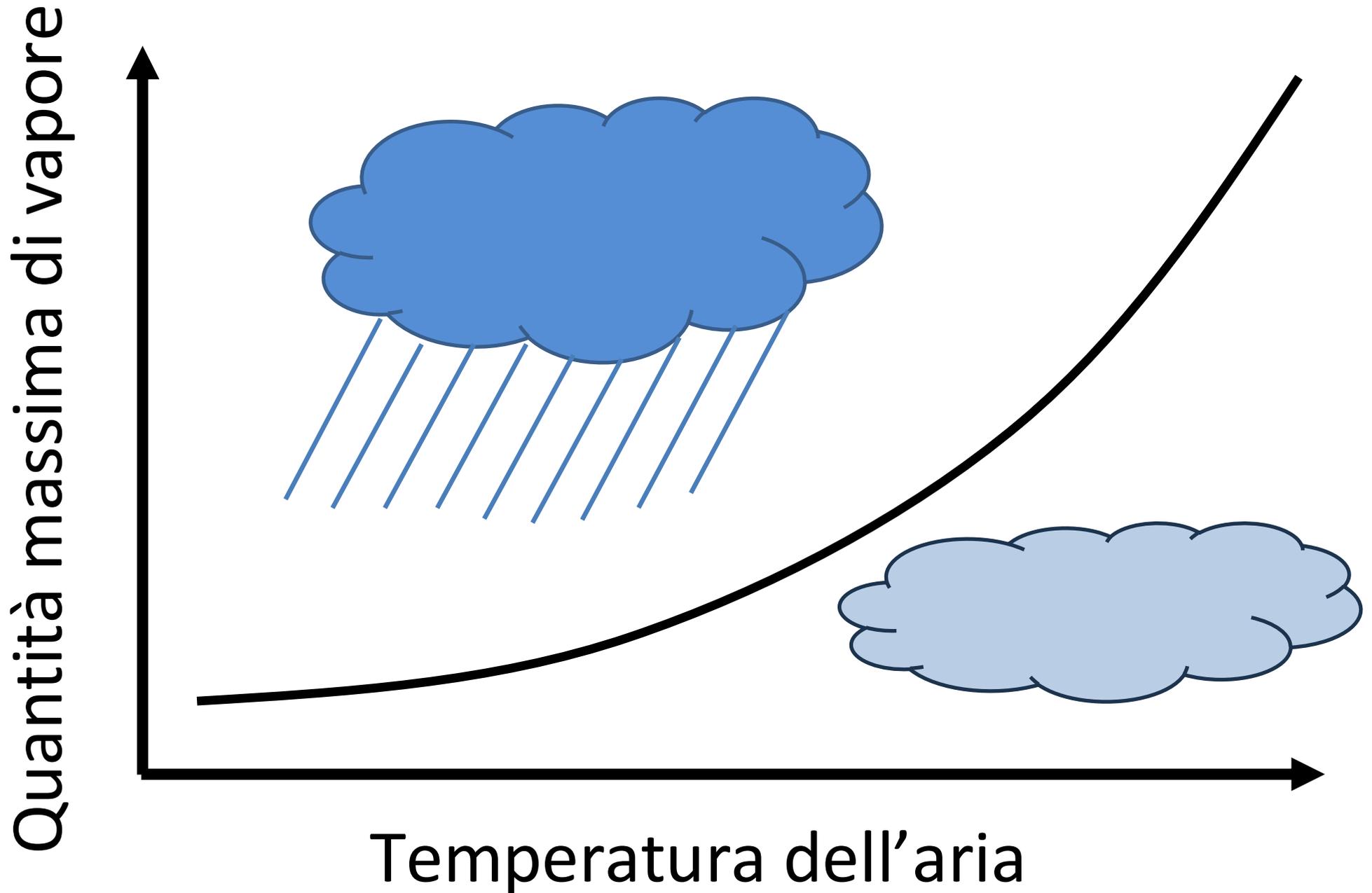
Aumento del livello del mare 2003-2014

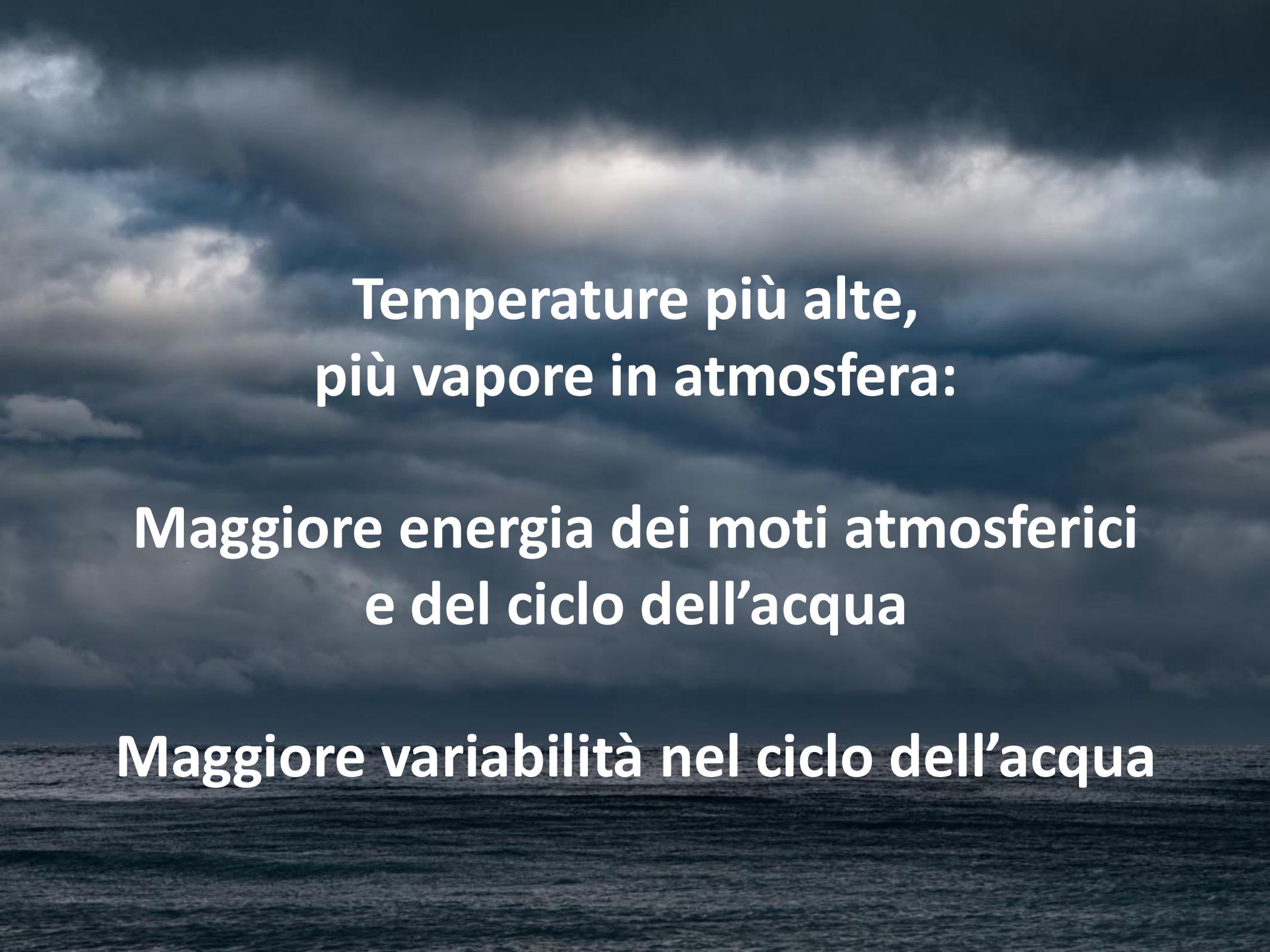


European Space Agency,

http://www.esa.int/ESA_Multimedia/Videos/2017/06/Contributors_to_sea-level_rise

Acqua in atmosfera: L'equazione di Clausius e Clapeyron





**Temperature più alte,
più vapore in atmosfera:**

**Maggiore energia dei moti atmosferici
e del ciclo dell'acqua**

Maggiore variabilità nel ciclo dell'acqua

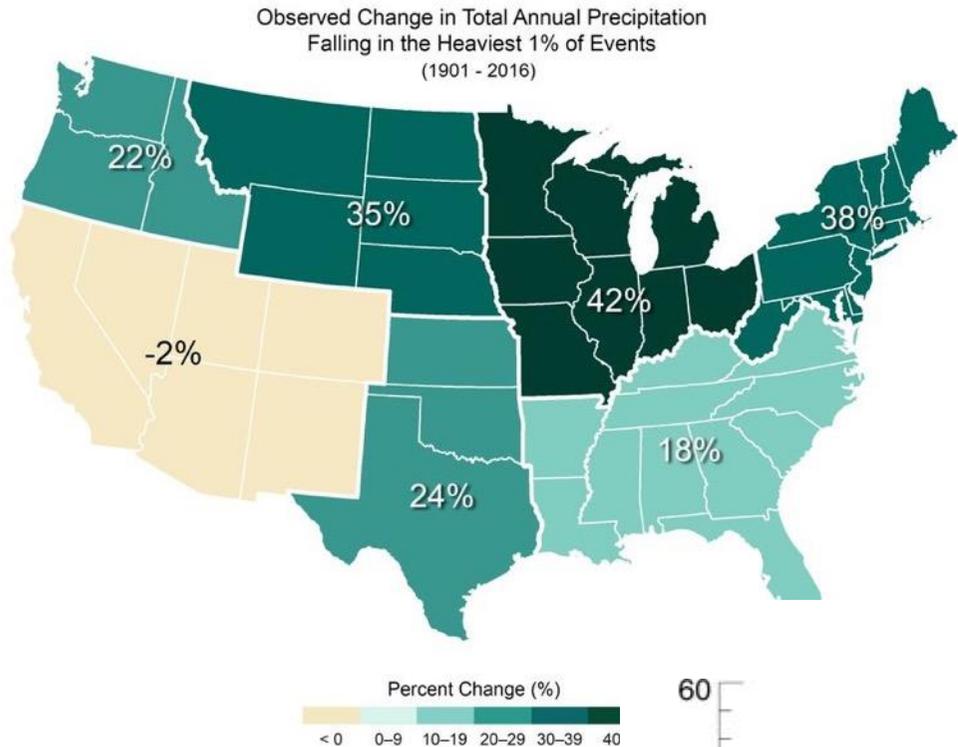
Maggiore rischio di eventi estremi

Foto: NASA

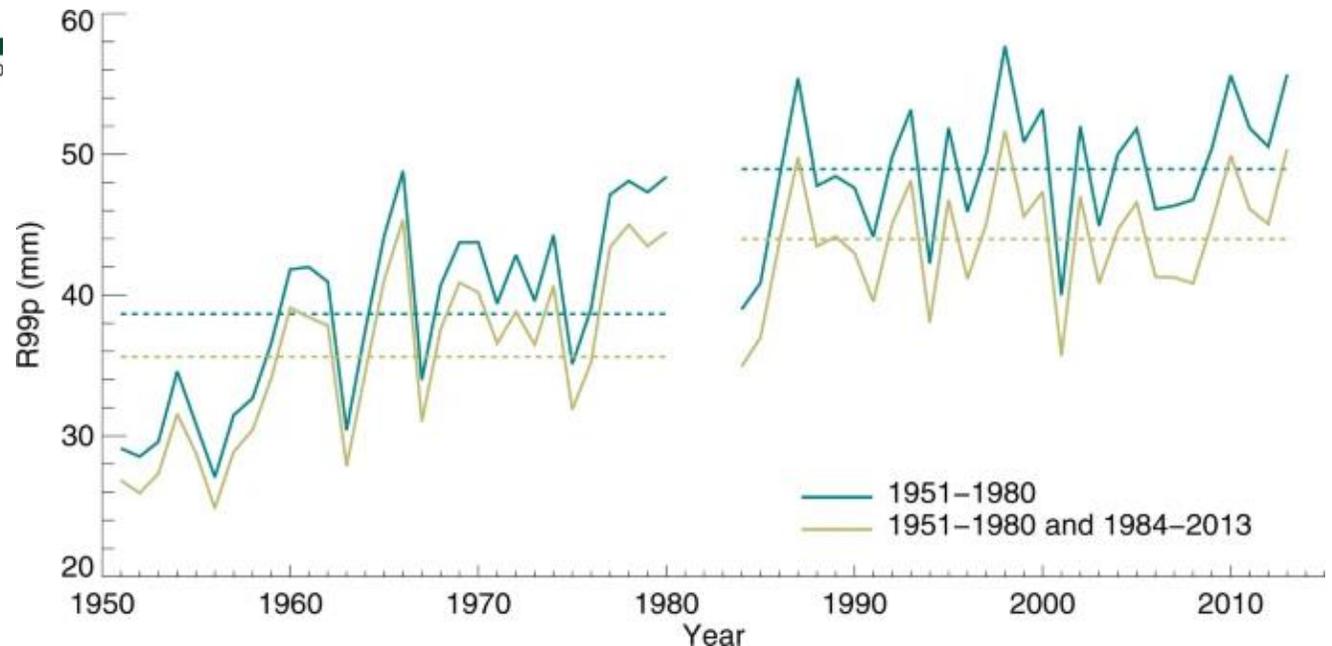


Eventi di precipitazione estrema

