

Laurea in Ingegneria per l'Ambiente ed il Territorio

CAMBIAMENTI CLIMATICI E ADATTAMENTI NEGLI ECOSISTEMI E NELLE SOCIETÀ

Docenti

Salvatore Pappalardo

Daniele Codato

Alessandro Ceppi (Politecnico di Milano)

Supporto didattico

Edoardo Crescini

- 6 CFU
- 48 ore
- 102 ore di studio individuale

Labs: Mapping for climate mitigation and adaptation



Prof. Daniele Codato (GIScience D4G)

- Lunedì 20/5
- Giovedì 23/5
- Lunedì 27/5



Daniele Codato

PhD in Geography, University of Padova - University of Padova
Italy

Luogo: Aula R
Ora: 08:45

Portarsi il laptop!

Introduzione ai GIS

Gli elementi geografici vengono localizzati nello spazio attraverso dei Sistemi di Riferimento (o di coordinate):

Geografiche Proiettate

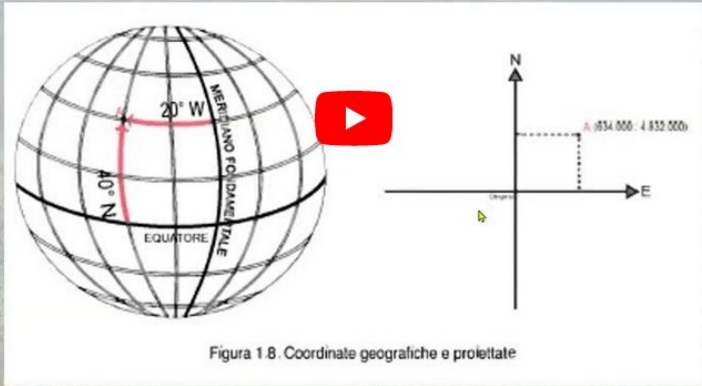


Figura 1.8. Coordinate geografiche e proiettate

Fonte: Noti, 2014

<https://www.youtube.com/watch?v=hNLjzEG952w>

Installazione QGIS



https://www.youtube.com/watch?v=4ixD_zQTyn8

QGIS 3.34 LTR

Scaricare e installare
InVEST

<https://naturalcapitalproject.stanford.edu/software/invest>

InVEST
Integrated Valuation of
Ecosystem Services
and Tradeoffs

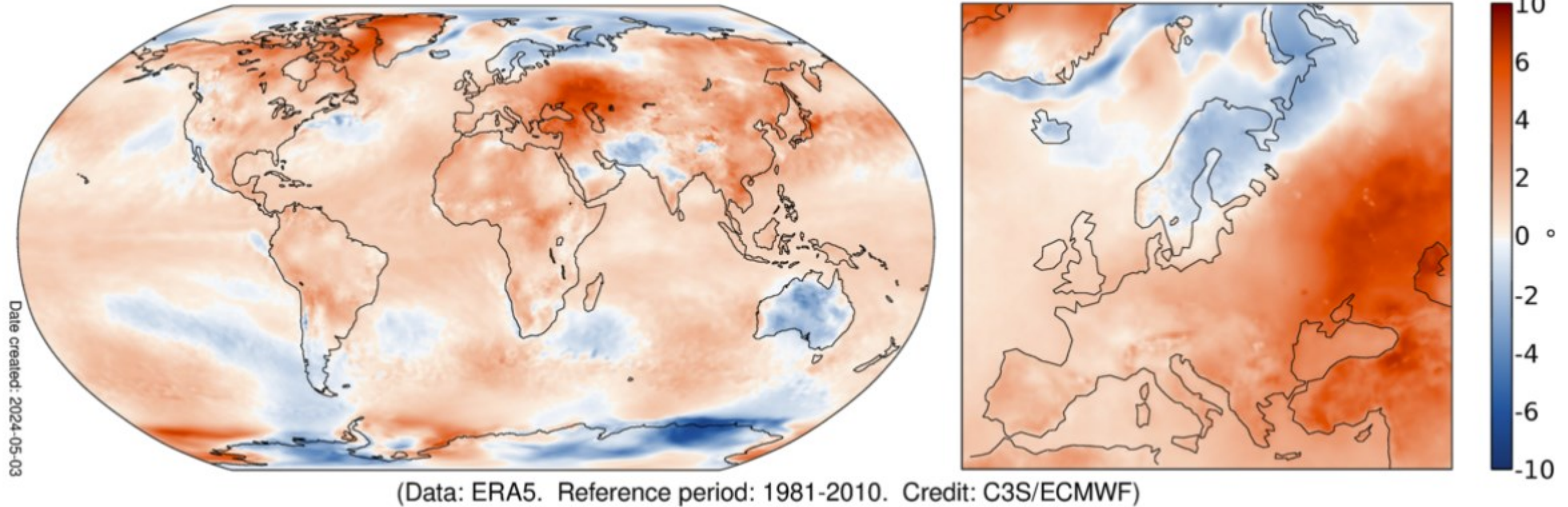
natural
capital
PROJECT

Natural Capital Project
Stanford University

1991-2020

1981-2010

Surface air temperature anomaly for April 2024



PROGRAMME OF
THE EUROPEAN UNION



<https://climate.copernicus.eu/surface-air-temperature-april-2024>



CLASSIFICA DEI MESI PIU' CALDI

Justice
ence

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
	24	18	19	23	12	17	15	22	14	11	20	16	13	10	7	3	5	9	4	2	8	6	1	?
GEN	30	12	14	19	15	22	5	39	18	16	23	28	17	13	9	2	4	10	6	3	11	7	8	1
FEB	29	12	21	14	20	15	16	38	24	11	27	26	19	23	8	2	4	10	6	3	17	7	5	1
MAR	25	12	23	21	16	20	17	15	27	9	19	24	18	14	8	2	6	11	4	5	10	7	3	1
APR	27	20	23	19	15	29	12	24	18	8	16	14	25	10	13	3	6	7	4	2	11	9	5	1
MAG	20	16	19	26	17	23	13	22	15	12	21	11	18	5	9	2	4	8	6	1	10	7	3	?
GIU	23	21	25	27	15	14	19	24	17	12	18	16	11	13	6	7	10	8	4	3	5	2	1	?
LUG	19	14	22	36	15	23	18	17	9	13	11	21	16	20	10	6	8	7	2	5	4	3	1	?
AGO	22	21	18	25	20	12	19	24	14	15	11	16	13	7	9	2	5	10	4	6	8	3	1	?
SET	23	17	18	24	13	15	20	19	14	16	21	12	11	7	8	5	10	9	4	2	3	6	1	?
OTT	24	23	13	21	12	15	22	17	18	14	19	11	16	10	2	8	7	3	4	9	5	6	1	?
NOV	17	21	24	16	15	13	22	18	12	10	23	11	8	19	3	6	7	9	4	2	5	14	1	?
DIC	18	27	12	22	14	10	23	20	15	26	16	21	13	11	2	7	4	5	3	9	6	8	1	?

2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024

DATI: NASA GISS SURFACE TEMPERATURE ANALYSIS (GISTEMP V4) | CREDITS: @GALSELO PER CHPDB

https://chpdb.it/ climate_dash/



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World / Climate

Planet endures record-hot April, as scientists warn 2024 could beat heat records for second year in a row

By Laura Paddison, CNN

3 minute read · Published 10:00 PM EDT, Tue May 7, 2024



ENVIRONMENT / CLIMATE CHANGE

World extends temperature streak to 11 months with hottest April ever



Climate & Energy | Climate Change

World's record-breaking temperature streak extends through April

By Kate Abnett

May 8, 2024 2:11 PM GMT+2 · Updated 5 days ago



Analysis

Weather tracker: global average temperature highest ever for April

James Parrish and Morgan Thomas for MetDesk

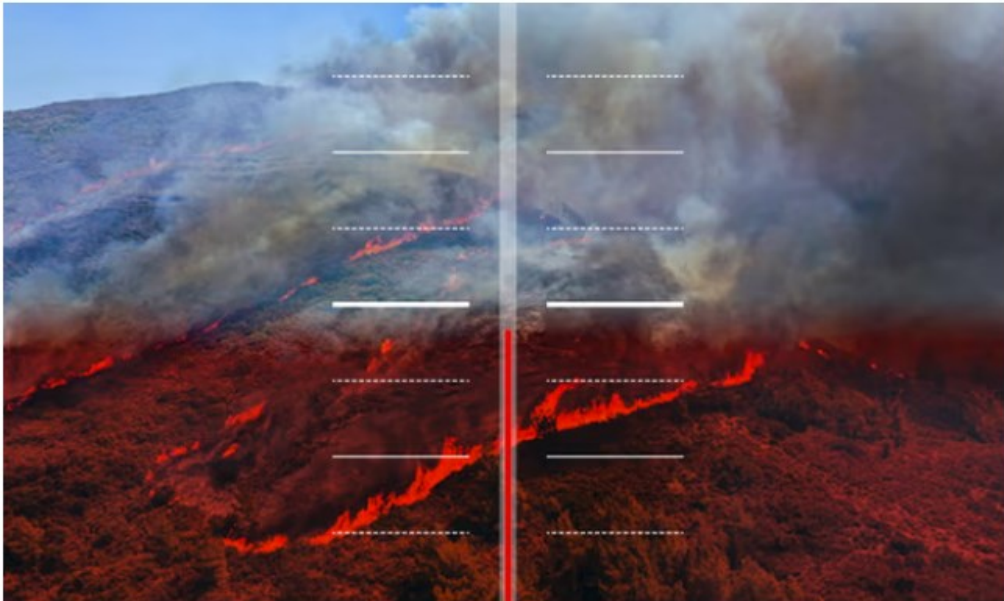
Figures from EU's Copernicus Climate Change Service show it was 11th time in a row monthly record has been broken



World's top climate scientists expect global heating to blast past 1.5C target

Exclusive: Planet is headed for at least 2.5C of heating with disastrous results for humanity, poll of hundreds of scientists finds

● **'Hopeless and broken': why the world's top climate scientists are in despair**

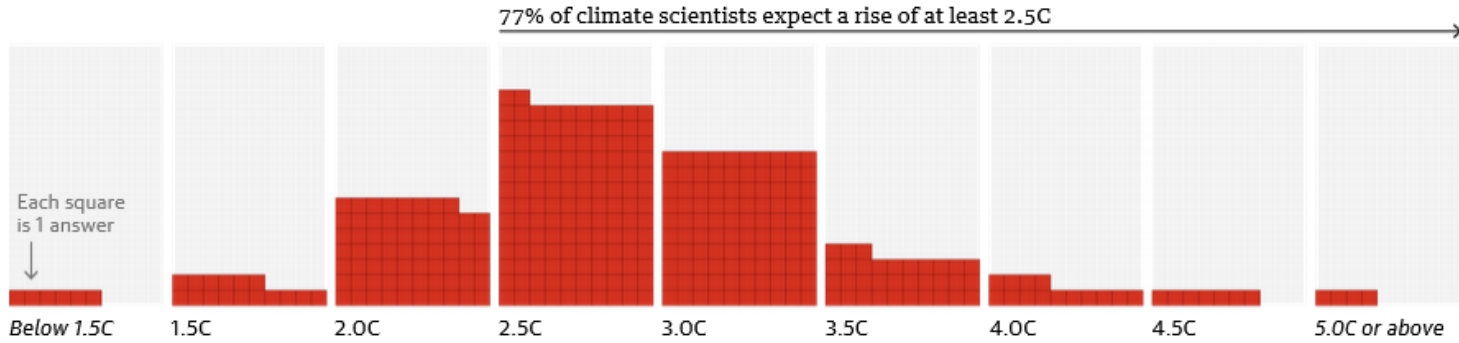


The climate crisis is already causing profound damage to lives and livelihoods across the world.
Illustration: Guardian Design/Halil Kahraman

How high will global heating go?

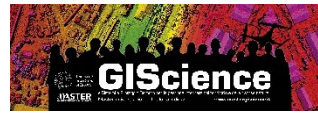
How high above pre-industrial levels do you think average global temperature will rise between now and 2100?

Count of answers given by IPCC climate experts



Guardian graphic. Source: Guardian survey of climate experts. 380 responses

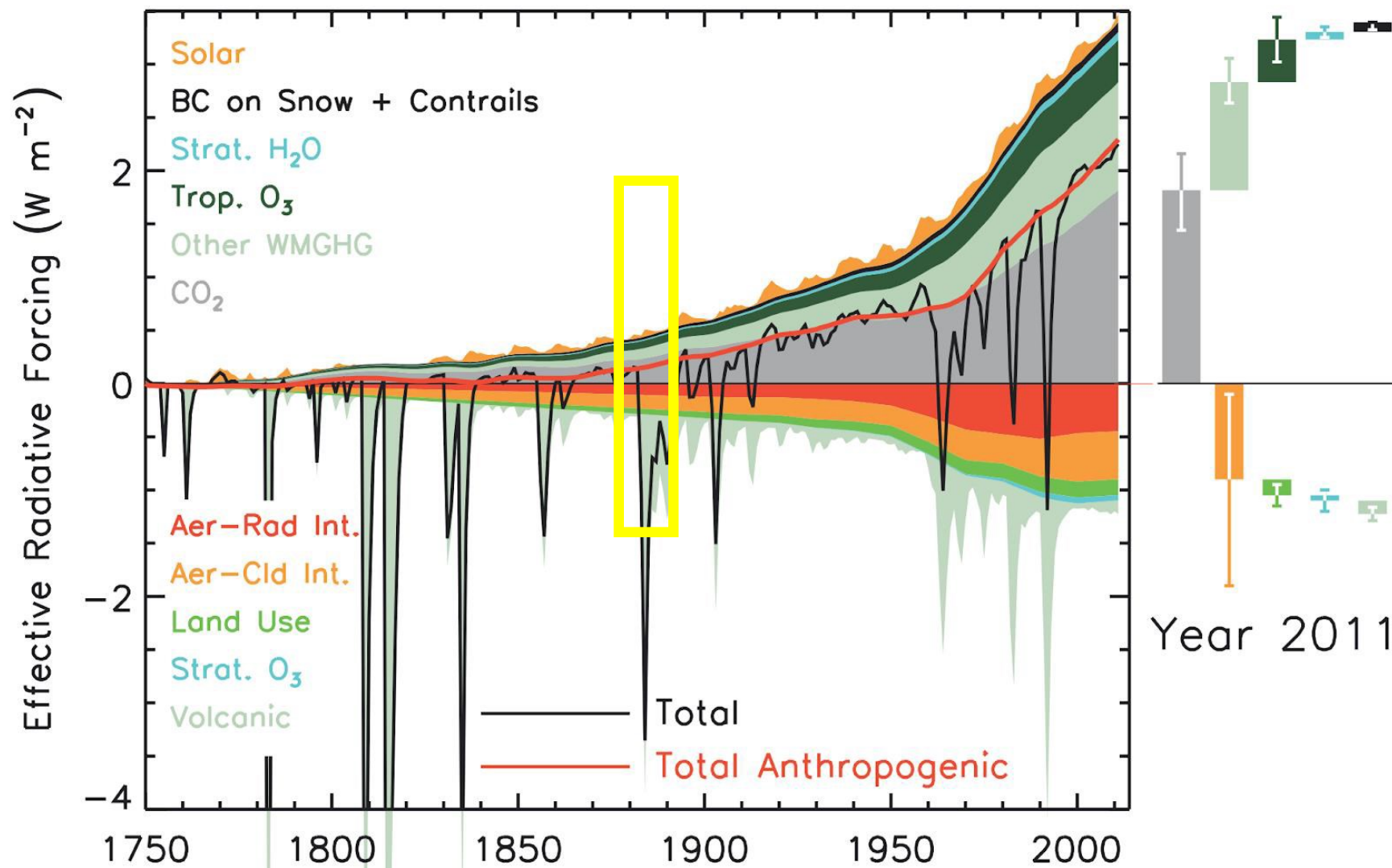
<https://www.theguardian.com/environment/article/2024/may/08/world-scientists-climate-failure-survey-global-temperature>