<https://www.globalchange.gov/browse/indicators/heavy-precipitation>



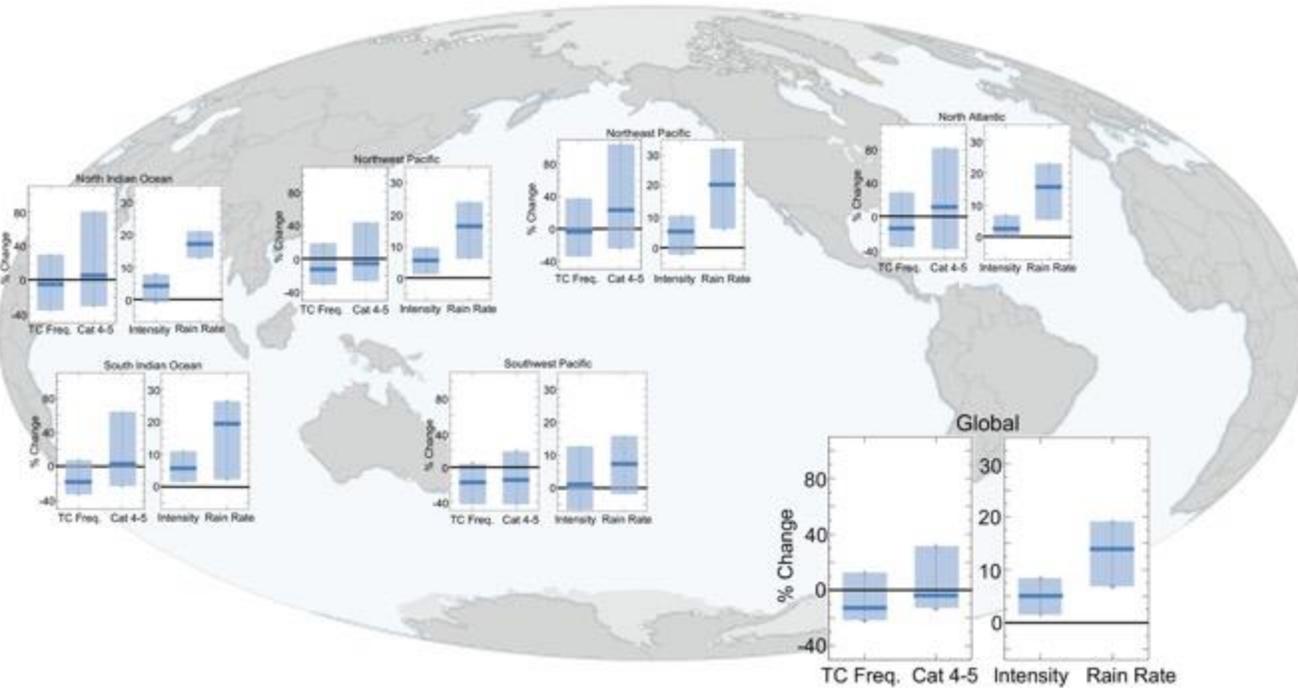
R99p over **Europe** from the E-OBS dataset, Myhre et al, Scientific Reports, <https://www.nature.com/articles/s41598-019-52277-4>



Cicloni tropicali e «Medicane»

Tropical Cyclone Projections (2°C Global Warming)

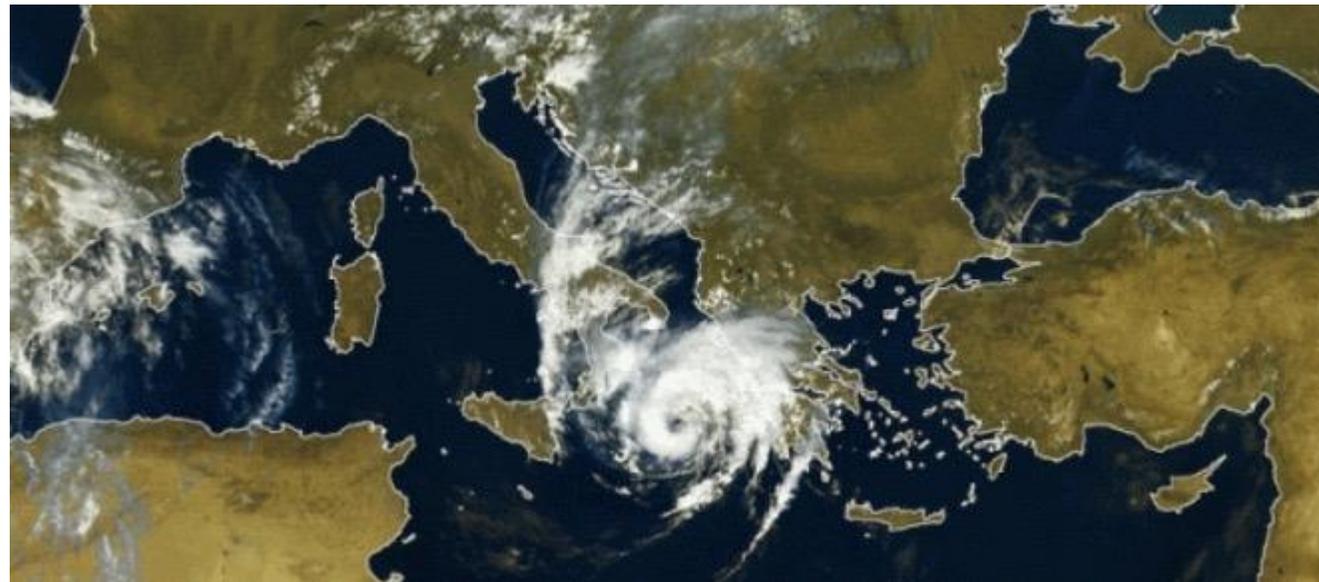
Guardian - AFP/Getty



Medicane

Es: <https://xaida.eu/medicane-and-climate-change/>

Knutson, T. et al., 2020:
Tropical Cyclones and Climate
Change Assessment. Part II:
Projected Response to
Anthropogenic Warming. *Bull.
Amer. Meteorol. Soc.*,
<https://doi.org/10.1175/BAMS-D-18-0194.1>