Outline

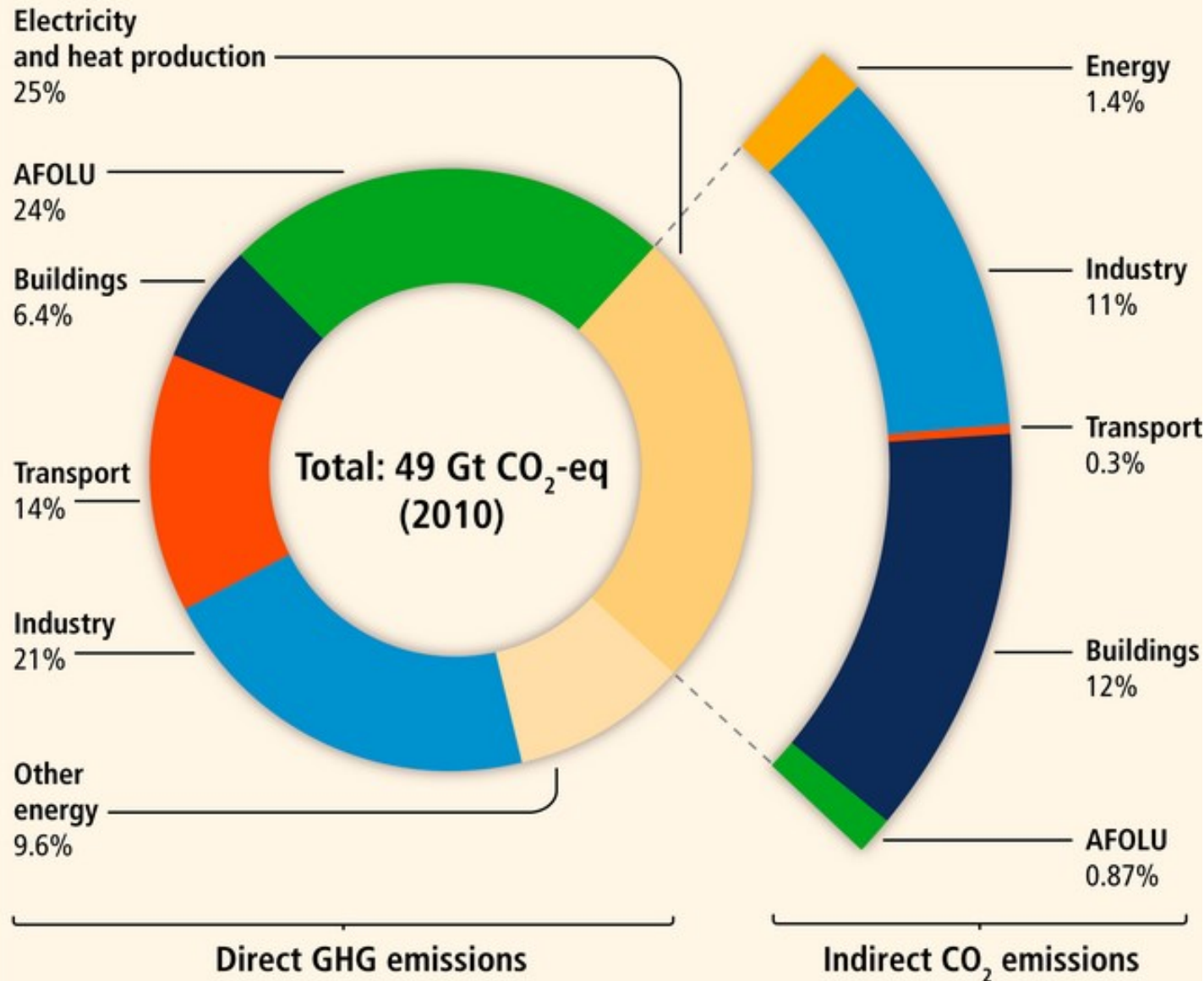
- Forzanti esogeni (GHG)
- *Climate feedback loops*
- *Tipping points*

Evoluzione temporale dal 1750 al 2011 dei diversi forzanti naturali e antropogenici



(IPCC, AR5, Myhre et al.; 2013)

Greenhouse gas emissions by economic sectors



Global anthropogenic GHG emissions by economic sectors (IPCC, 2014, pg. 47)

a. Trends in global GHG emissions by sector

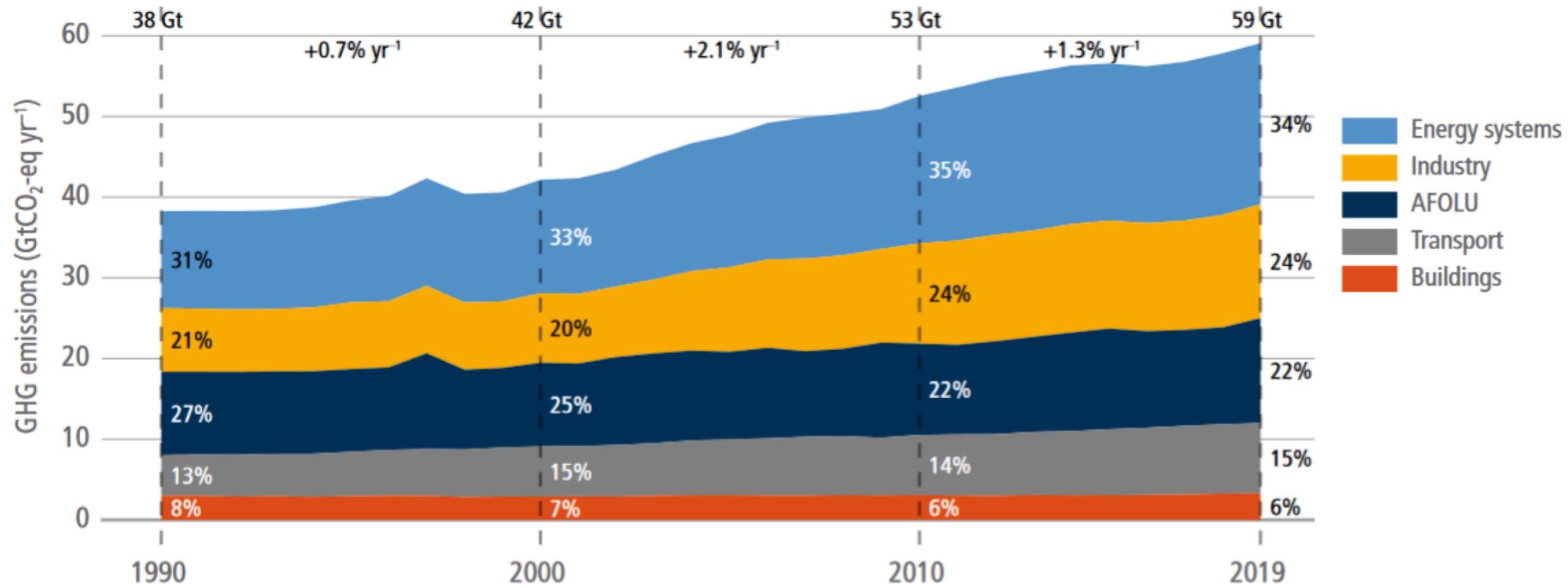


Figure 2.13 | Total annual anthropogenic GHG emissions by major economic sector (IPCC, AR6, WGIII, Chapt. 2)

(a) Long term trend of anthropogenic CO₂ emissions sources

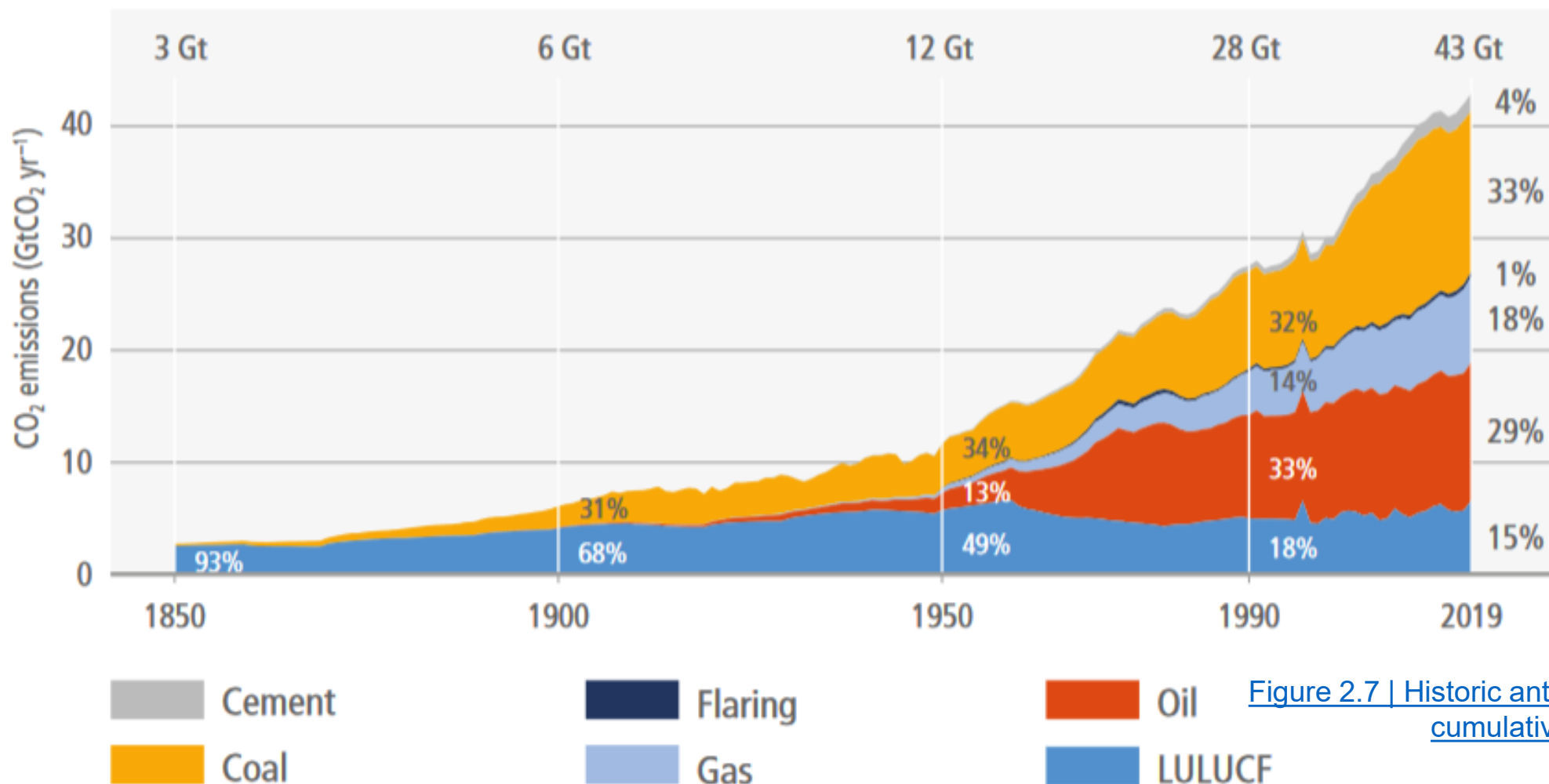
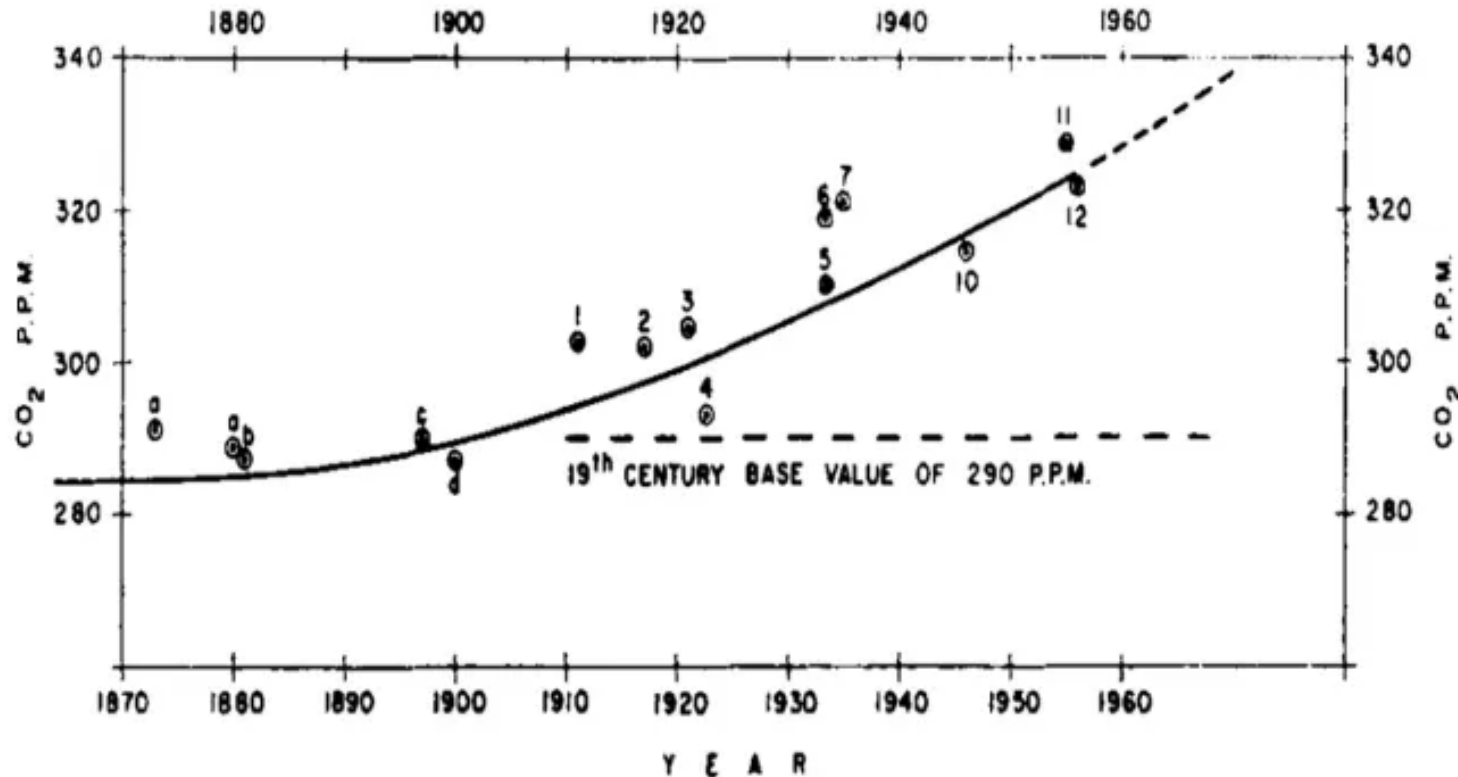


Figure 2.7 | Historic anthropogenic CO₂ emission and cumulative CO₂ emissions (1850–2019) (IPCC, AR6, WGIII, Chapt. 2)

CO₂



Roger Revelle (1909-1991)

1957 “large-scale geophysical experiment” on the planet by releasing greenhouse gases



Dove misurare una concentrazione rappresentativa di WMGHG?
(es. CO₂)

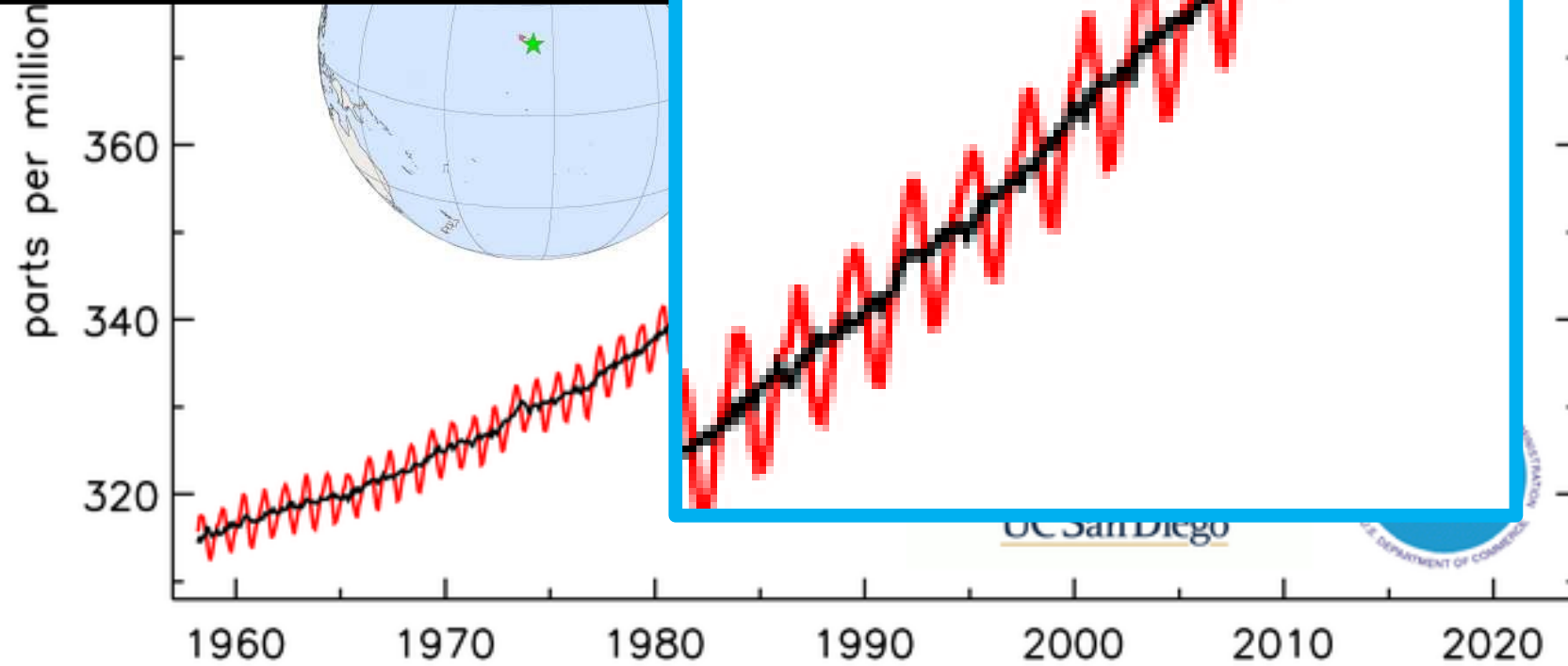


Pinatubo eruption 1991 (P)



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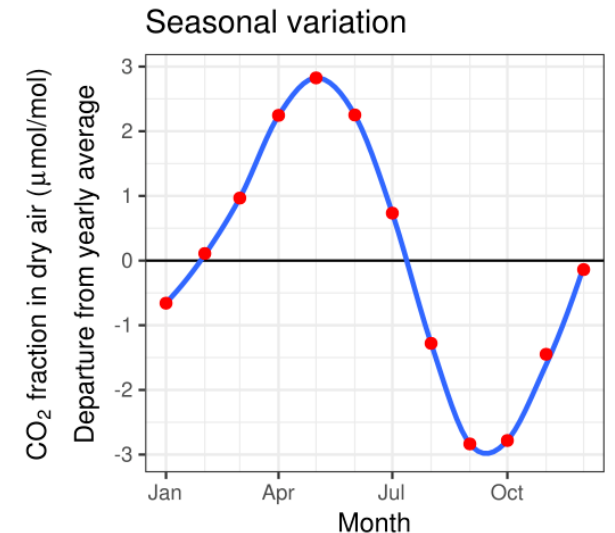
Mauna Loa Observatory



<https://keelingcurve.ucsd.edu/2013/04/03/the-history-of-the-keeling-curve/>



Charles David Keeling



Record MAY 11^o 2024 = 427.90 ppm

<https://gml.noaa.gov/ccgg/trends/>

<https://www.co2.earth/daily-co2>

NOAA Global Greenhouse Gas Reference Network (GGGRN)

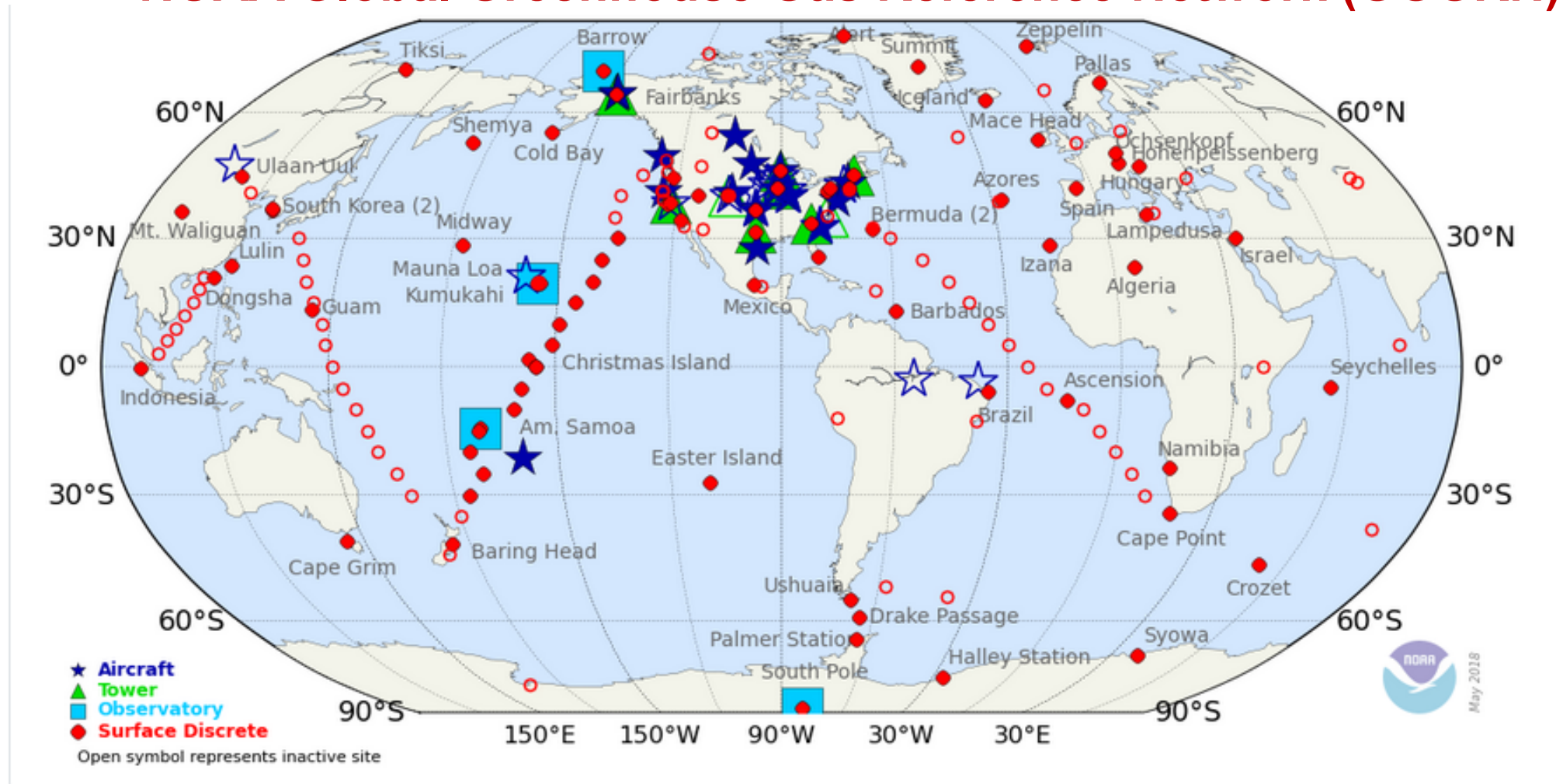
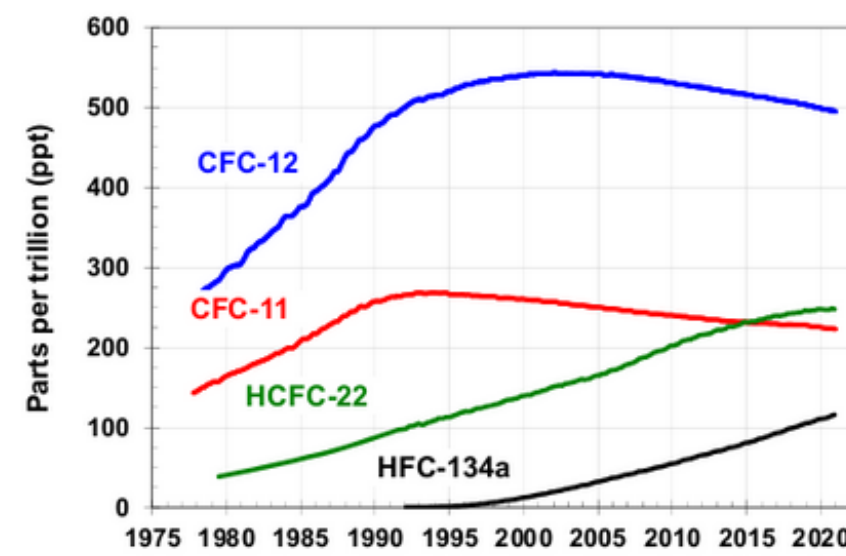
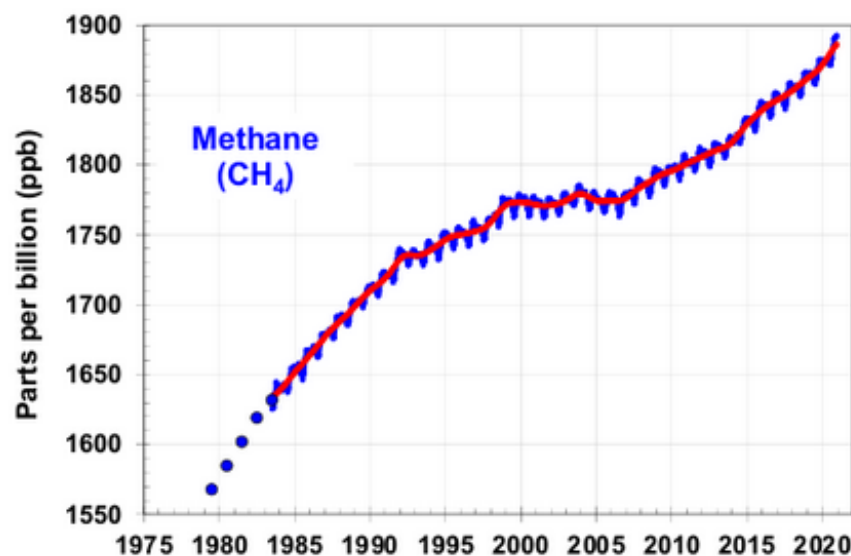
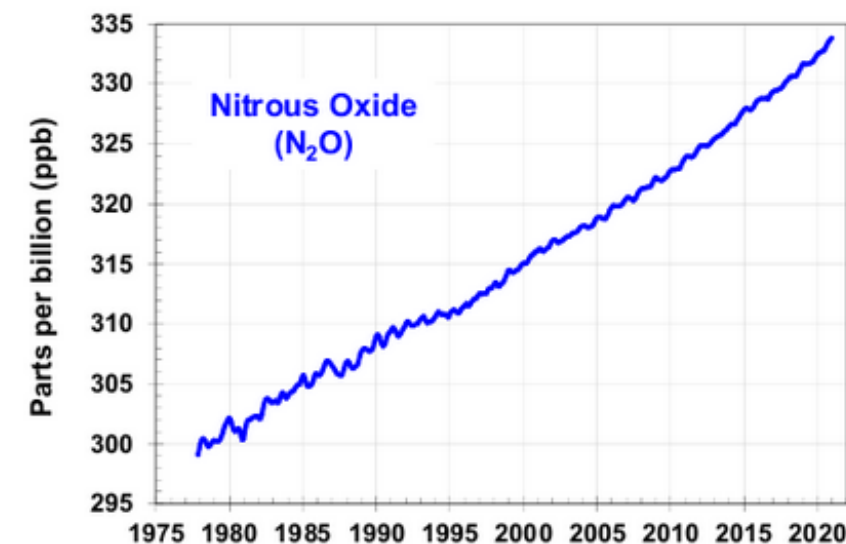
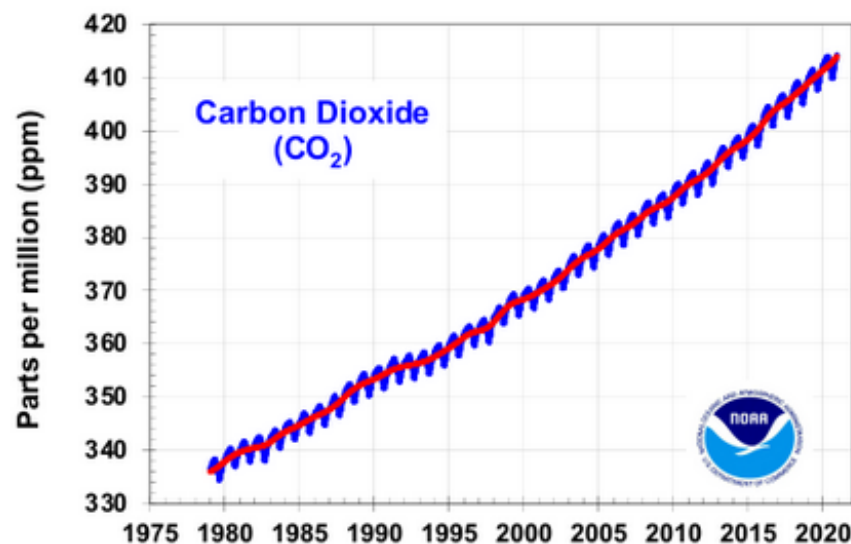