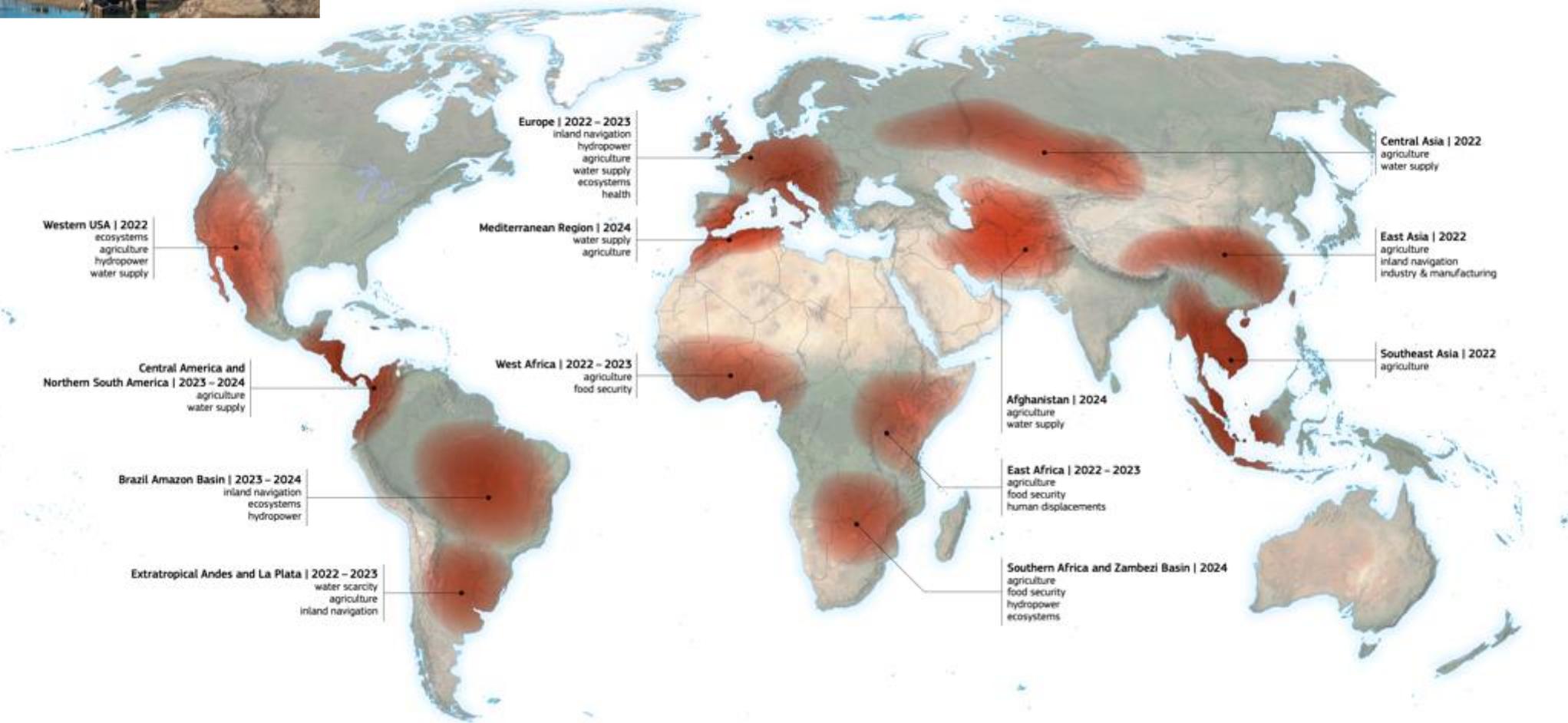


WORLD DROUGHT ATLAS

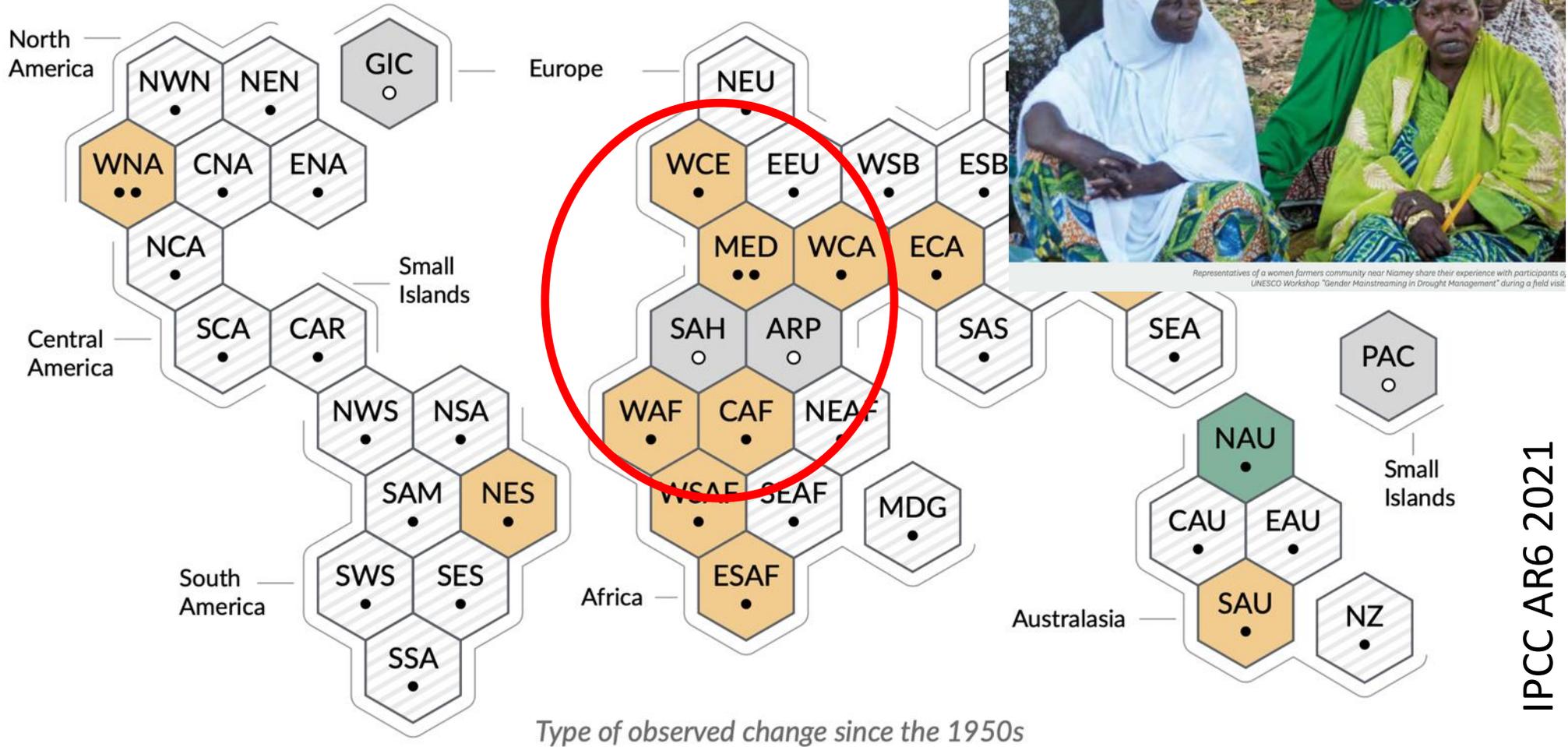
Eventi di siccità 2022-2024

Map 1: Major drought events, 2022–2024. Examples of major drought events that occurred between 2022–24, with examples of impacted systems. Red areas represent the approximate spatial extent of drought impacts. The boundaries of these shaded areas are blurred to indicate that droughts do not have finite geographic boundaries and there can be considerable uncertainty in determining the extent of impacts.

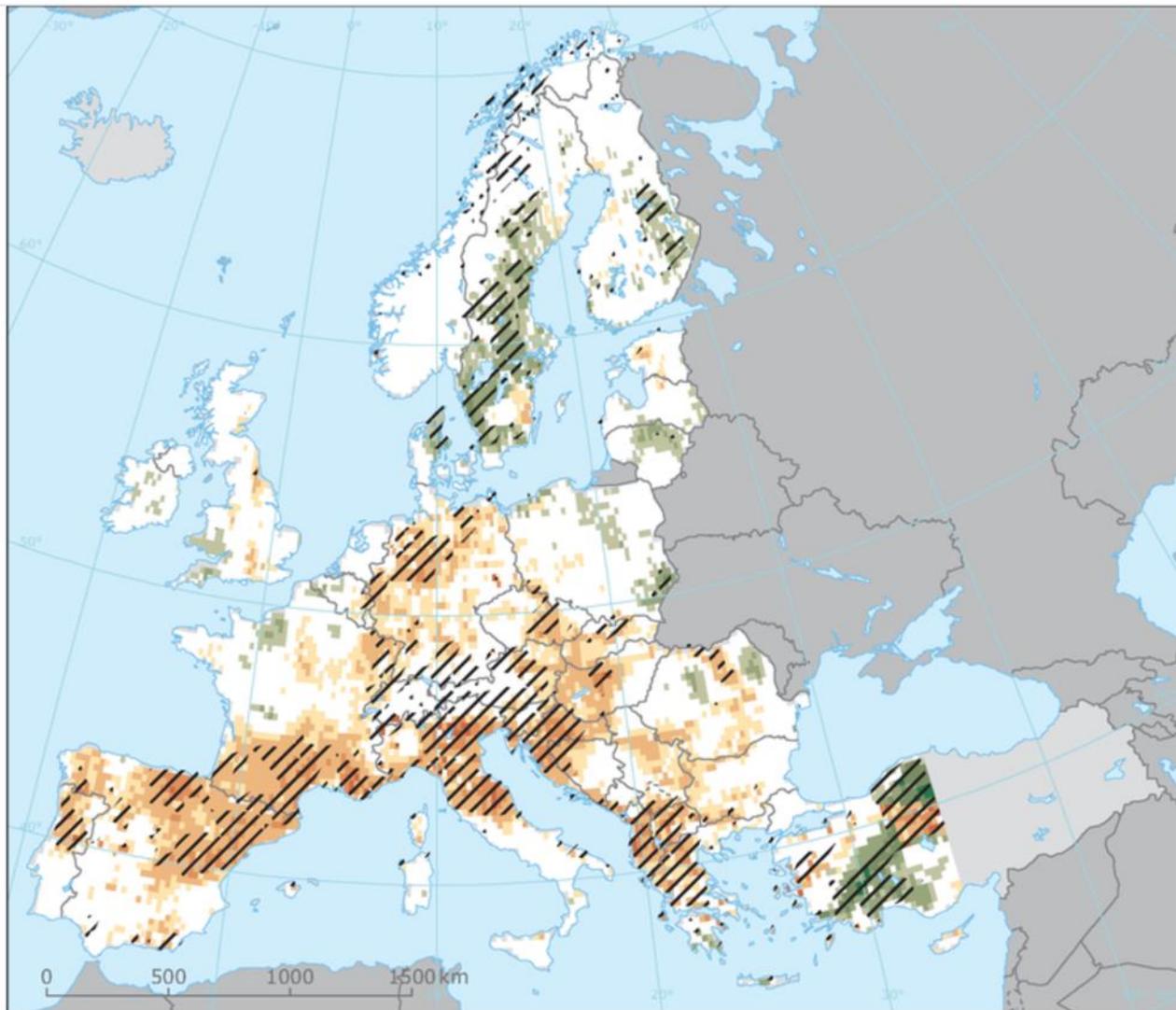
the poorest, most vulnerable and more marginalised people in society, increasing inequality and hampering progress towards the United Nations' Sustainable Development Goals (SDGs). hazards¹³, causing billions of dollars in losses annually⁸. They affect countries' economic growth and overall development in both the Global North¹⁴ and the Global South¹⁵. Economic effects are particularly felt in the agricultural sector⁸.



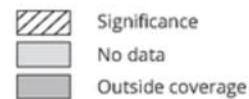
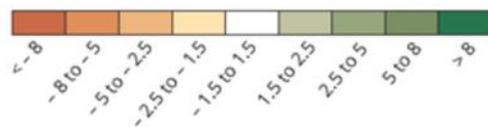
Meno precipitazione, maggiore evapotraspirazione: Maggiore rischio di siccità



Impatti sulla «food security», igiene, salute, accesso alle risorse
Impatti differenziati in base al genere (uomini e donne e bambini)
Un fattore ambientale che aggrava le tensioni geopolitiche



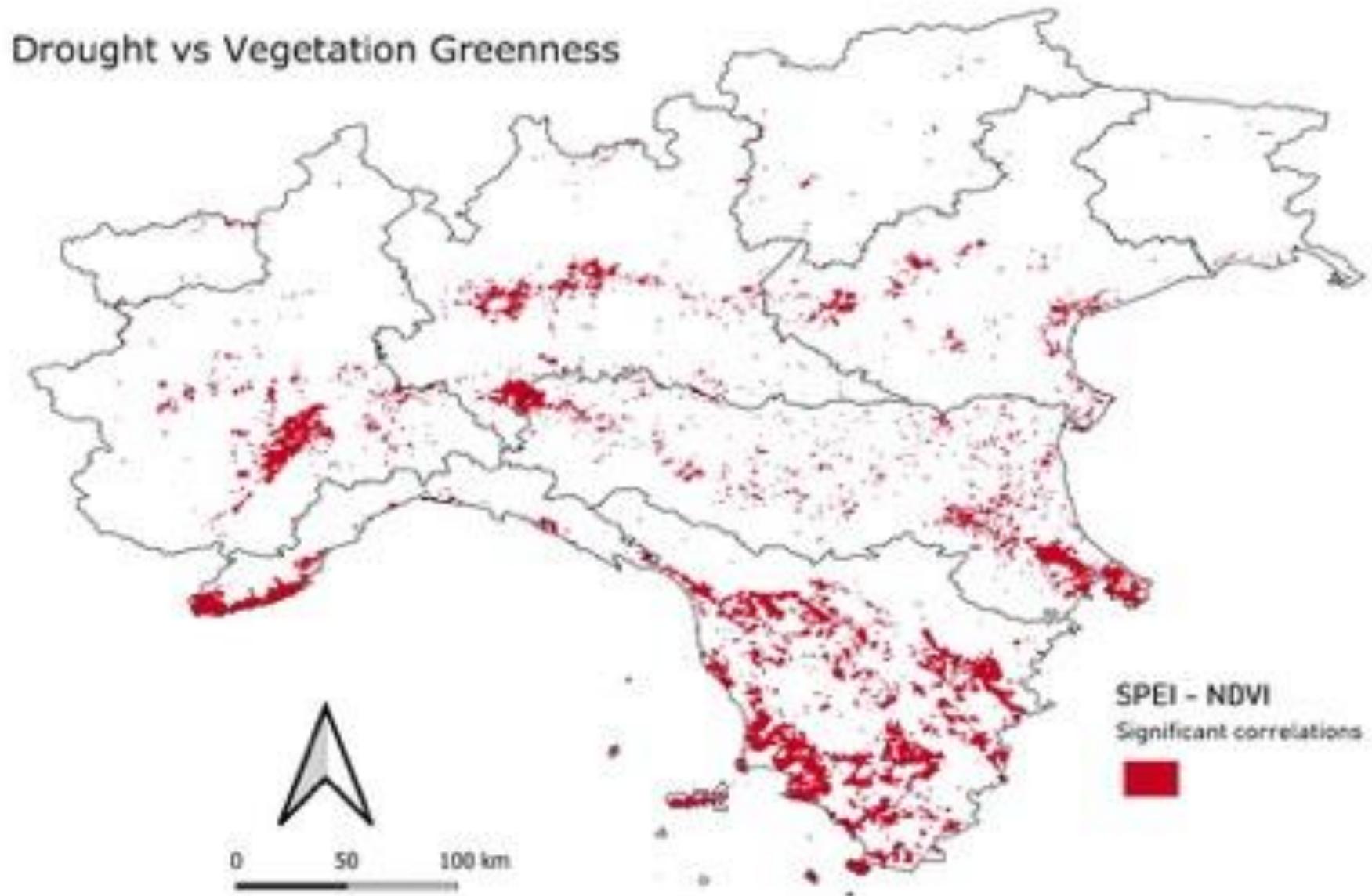
Trends in summer soil moisture in Europe (litres/m²/10 years)