Figure 1. The NOAA Global Greenhouse Gas Reference Network (GGGRN), where greenhouse gases are measured in ambient air. Results from subsets of these sites are used to determine global background greenhouse gas concentrations and the AGGI. Click on image to view full size figure.
<https://gml.noaa.gov/aggi/aggi.html>

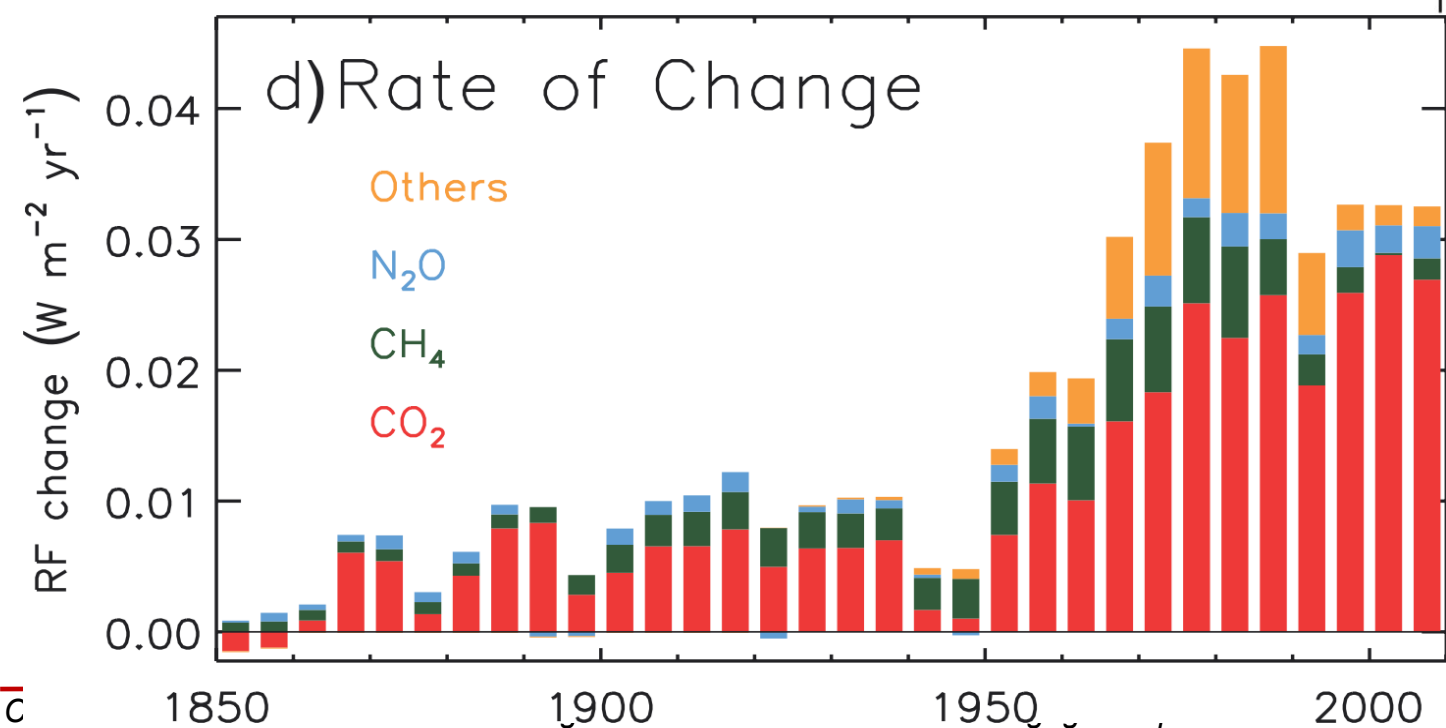
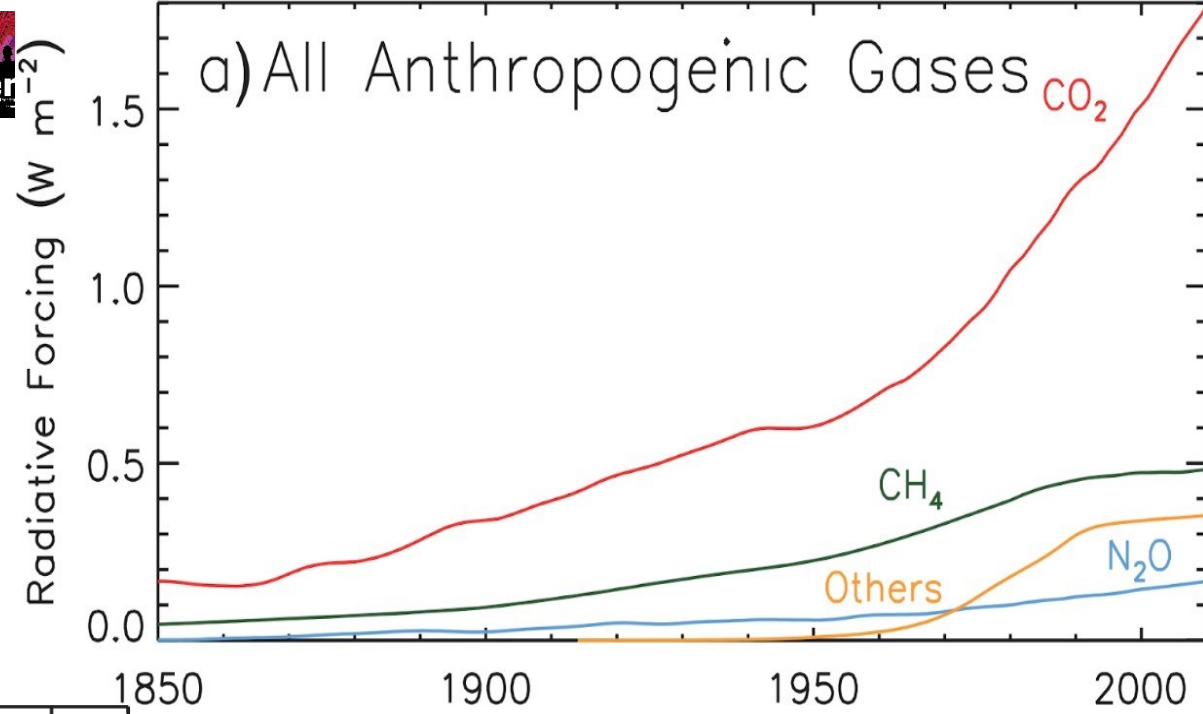
2) Forzanti endogeni: Anthropogenic GHG

NOAA
GGGRN
(Since 1979)

<https://gml.noaa.gov/aggi/aggi.html>

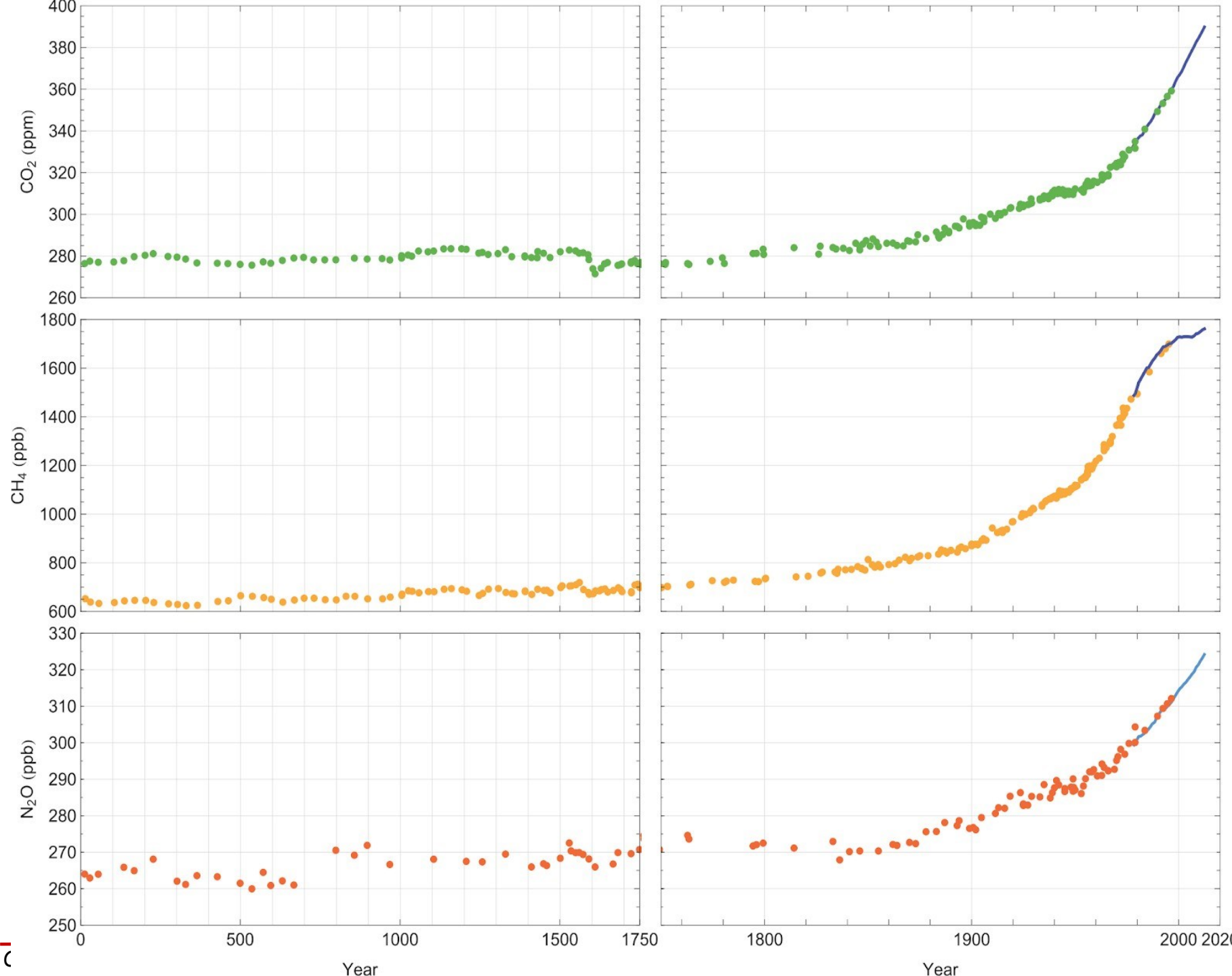


2) Forzanti endogeni: Anthropogenic GHG





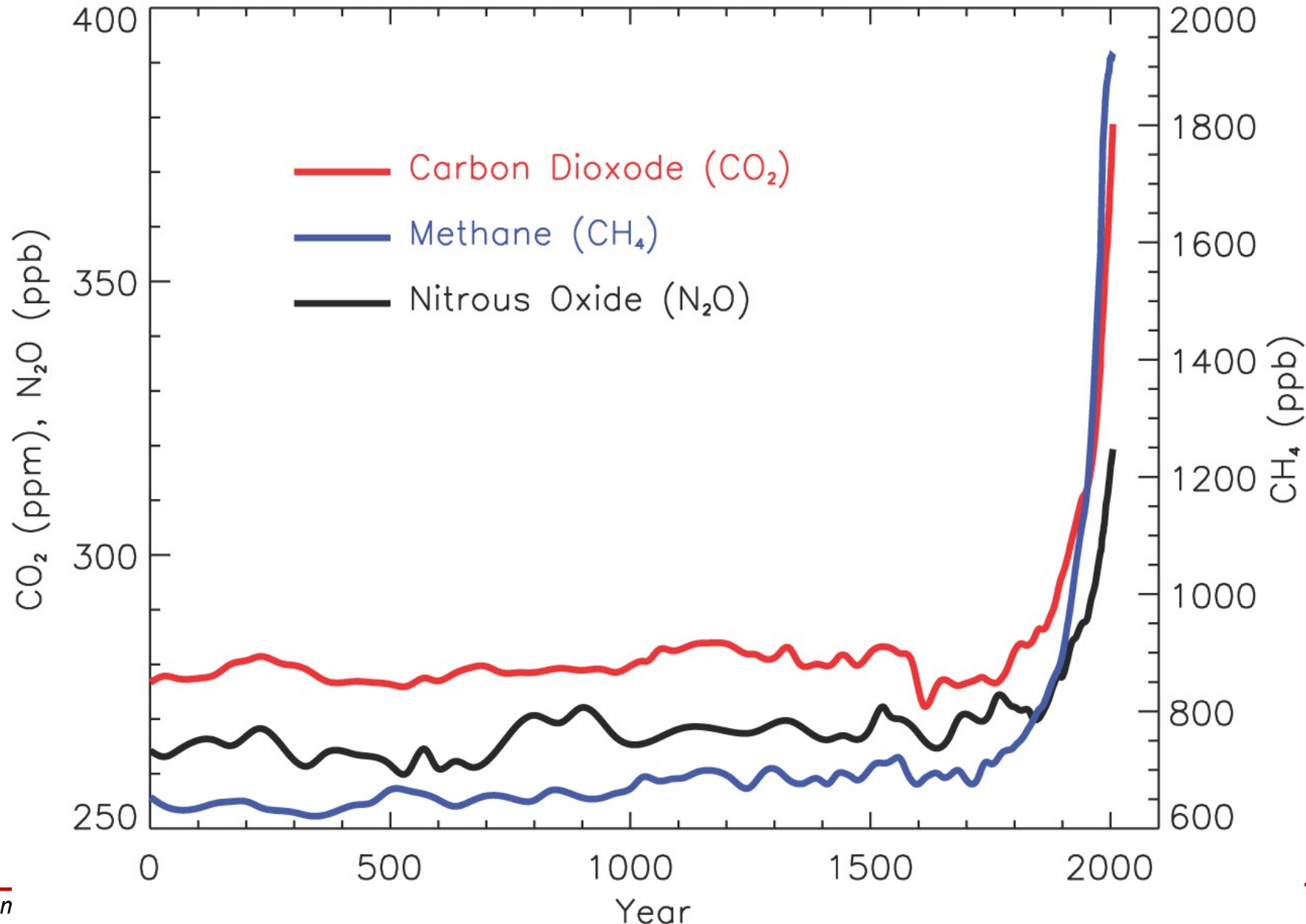
2) Forzanti endogeni: anthropogenic GHG



2000 anni

MacFarling-Meure et al. (2006)

Concentrations of Greenhouse Gases from 0 to 2005

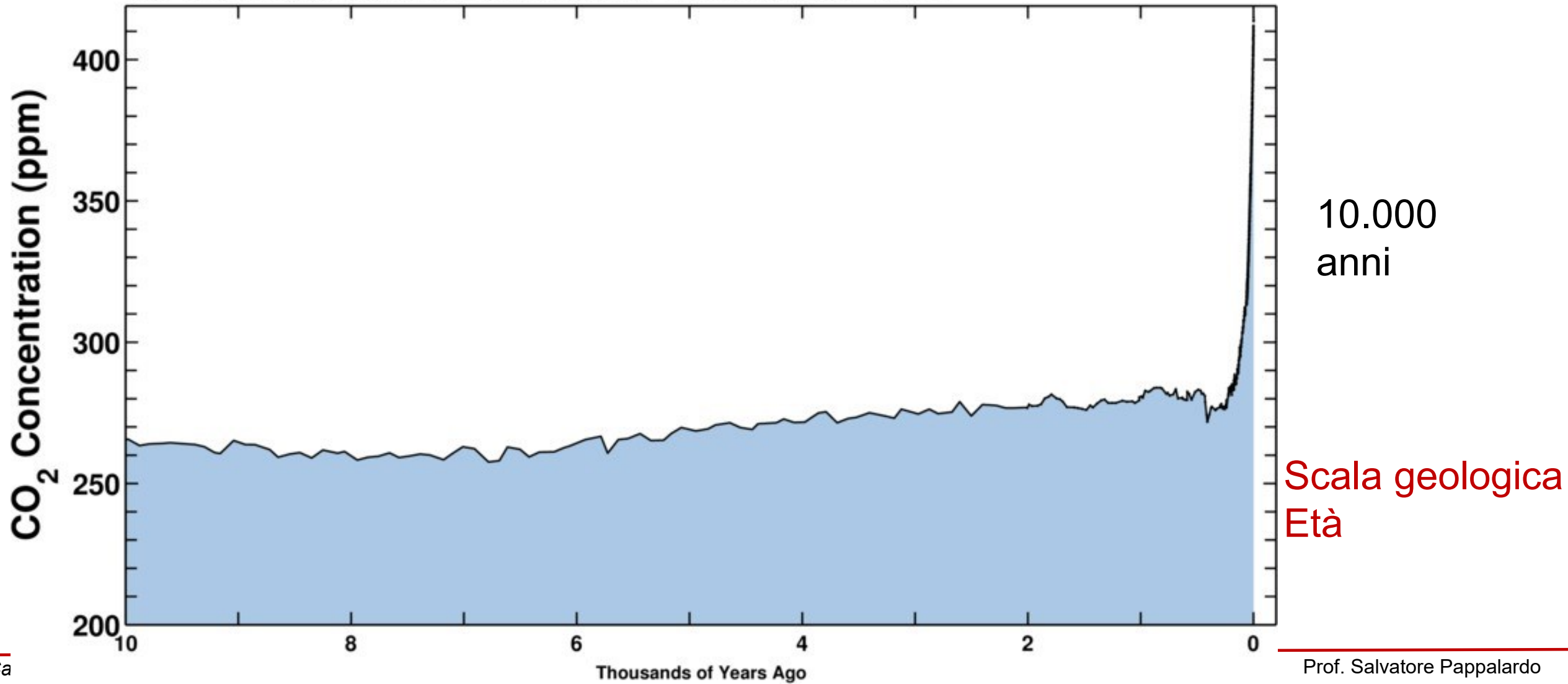


AR4 (IPCC, 2007)

2) Forzanti endogeni: anthropogenic GHG

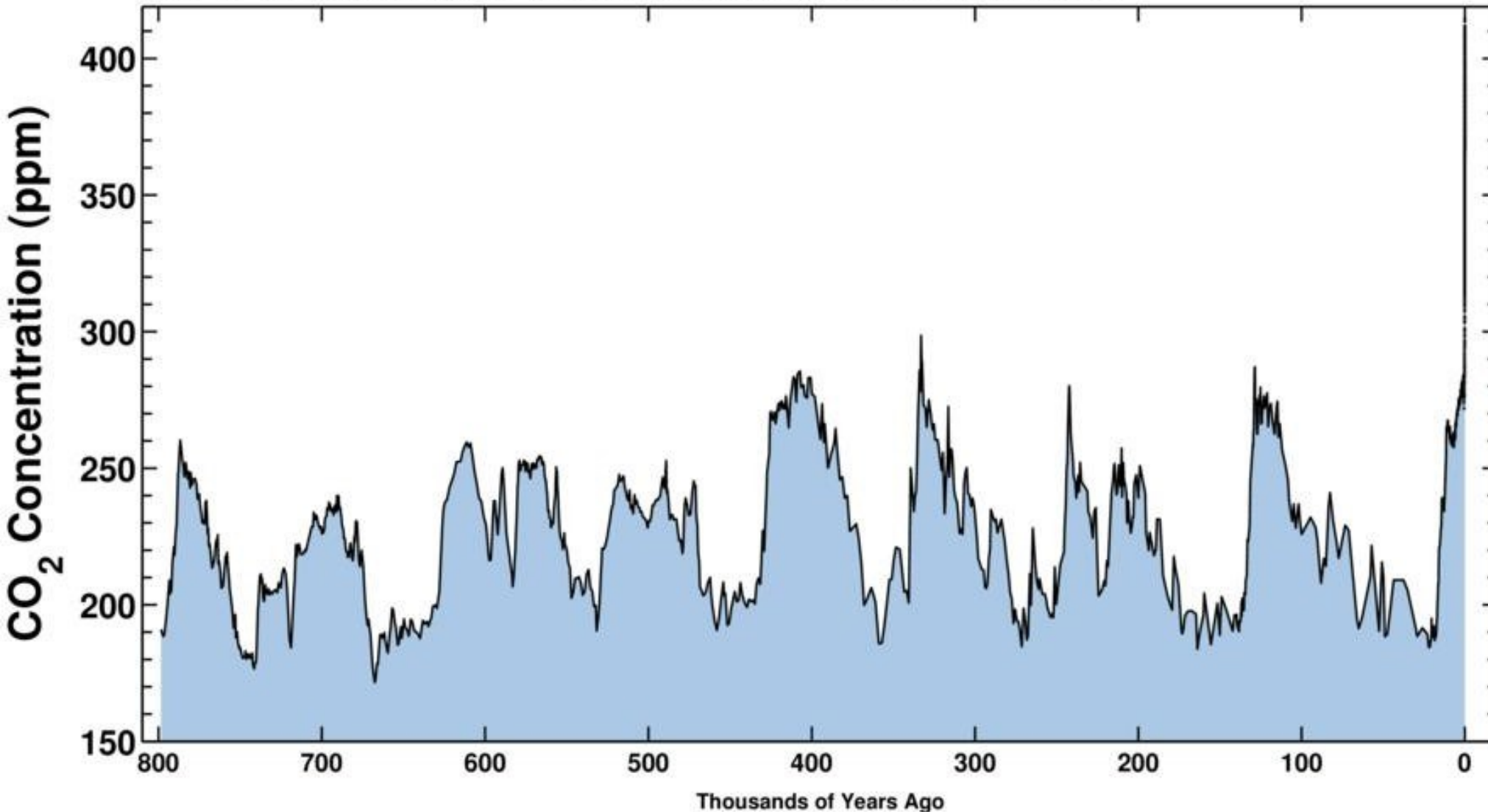
December 12, 2019

Ice-core data before 1958. Mauna Loa data after 1958.



December 12, 2019

Ice-core data before 1958. Mauna Loa data after 1958.

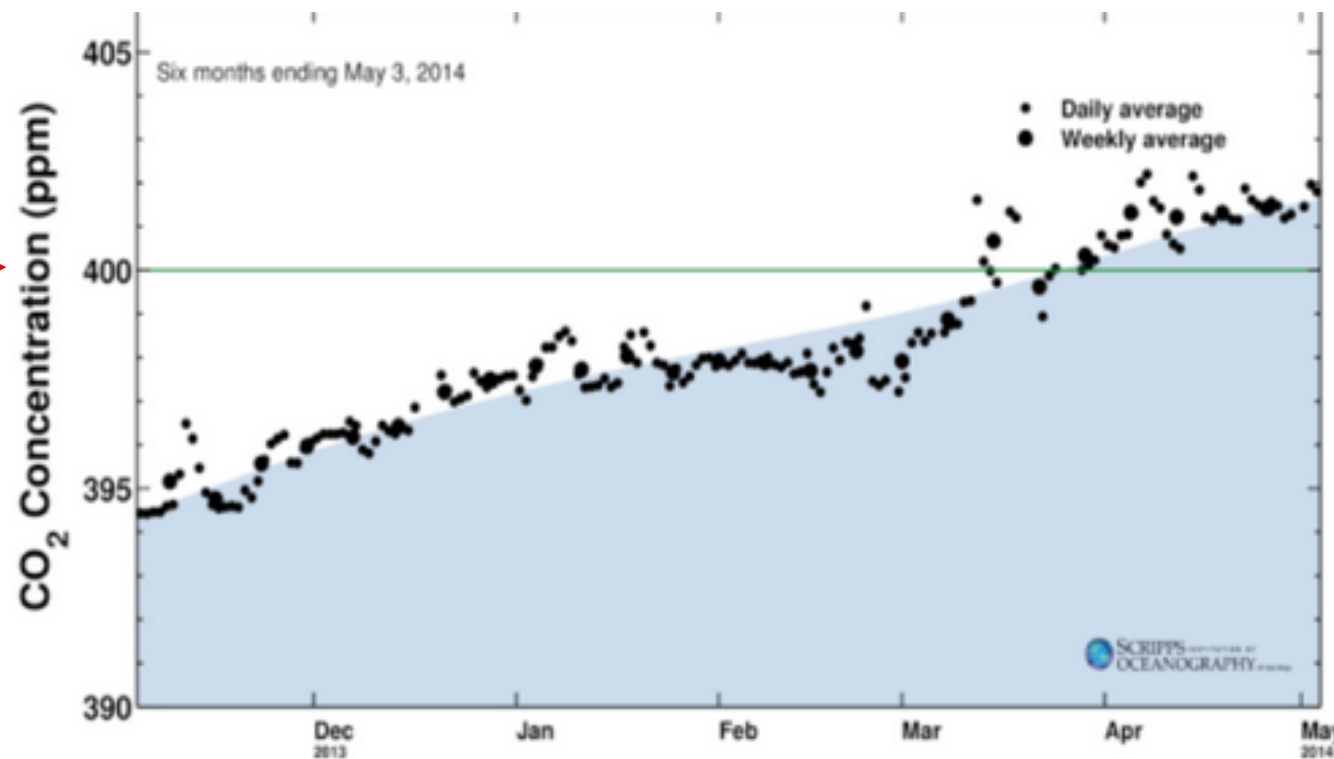


800.000
anni fa

Scala geologica
Epoca

Quanto bisogna andare indietro per trovare 400 ppm di CO₂?

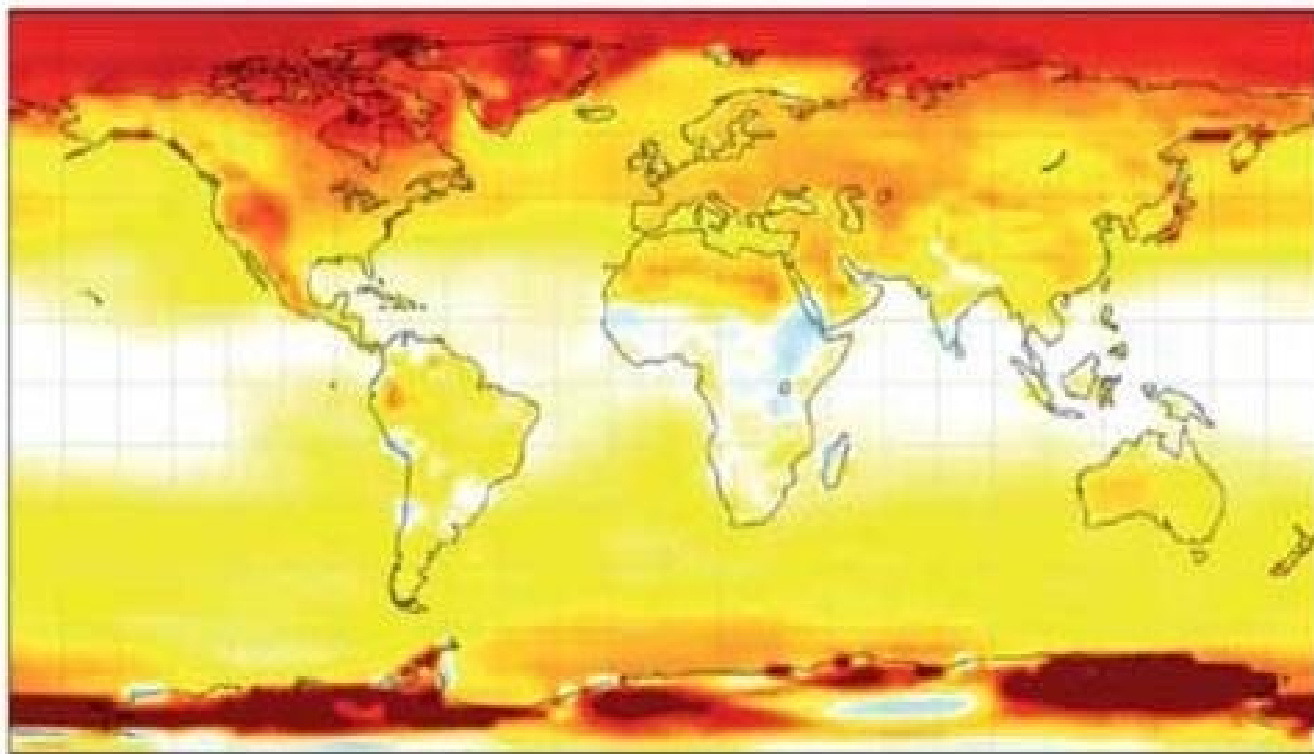
La soglia psicologica dei 400 ppm



www.climalteranti.it

Concentrazioni giornaliere e settimanali di CO₂ a Manua Loa (Fonte: [The Keeling Curve](http://TheKeelingCurve.com))

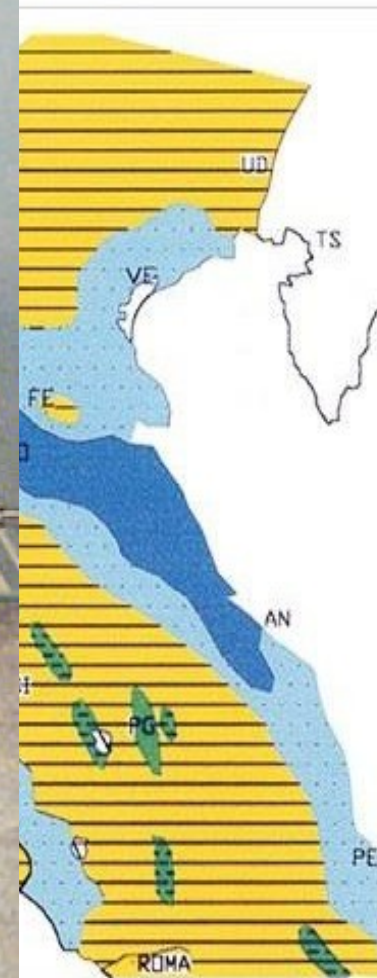
400 ppm nel periodo (geol) del Pliocene (3 M anni)



La temperatura (K) della terra a 400 ppm CO₂



Genere Australopithecus



Monticino (Pliocene)



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Feedback loops climatici

Rapid adjustment e feedback loops

Rapid adjustments

aggiustamenti rapidi del sistema climatico su **scale temporali brevi** (settimane), attraverso meccanismi **che non modificano direttamente il bilancio radiativo planetario e non inducono una variazione diretta della temperatura media superficiale terrestre.**

Questo tipo di risposta si attiva quando i forzanti provocano, oltre ai cambiamenti dei flussi radiativi, anche **una variazione della copertura nuvolosa** o di altre componenti del sistema che, a loro volta, modificano il bilancio radiativo. In questo senso gli aggiustamenti rapidi sono caratterizzati da una interazione indiretta con il bilancio radiativo, che non è mediata da una variazione della temperatura media superficiale ma è dovuta a rapidi cambiamenti atmosferici e superficiali.