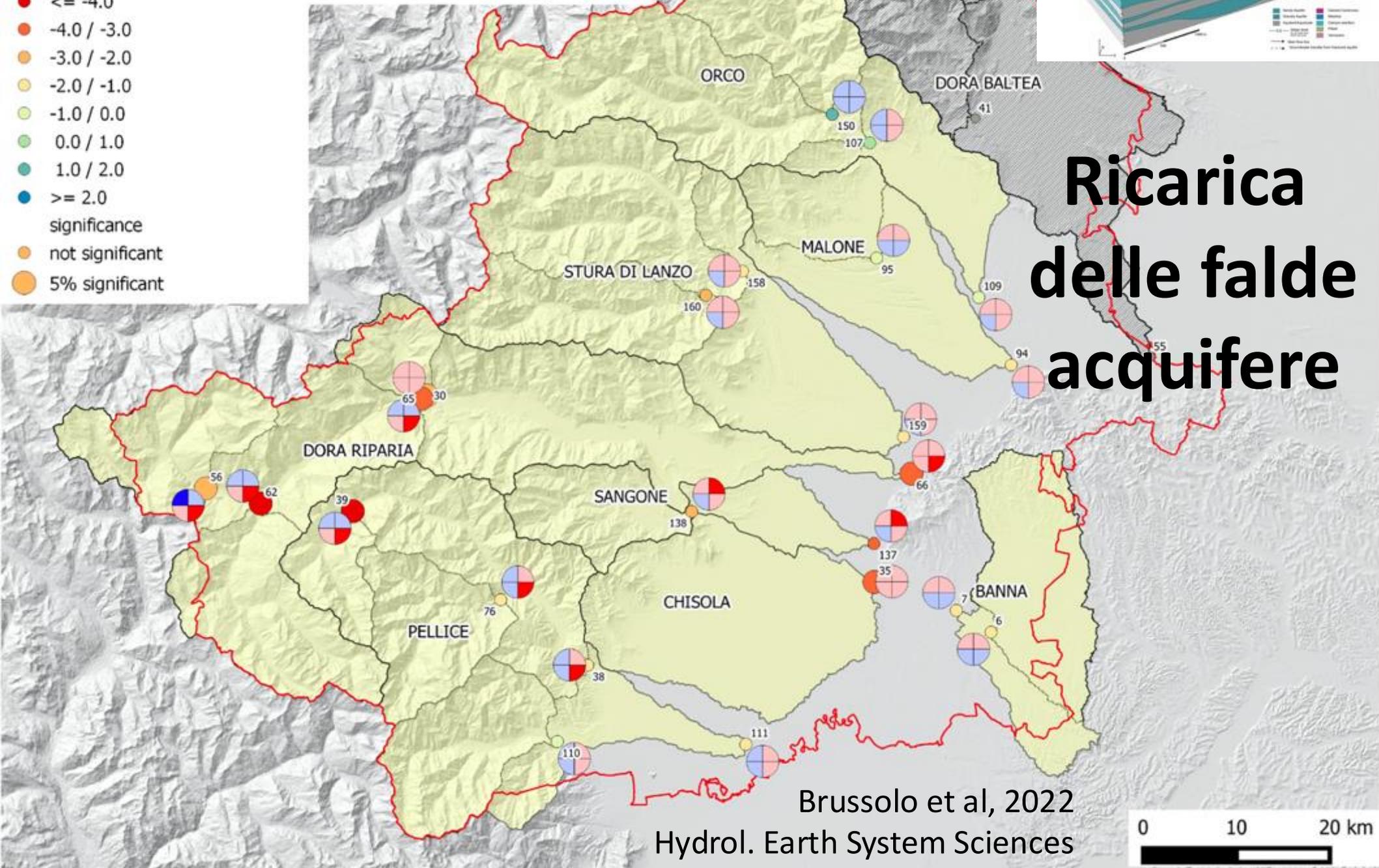
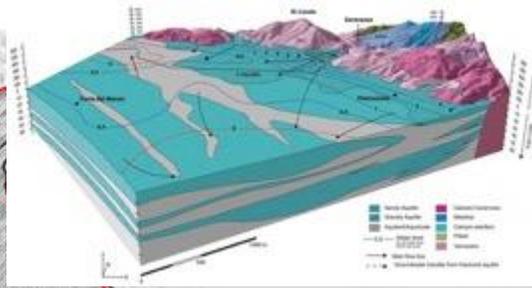
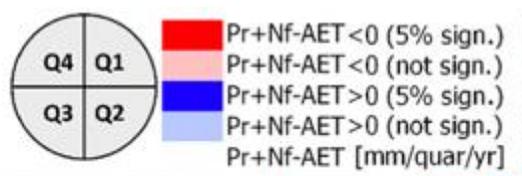
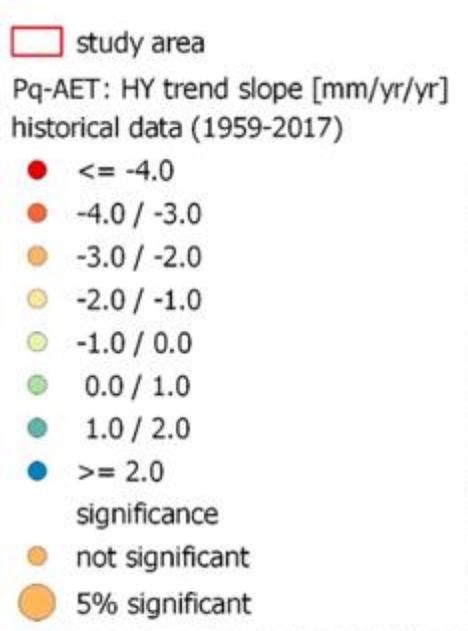
European Environmental Agency,

<https://www.eea.europa.eu/data-and-maps/figures/trends-in-summer-soil-moisture-1>

Effetti della siccità sulla vegetazione (2000-2020)



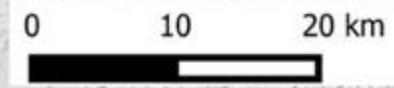
Alice Baronetti et al, 2023



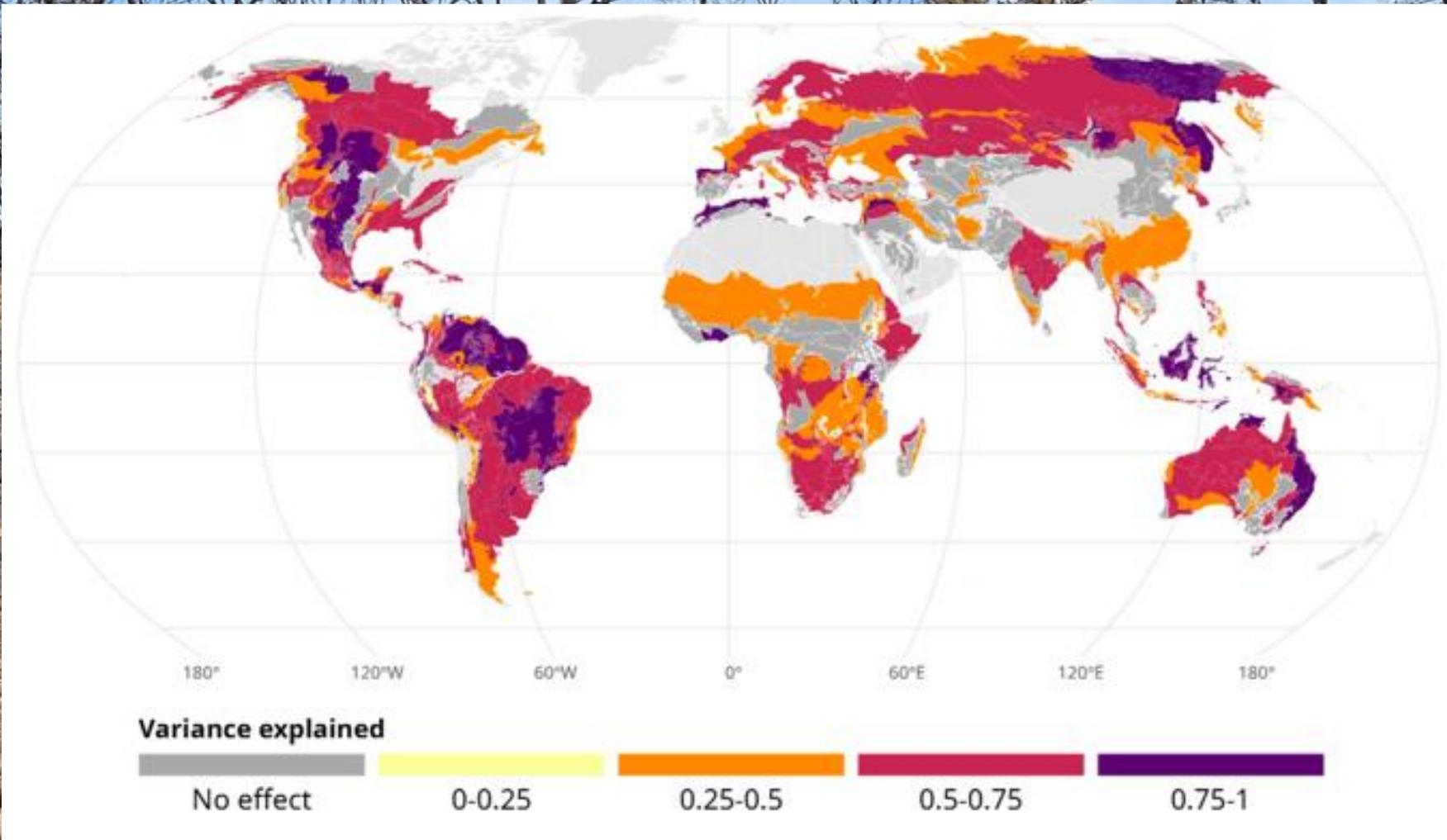
Ricarica delle falde acquifere

Brussolo et al, 2022

Hydrol. Earth System Sciences



Incendi boschivi



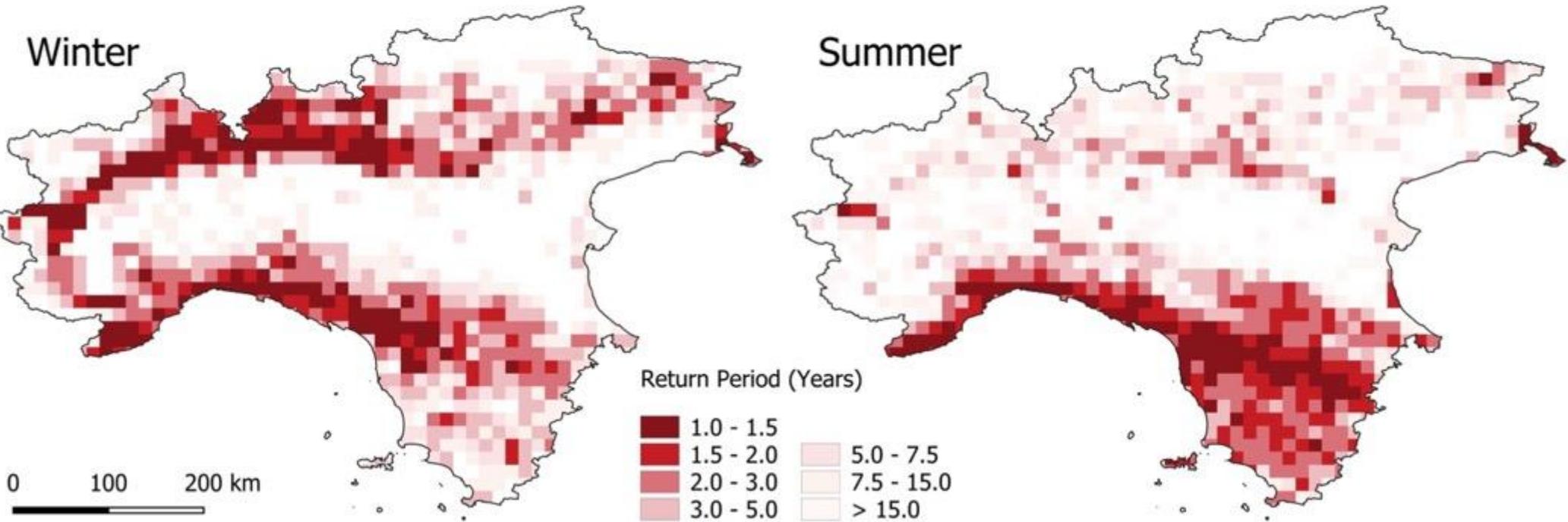
Incendi estivi e invernali in Italia settentrionale

Wildfires occurrence

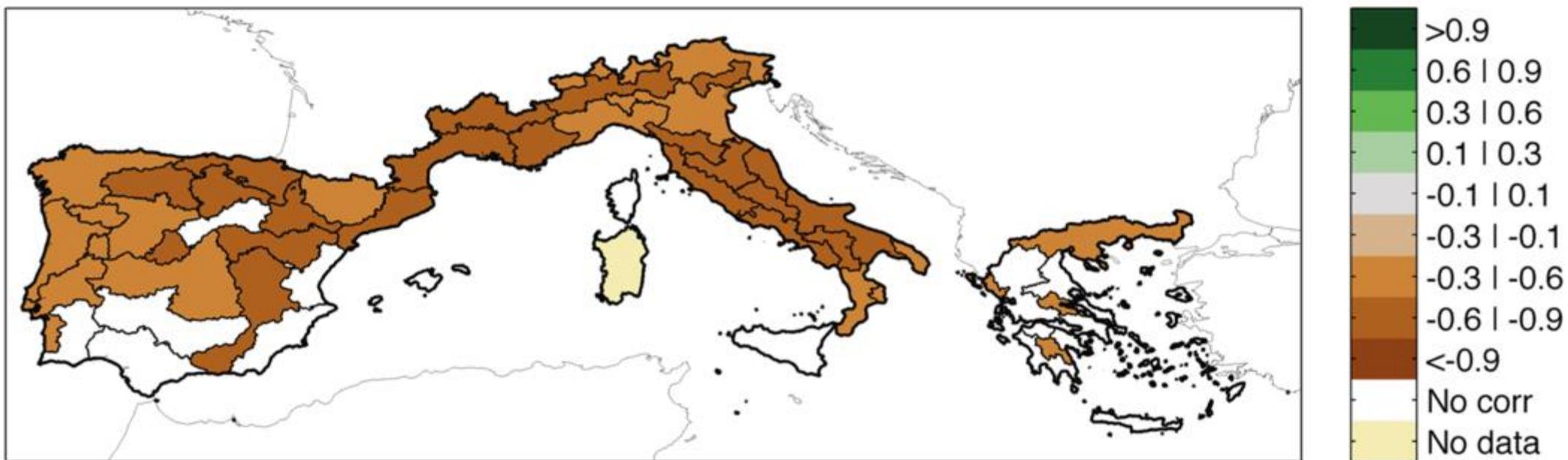


Winter

Summer



Europa Mediterranea: legame fra incendi e condizioni siccitose



Correlazione fra area bruciata e indici di umidità

Aumentata capacità di intervento

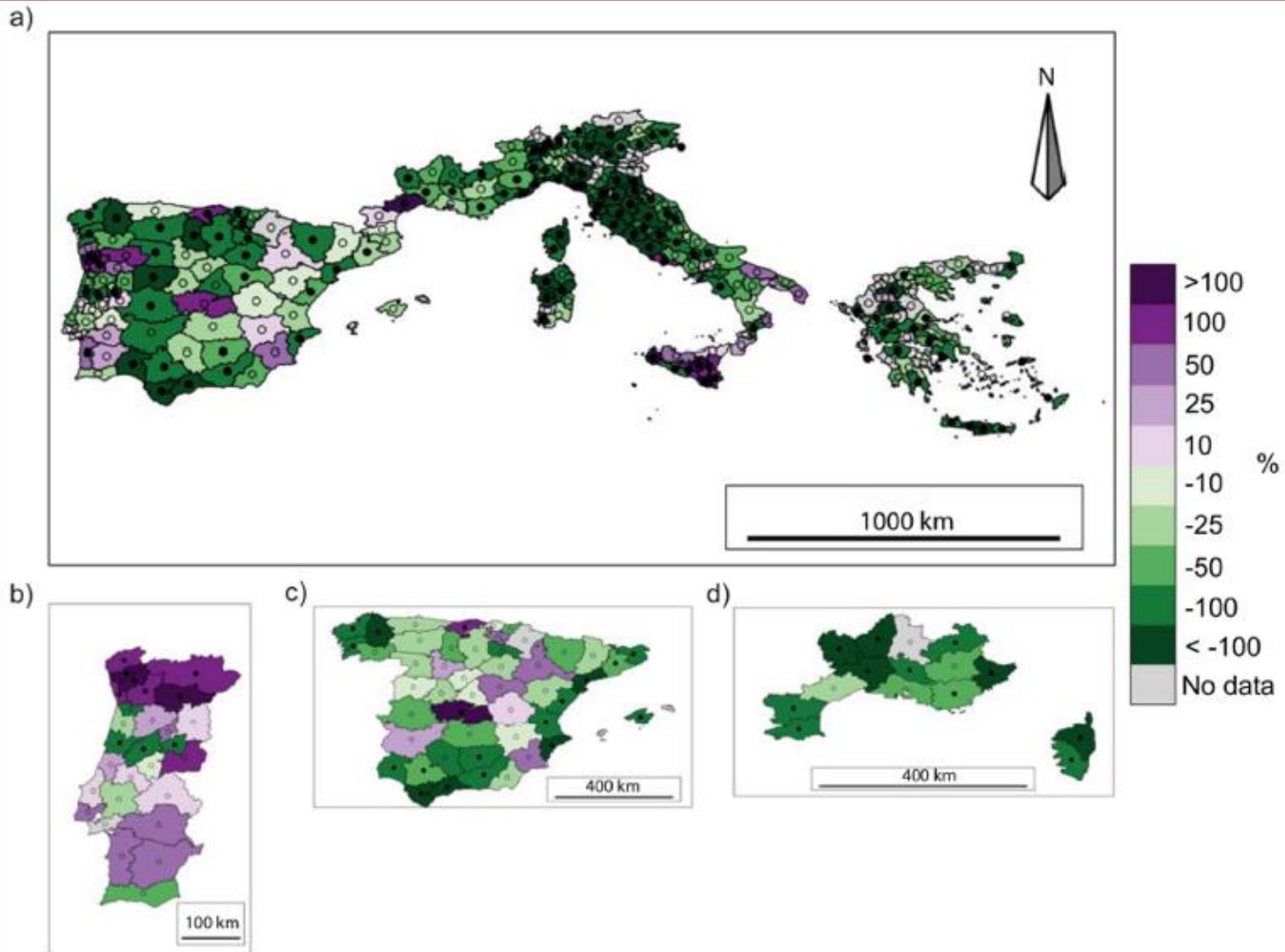
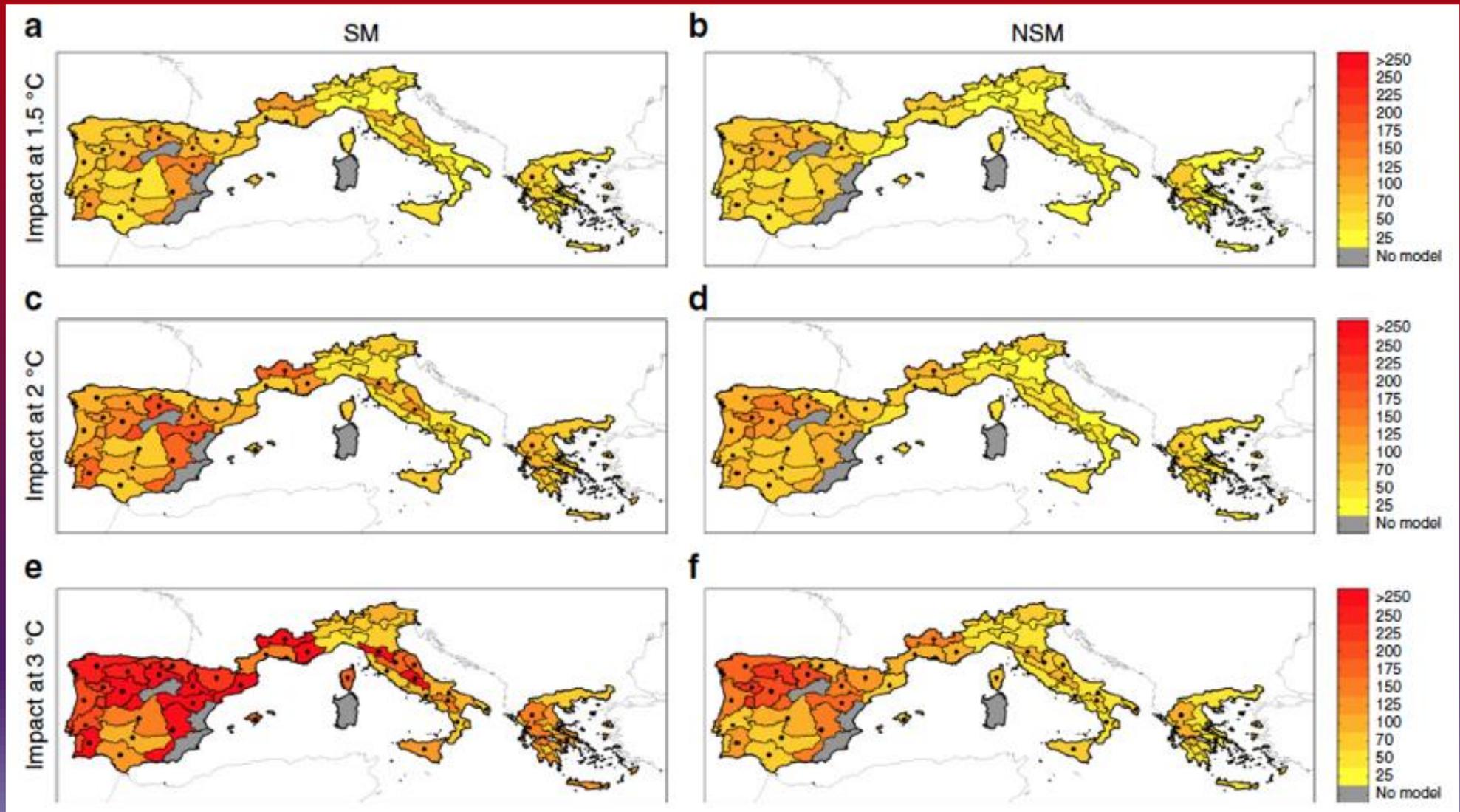


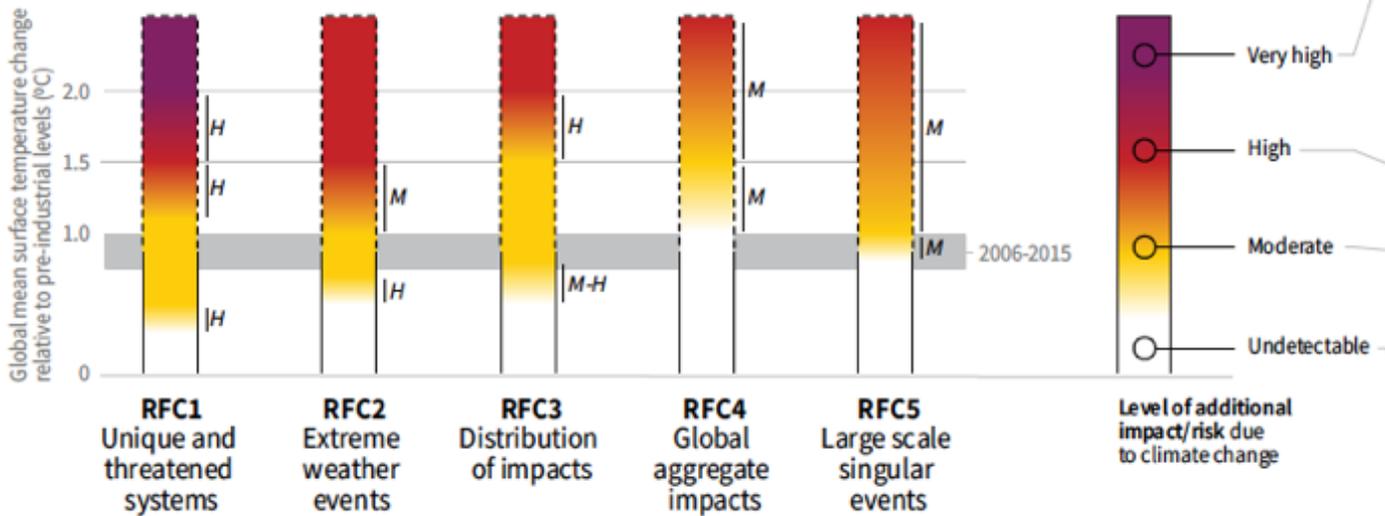
Fig 5. Trends of the annual burned area for (a) the studied domain for the period 1985-2011, (b) Portugal for the period 1980-2011, (c) Spain for the period 1974-2011 and (d) southern France for the period 1974-2011. NUTS3 units with more than 5 years of missing data are excluded from the analysis. Significant trends ($p < 0.05$) are indicated by the filled black circles. Trends are shown as the percentages of the total trend for the available period (e.g. ha per 27 years) divided by the historical mean calculated over the same period (e.g. 1985-2011).