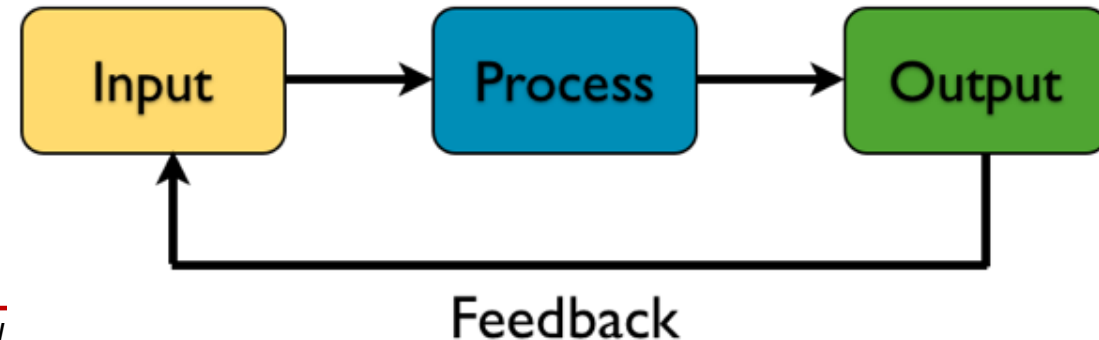
Feedback loops

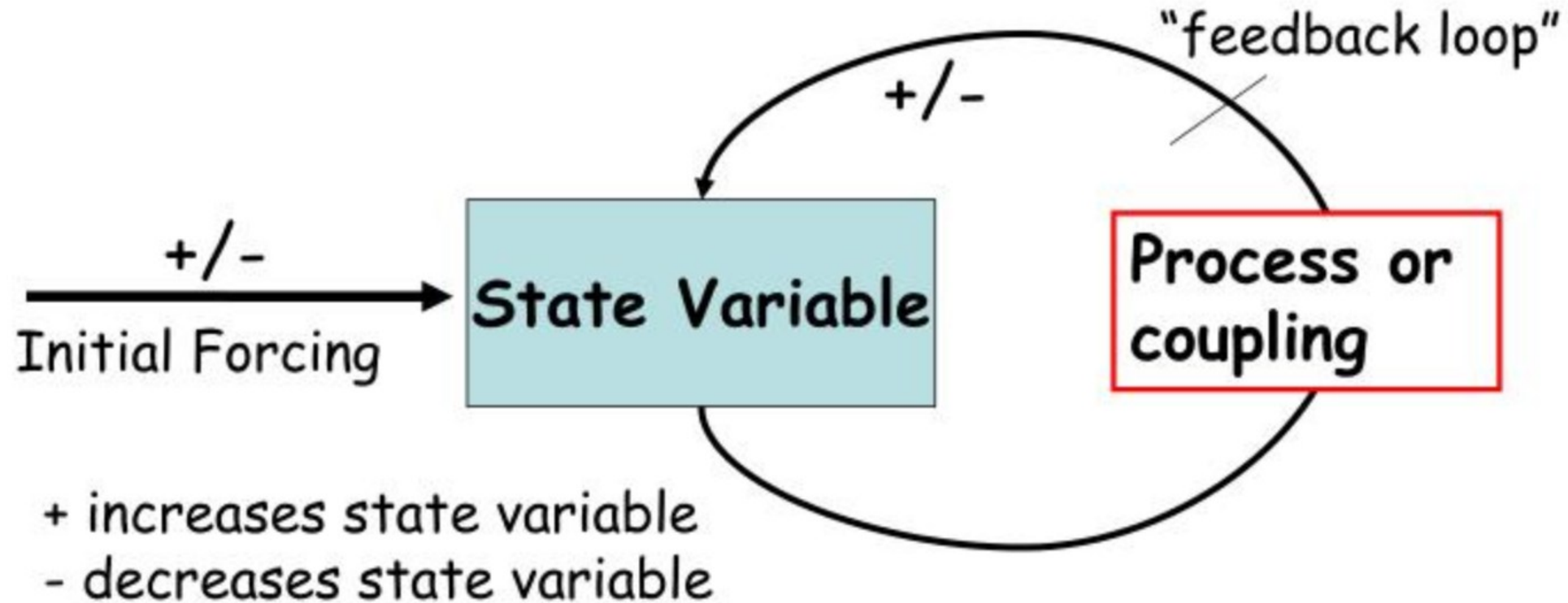
retroazioni climatiche ricorsive (positive o negative), tempi scala medio-lunghi

(Bagliani, 2019)

Feedback loops (retroazioni climatiche ricorsive)

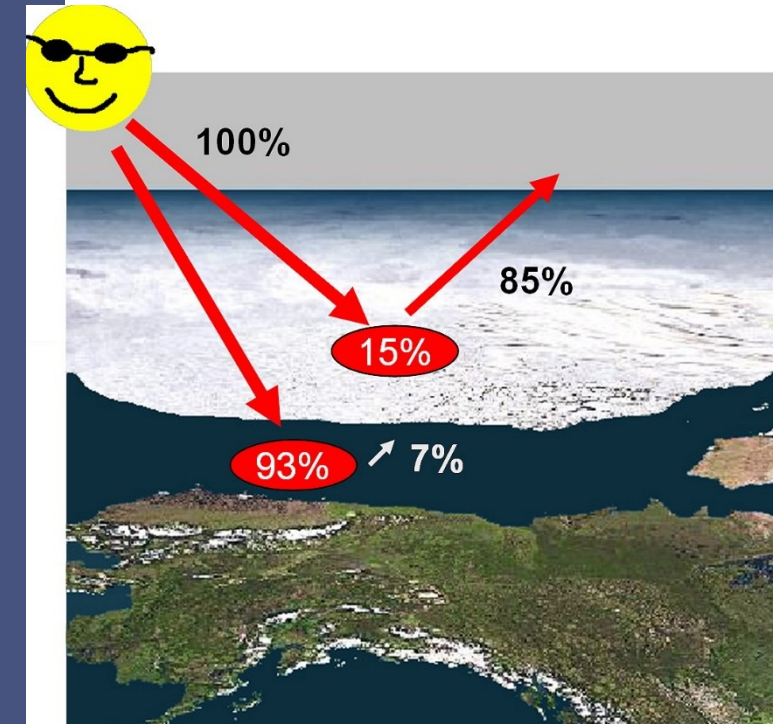
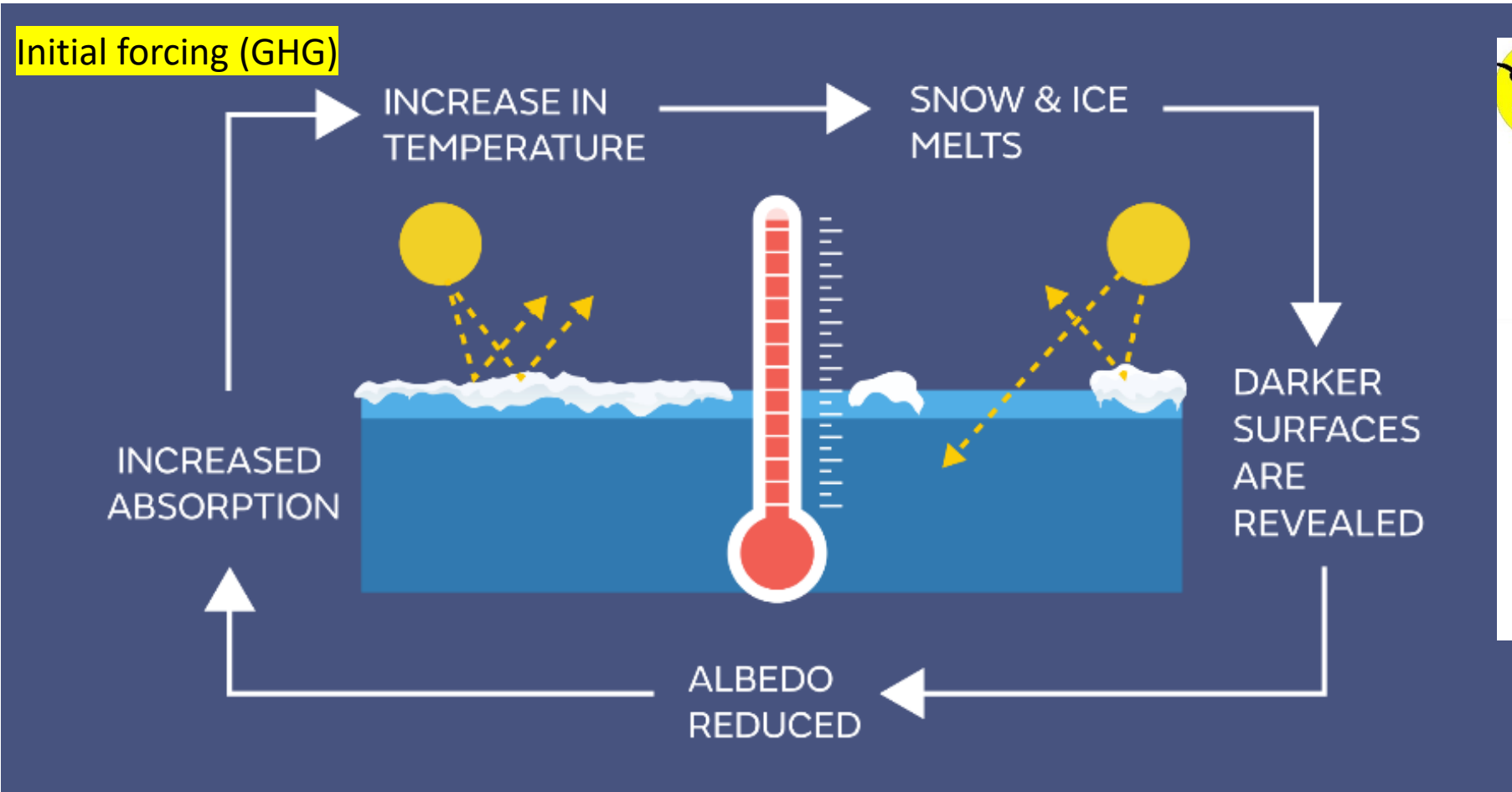
- Risposte del sistema climatico che agiscono **direttamente** sul **bilancio radiativo** inducendo modificazioni sulla T media superficiale terrestre
- Ricorsività
- *Feedback* positivi (amplificano il segnale, destabilizzano il sistema)
- *Feedback* negativi (riducono il segnale, stabilizzano il sistema)
- Tempi scala medio-lunghi (inerzia degli oceani)





Feedback loops: ice-albedo (+)

... e se la forzante iniziale causasse una diminuzione della temperatura?

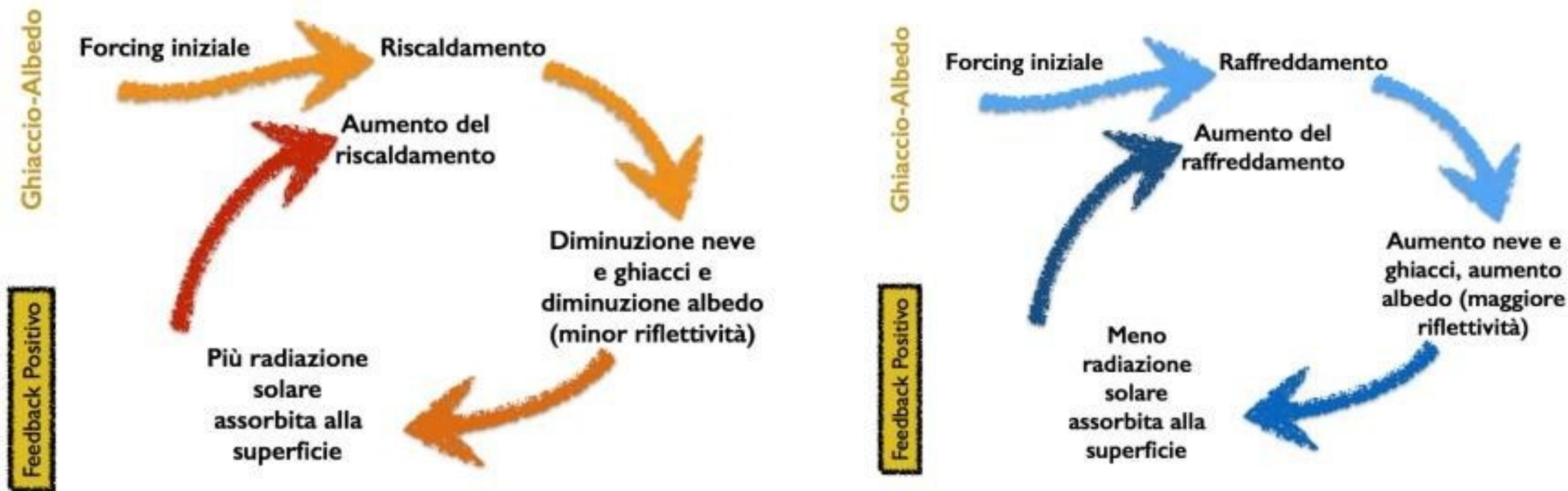


(M. Serreze 2008 NOAA)

(Figure 1 MET Office)

STORY MAP: Ice-Albedo Feedback in the Arctic

Il feedback ghiaccio - albedo



Arctic Sea Ice Loss

The September minimum Arctic sea ice extent in 2019 was the 2nd lowest on record.

Over the last four decades, September Arctic sea ice extent has declined by over 87,000 km² per year equating to an average of 12% per decade.*



Annual loss

87,055 km²

An area greater than Scotland.

Surface area of Scotland = 80,226km² (World Bank)

Decadal loss

870,550 km²

An area greater than the UK, Ireland and France combined.

Surface area of UK, Ireland & France = 862,977km² (World Bank)

40 year loss

3.48 million km²

An area greater than India, Bangladesh and Bhutan combined.