Proiezioni future: area bruciata

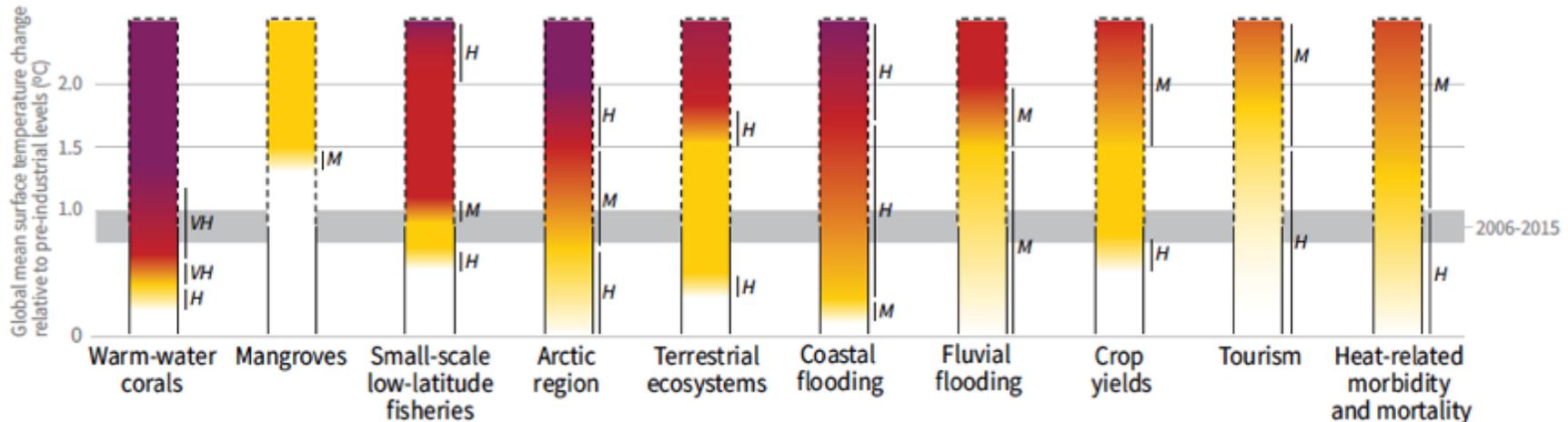


Conseguenze per un dato livello di riscaldamento

Impacts and risks associated with the Reasons for Concern (RFCs)

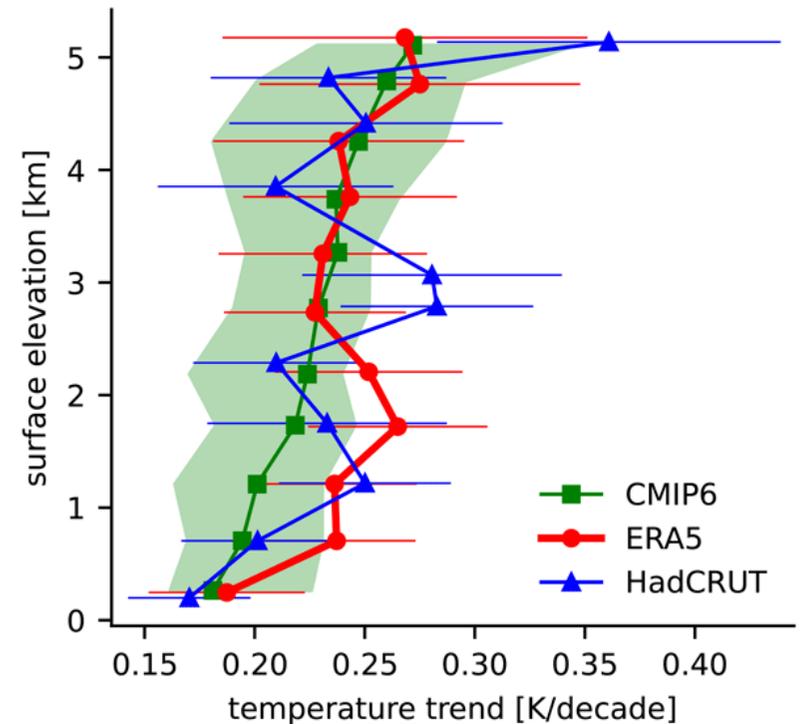
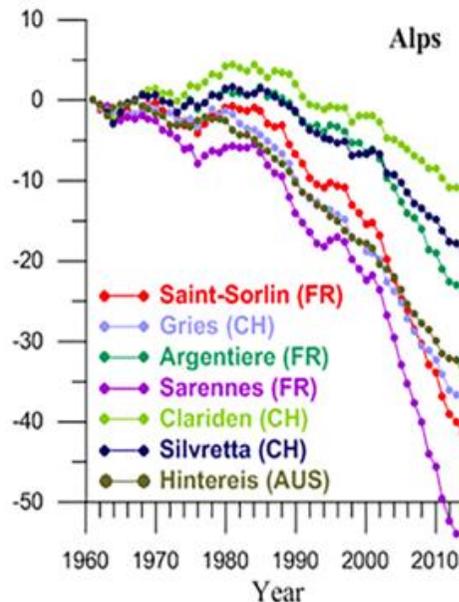
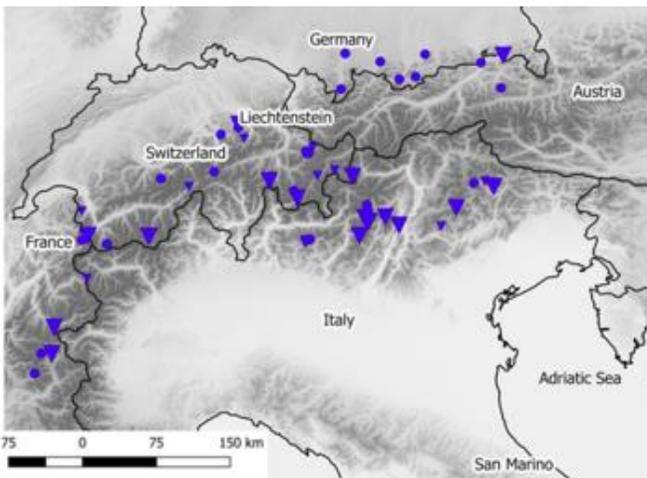
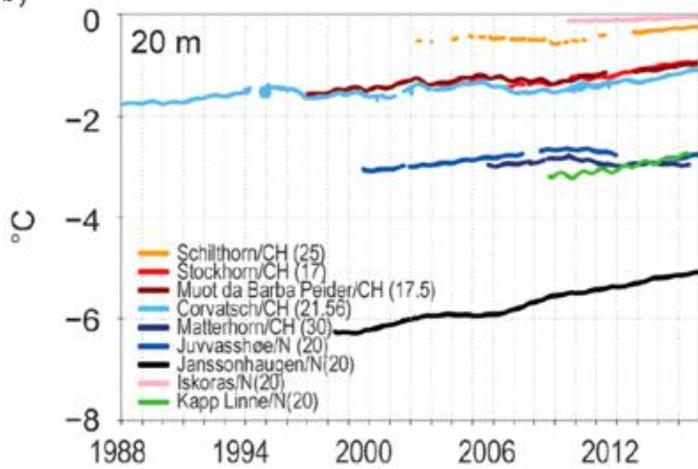
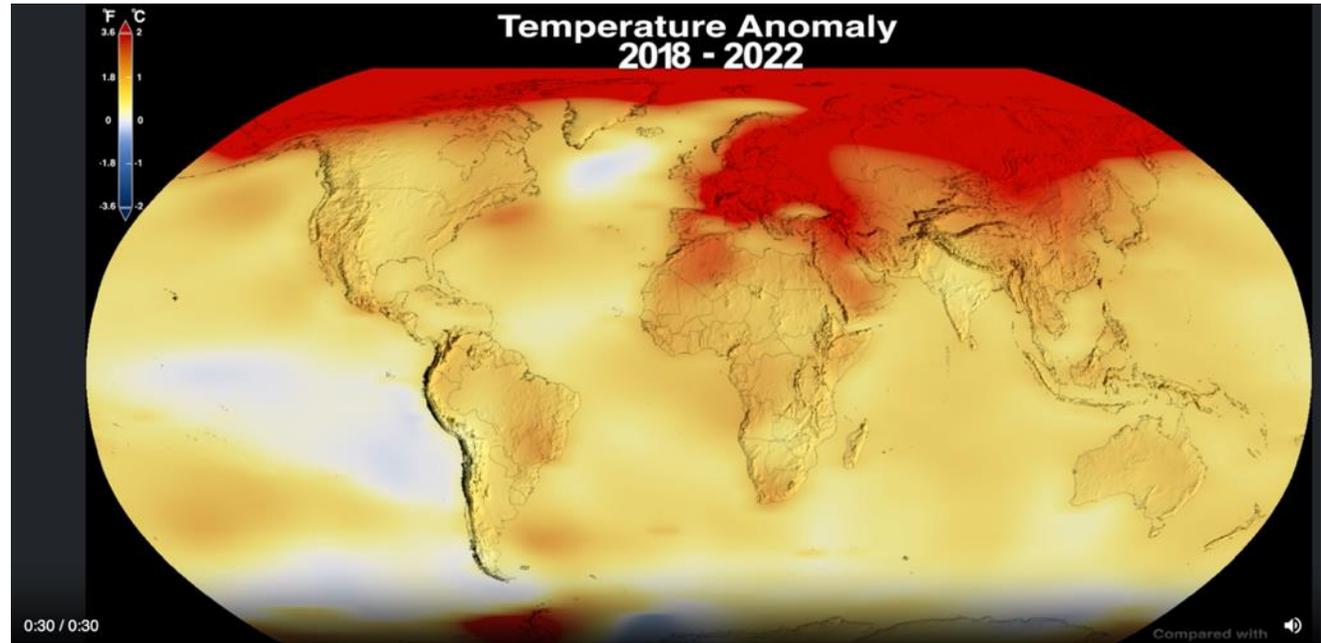


Impacts and risks for selected natural, managed and human systems



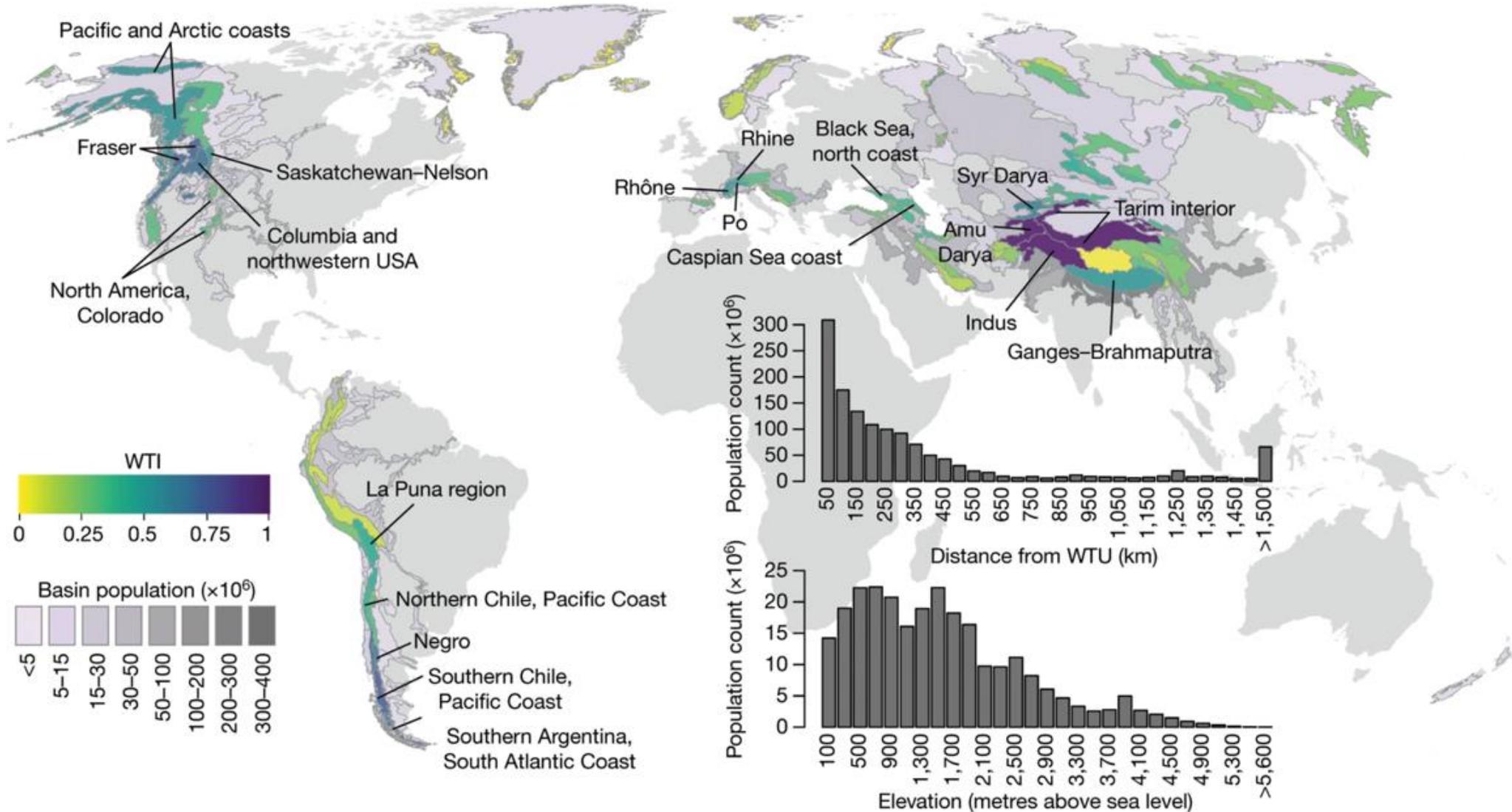
Due luoghi a rischio: montagne e Artico

<https://svs.gsfc.nasa.gov/5060/>

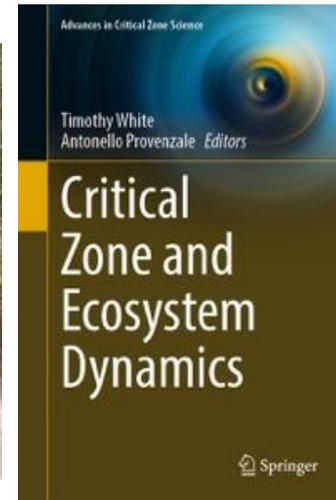
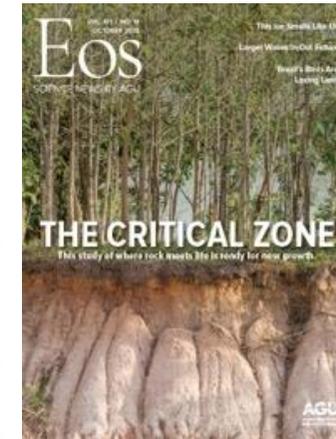
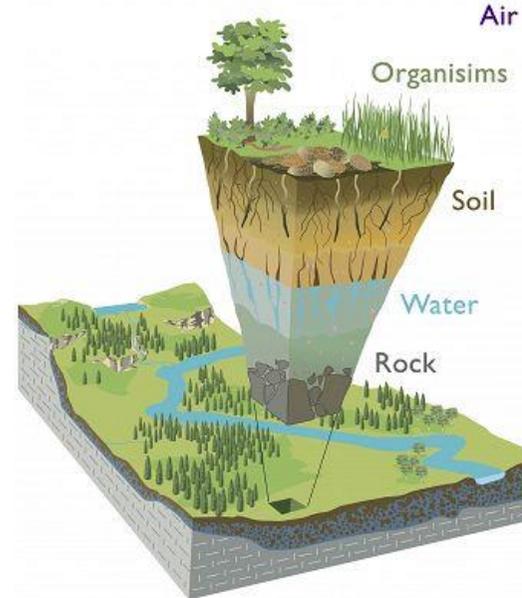
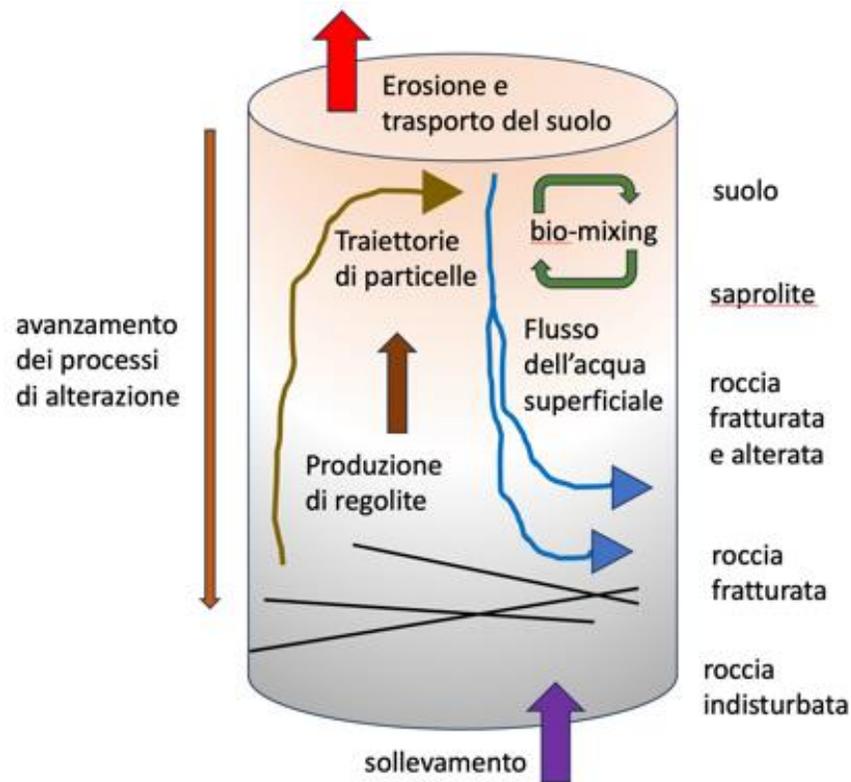


Beniston et al,
The Cryosphere, 2018
IPCC, SROCC, 2019

Le montagne come serbatoi d'acqua



La Zona Critica è il sottile strato superficiale dove «la roccia incontra la vita»



Lo strato fra la cima della vegetazione e il fondo dell'acquifero superficiale, dove avvengono tutti processi che sostengono gli ecosistemi terrestri