Surface area of India, Bangladesh & Bhutan = 3,473,283 km² (World Bank)

Arctic sea ice extent (1979-2018)



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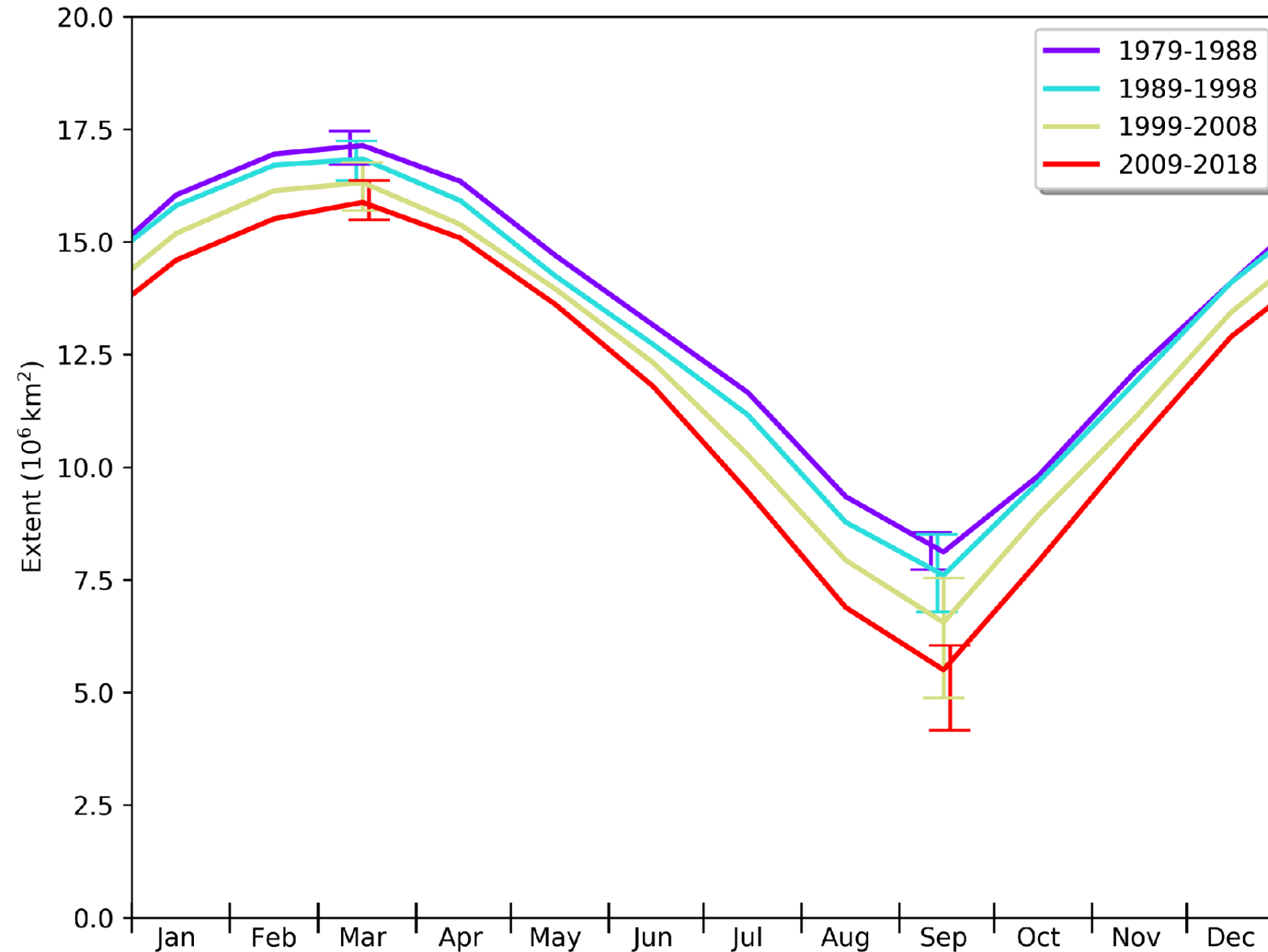
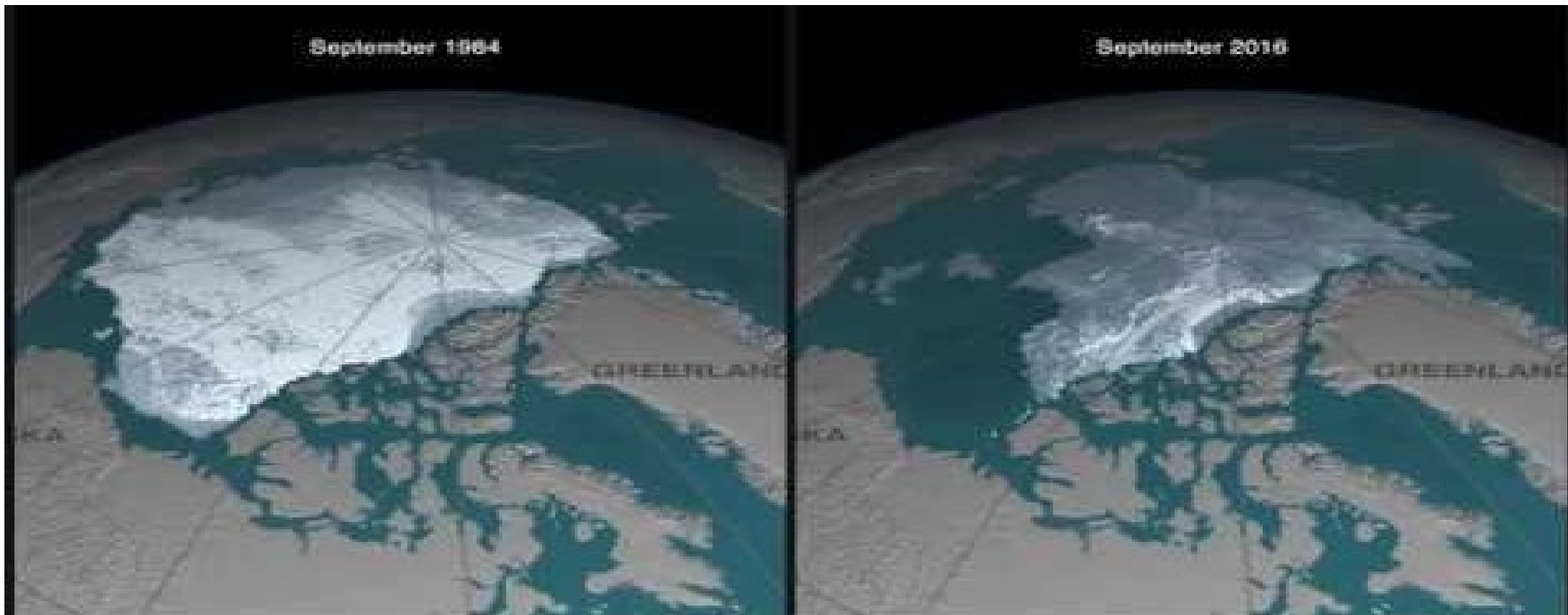


Figure 3: Changes to the seasonal cycle of Arctic sea ice cover shown using decadal averages of daily extent. Data are from Met Office Hadley Centre HadISST dataset

Disappearing Arctic sea ice



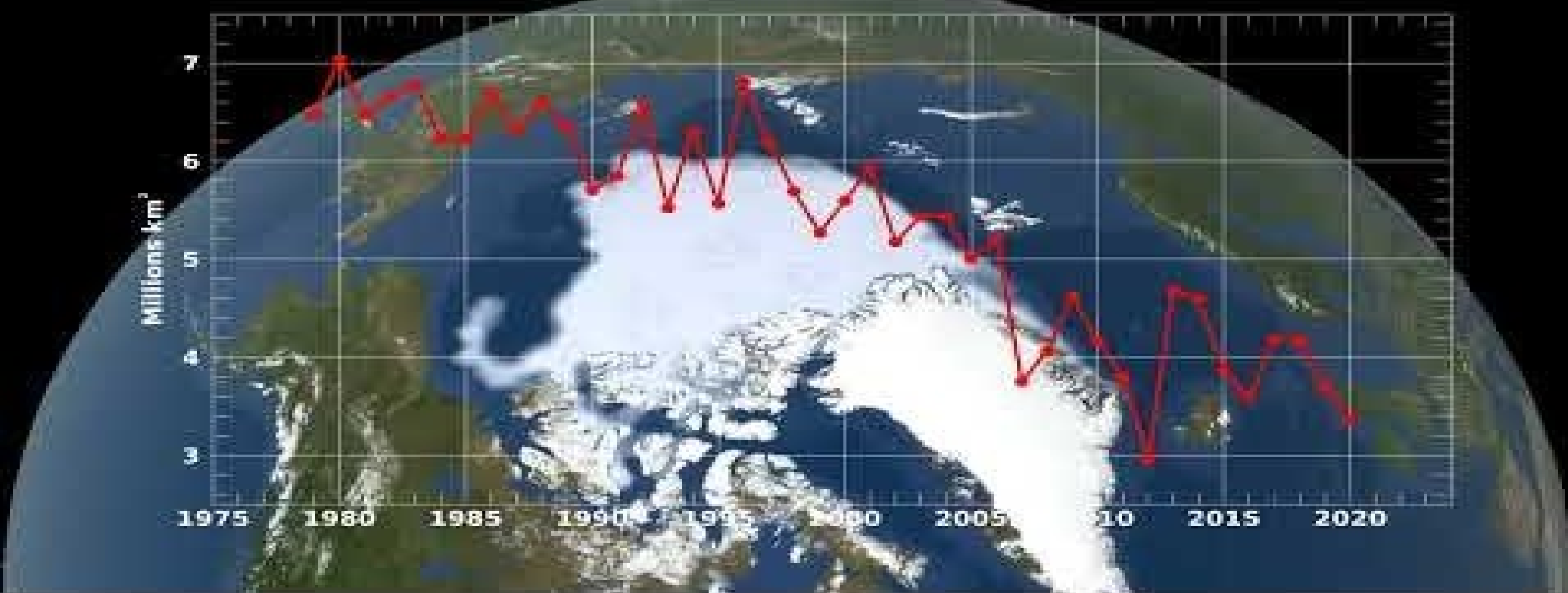
[NASA Climate Change](https://www.youtube.com/watch?v=XZHmS1EPfXY)