Osservatori di Zona Critica in aree montane... e in Artico



Gran Paradiso



Etna



Spitzbergen

**Fotosintesi
(assorbimento, GPP)**



**Respirazione
(emissione, ER)**



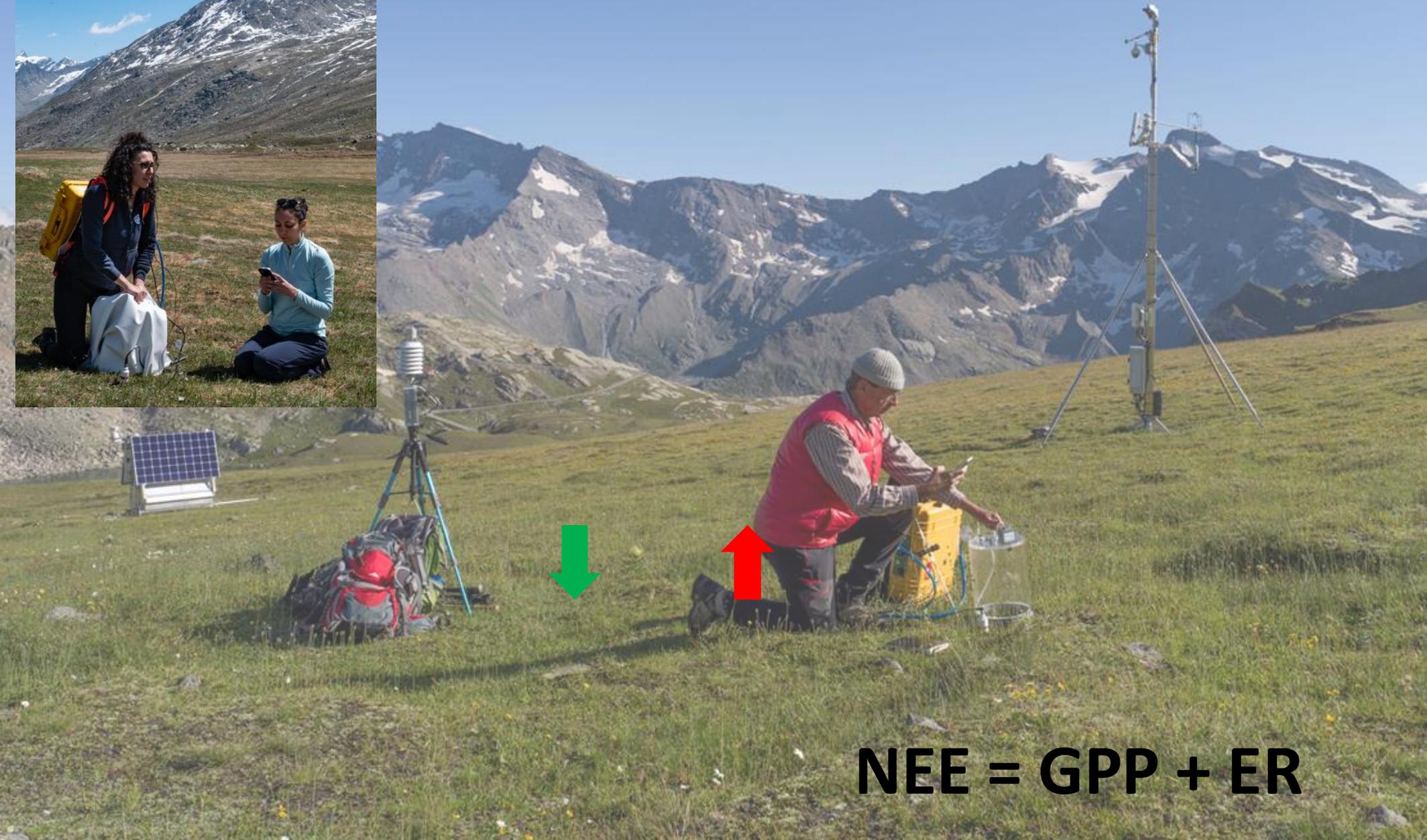
$$\text{NEE} = \text{GPP} + \text{ER}$$

**Ruolo degli ecosistemi terrestri e marini
nell'assorbimento della CO₂**

Il ciclo del carbonio

**Quali sono i fattori interni ed esterni
che controllano i flussi di carbonio
nella Zona Critica?**

Flussi di carbonio e acqua nella Zona Critica alpina

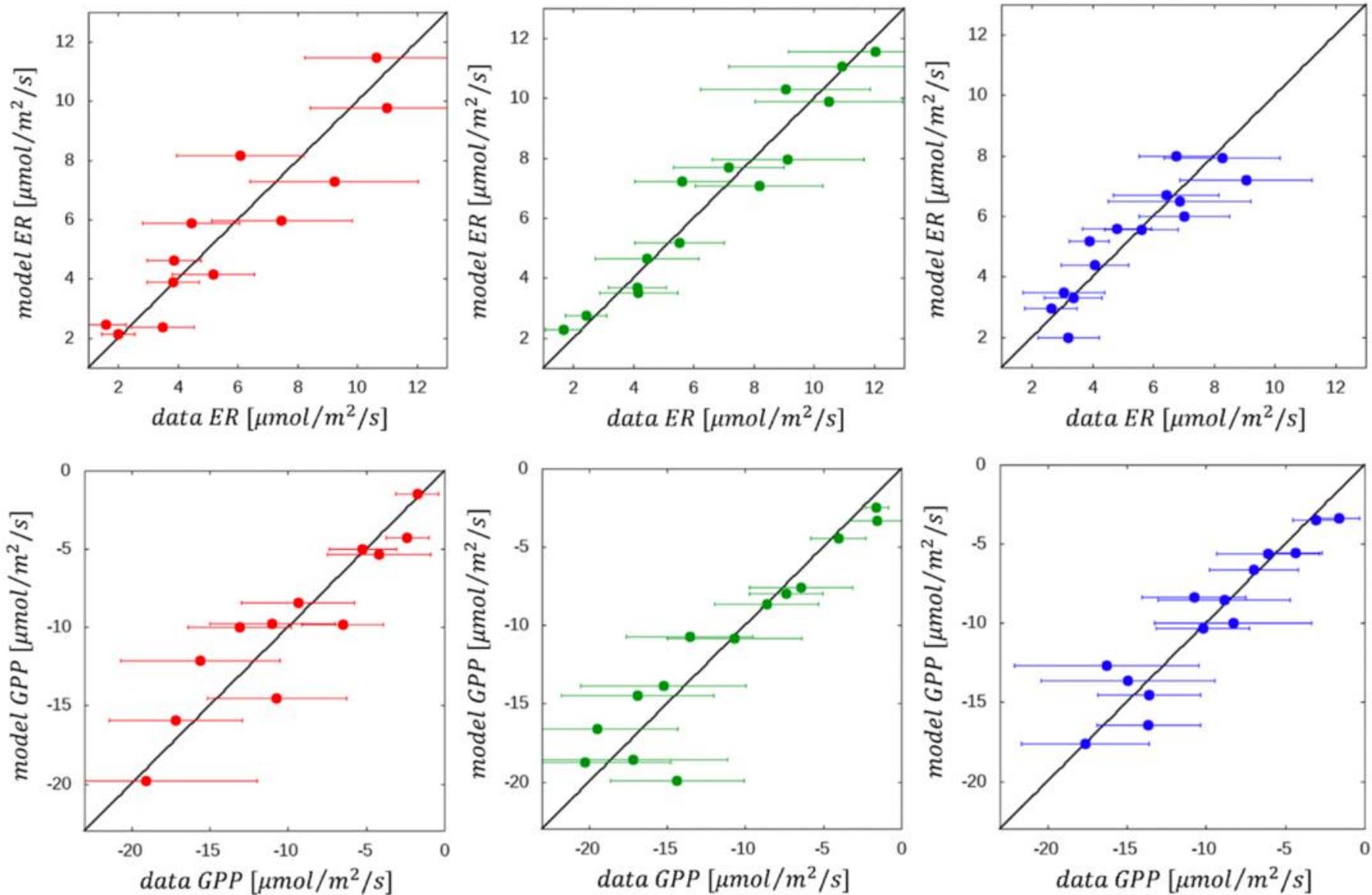


$$NEE = GPP + ER$$

Modelli multivariati per i flussi di carbonio

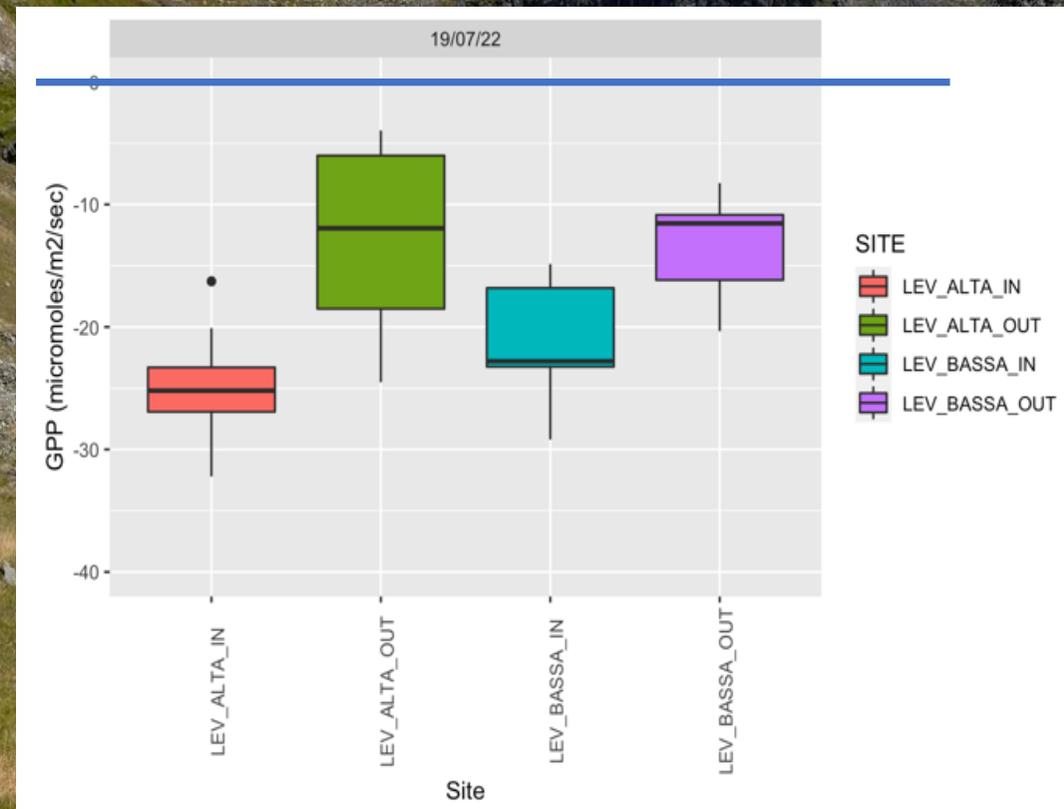
$$ER = (a_0 + a_1 VWC + a_2 Pr + a_3 DOY) e^{b_0 T_a} + \delta$$

$$GPP = \frac{F_0 \alpha_0 r_s}{F_0 + \alpha_0 r_s} (A_0 + A_1 VWC + A_2 DOY) + \delta$$



Magnani et al STOTEN 2020, Sci. Rep. 2022,
 Lenzi et al PLoS ONE 2023, Parisi et al Scientific Data 2024

Il ruolo dell'umidità del suolo



Siccità e Zona Critica:
Il caso di Levionaz

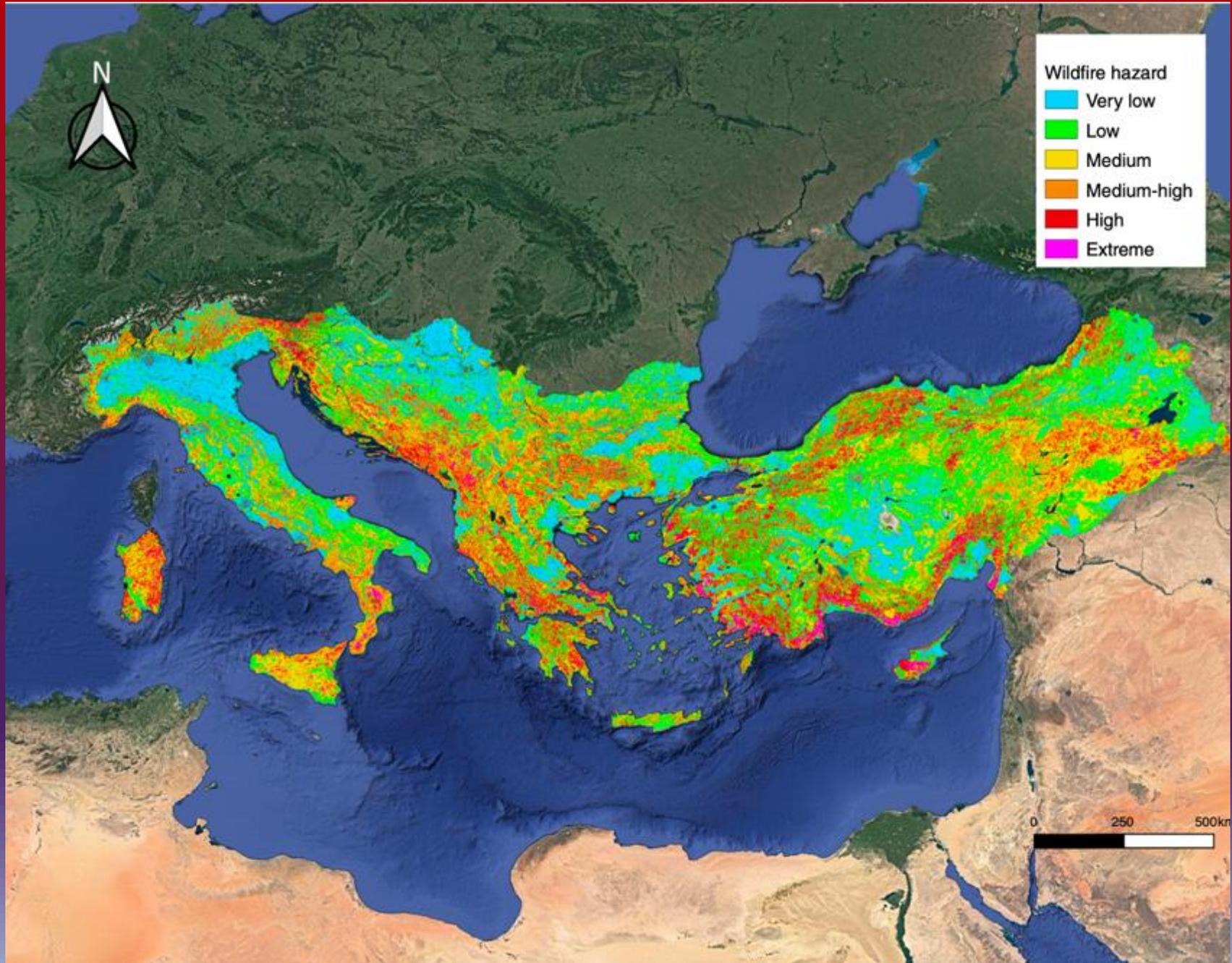
Le sfide da affrontare:

- **Riduzione delle emissioni** di CO₂ e gas climalteranti
- **Guadagnare tempo** per permettere la transizione a energie a bassa emissione di CO₂
- **Adattamento**: ad esempio, gestione dell'ambiente e della società in condizioni di **forte variabilità interannuale**
- Capire che «**si può fare**»



<https://www.consilium.europa.eu/it/infographics/how-is-eu-electricity-produced-and-sold/>

Mappe di pericolosità di incendio



«Success stories» nella gestione delle siccità

Story 3: Adapting to reducing rainfall in Kenya

The role of Farmer Managed Natural Regeneration

Nancy is a smallholder farmer living in Baringo County, Kenya. This is an area where rainfall patterns are becoming more erratic due to climate change, resulting in prolonged, multi-year droughts which mean insufficient food, pasture and water for communities and their livestock. In such extreme climatic conditions, livestock starve and die. However, Nancy has been able to withstand these challenges. During periods of severe drought, her livestock may become weak, but none of them die. She attributes this to practicing Farmer Managed Natural Regeneration (FMNR), a low-cost practice for regenerating trees and fostering land restoration that involves using a system of pruning sprouting tree saplings to encourage rapid tree-growth.

World Vision Kenya has been successfully working with farmers like Nancy to help them adapt to climate change for over ten years now. The primary approach for doing this is supporting communities to restore the health of their landscapes using low-cost restoration approaches like FMNR. This is supplemented by community committees who make proactive plans for how they will respond to potential disasters. As with all of World Vision's work, the aim is for communities to lead the restoration of their environment. In Nancy's case she has been able to opt into which practices are most appropriate for her farm – from FMNR to farm ponds. Nancy now generously shares her time and wisdom with her community by running demonstrations in FMNR and the other practices she uses. She is also working alongside Kenya Forestry Research Institute to use research to validate and share findings about the power of FMNR.

"Before practicing the farmer-managed natural regeneration approach, this land was bare. The soil was eroded and we used to walk for long distances to get firewood. Now, with the regenerated trees, we have a beautiful environment, shade, herbal medicine, fresh air, soothing sounds of birds chirping, increased pasture yields and fodder from trees," Nancy says.

In preparation for the dry season, Nancy usually harvests surplus pasture. She then dries and grinds it and proceeds to store the pasture for use during the dry season. During long dry spells or in times of drought, the pasture may be depleted. In such situations, Nancy usually uses the leaves and barks of trees on her farm to supplement the animal feed. The over 30 species of regenerated acacia trees on her farm, as well as other tree species, offer a diversified source of nutrition for her livestock. The regenerated trees have also provided a favourable environment for beekeeping to thrive, thus enabling Nancy to gain extra household income from selling honey. From these proceeds, she can buy additional animal feed for her livestock in the dry season.

In March 2023, she hosted guests from 11 countries who represent the first cohort of World Vision staff that has been trained on the organisation's Regreening Communities Project Model. This is a community-led environmental restoration project model based on the work of communities and individuals like Nancy. It provides opportunities for communities to actively restore and protect their landscapes using various regreening approaches such as FMNR.



Fig. 1: Nancy usually pounds pruned branches using a stone to peel their barks. These peelings (in her left hand) are used as animal feed in dry periods while the peeled branches are used as firewood.

Source: © World Vision Photo/Hellen Owuor.

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Assorbimento di CO₂ e protezione dall'erosione costiera

«Nature-based solutions»: la posidonia



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