<https://www.youtube.com/watch?v=XZHmS1EPfXY>

<http://nsidc.org/arcticseaicenews>,

Annual Arctic sea ice minimum 1979-2020

Annual Arctic Sea Ice Minimum Area



<https://www.youtube.com/watch?v=Vphz0HbbQVo>



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Regione Artica

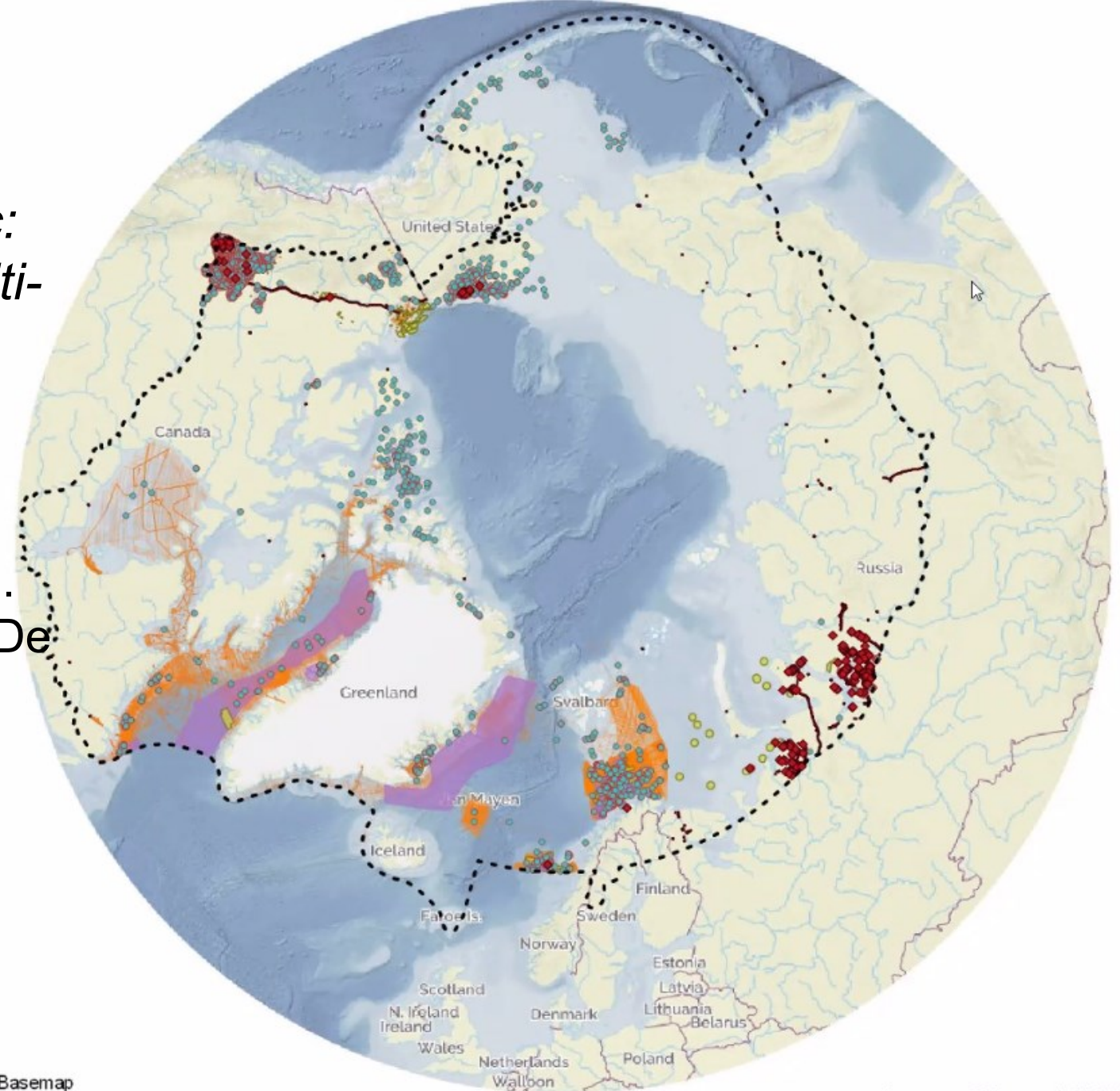
Produzione di energia fossile



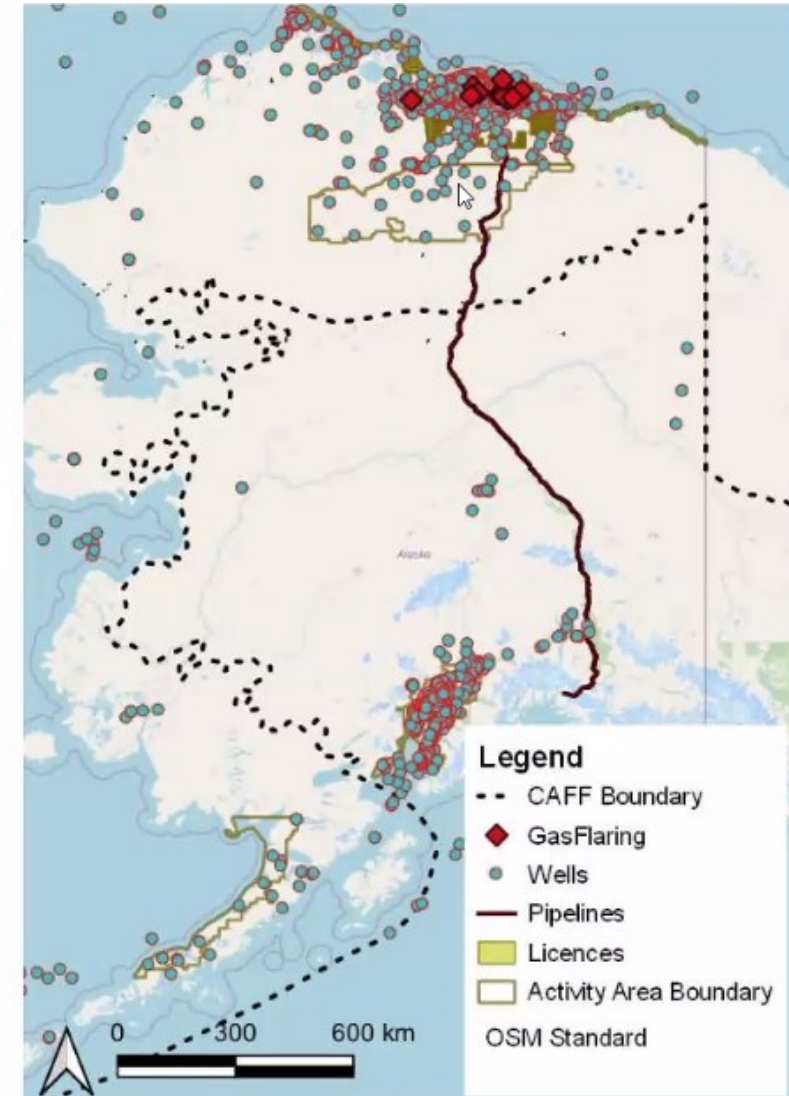
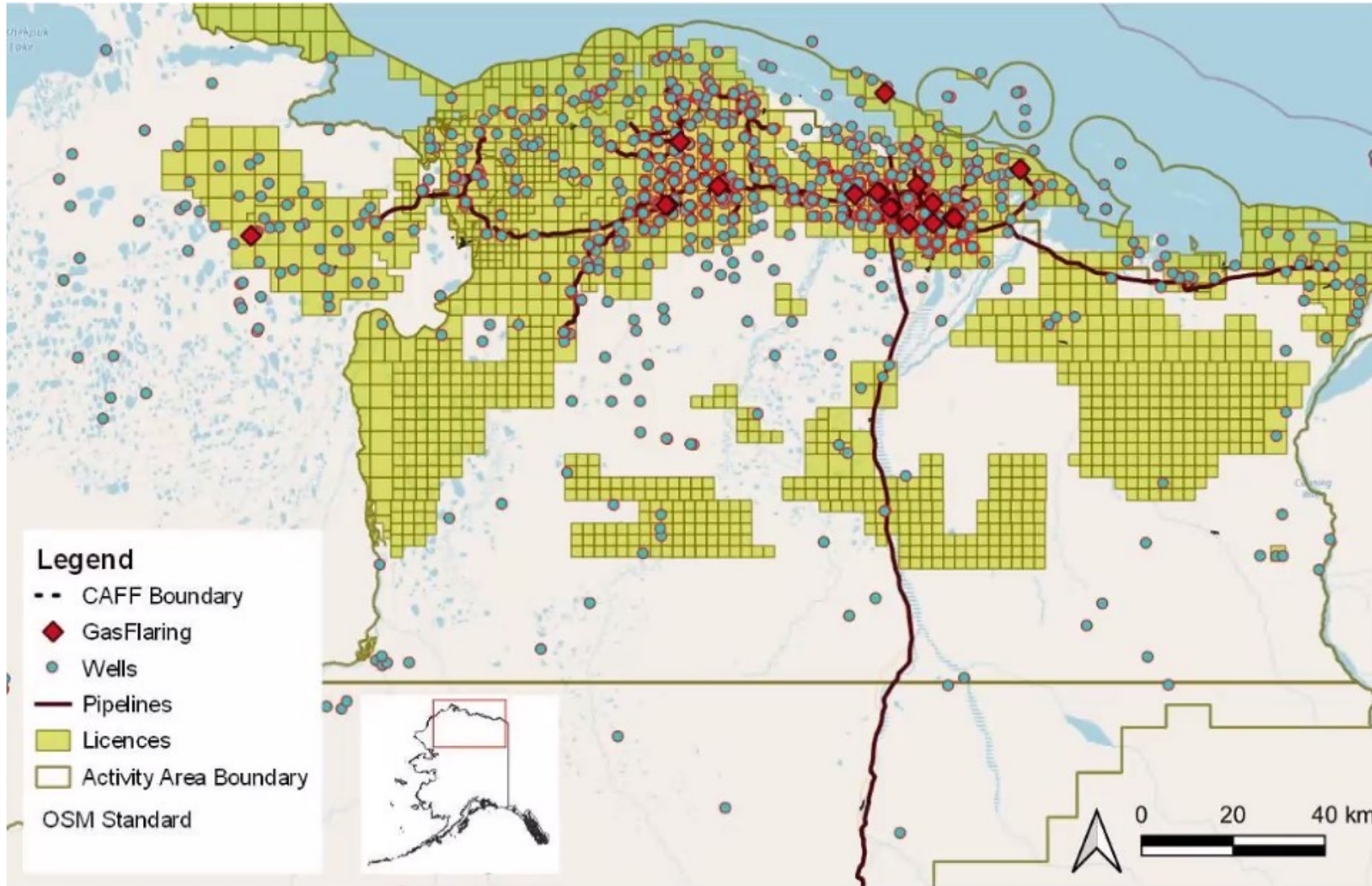
Hydrocarbon extraction in the Arctic: Geographical criteria towards a Multi- Criteria Analysis for identifying unburnable carbon areas

(In submission

Codato D., Vezzelli D., F. Ammaturo, G.
Lazazzera, A. Stralla, Pappalardo SE, De
Marchi M.)



Produzione di energia fossile nella regione artica



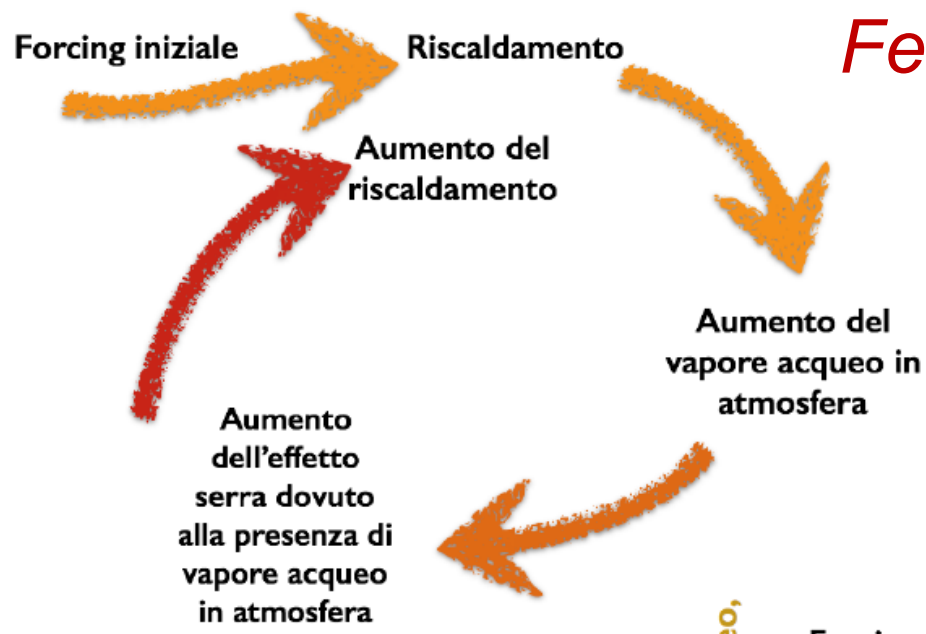
(F. Ammataro, G. Lazazzera, A. Stralla, Master GIScience 2021)

Feedback loops: il vapore acqueo

Positivo

Vapore Acqueo,
gas serra

Feedback Positivo



Positivo

Vapore Acqueo,
gas serra

Feedback Positivo



(Bagliani, 2019)

Feedback loops: il vapore acqueo

Il vapore acqueo è responsabile per circa il 75% dell'effetto serra:

- 50% direttamente
- 25% indirettamente, tramite l'effetto sulle nubi

Il vapore acqueo è un gas serra che **condensa** in atmosfera.

Le **concentrazioni** atmosferiche di vapore acqueo non dipendono tanto dalle emissioni quanto dalla **temperatura media** dell'atmosfera.

L'effetto serra esercitato dal vapore acqueo non viene pertanto considerato come forzante ma come retroazione, a partire da un forzante iniziale degli altri gas serra, che cambia la temperatura media atmosferica.

(Bagliani, 2019)

REPORT

Atmospheric CO₂: Principal Control Knob Governing Earth's Temperature

ANDREW A. LACIS, GAVIN A. SCHMIDT, DAVID RIND, AND , RETO A. RUEDY [Authors Info & Affiliations](#)

SCIENCE · 15 Oct 2010 · Vol 330, Issue 6002 · pp. 356-359 · DOI:10.1126/science.1190653

346 278



GET ACCESS

Turning Up the Heat

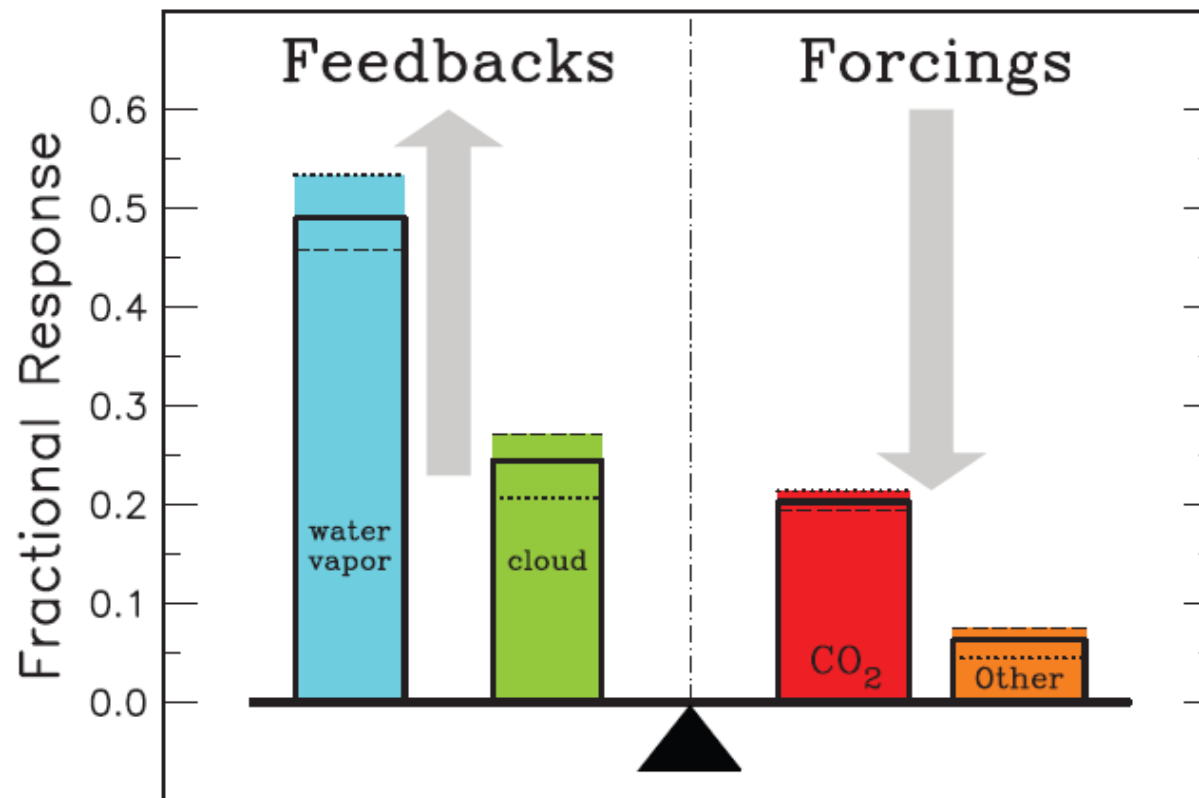
The physical effect of atmospheric carbon dioxide on Earth's energy budget—that is, its “greenhouse effect”—has been understood for more than 100 years, but its role in climate warming is still not universally accepted. **Lacis *et al.*** (p. 356) conducted a set of idealized climate model experiments in which various greenhouse gases were added to or subtracted from the atmosphere in order to illustrate their roles in controlling the temperature of the air. The findings clearly show that carbon dioxide exerts the most control on Earth's climate, and that its abundance determines how much water vapor the atmosphere contains, even though the radiative effect of the water vapor is greater than that of carbon dioxide itself.

Abstract

Ample physical evidence shows that carbon dioxide (CO₂) is the single most important climate-relevant greenhouse gas in Earth's atmosphere. This is because CO₂, like ozone, N₂O, CH₄, and chlorofluorocarbons, does not condense and precipitate from the atmosphere at current climate temperatures, whereas water vapor can and does. Noncondensing greenhouse gases, which account for 25% of the total terrestrial greenhouse effect, thus serve to provide the stable temperature structure that sustains the current levels of atmospheric water vapor and clouds via feedback processes that account for the remaining 75% of the greenhouse effect. Without the radiative forcing supplied by CO₂ and the other noncondensing greenhouse gases, the terrestrial greenhouse would collapse, plunging the global climate into an icebound Earth state.

Science

Total GHG effect



(Lacis et al 2010)

<https://www.science.org/doi/abs/10.1126/science.1190653>

Feedback loops delle nubi (+ o -)

- I **cirri** (alta troposfera, 8.000 e i 12.000 m) e sono composte da **crystalli di ghiaccio**; essendo trasparenti lasciano passare la radiazione solare incidente, mentre ne bloccano la radiazione terrestre di ritorno ad onda lunga. Questo tipo di nubi **incrementa l'effetto serra** producendo un riscaldamento della superficie terrestre (**feedback positivo**)
- Gli **stratocumoli**, essendo nuvole più spesse e avendo **un albedo maggiore** rispetto alle nuvole alte come i cirri, riflettono maggiormente la luce solare nello spazio e, diminuendo la quantità di raggi solari che raggiungono la superficie terrestre, **tendono a raffreddare la Terra**
- **Nubi alte (cirri) agiscono da feedback positivo** aumentando la temperatura terrestre
- **Quelle basse (stratocumuli) fungono da feedback negativo** riflettendo la radiazione solare e diminuendo quindi la temperatura

https://www.weather.gov/lmk/cloud_classification

<https://www.metoffice.gov.uk/weather/learn-about/weather/types-of-weather/clouds/cloud-names-classifications>

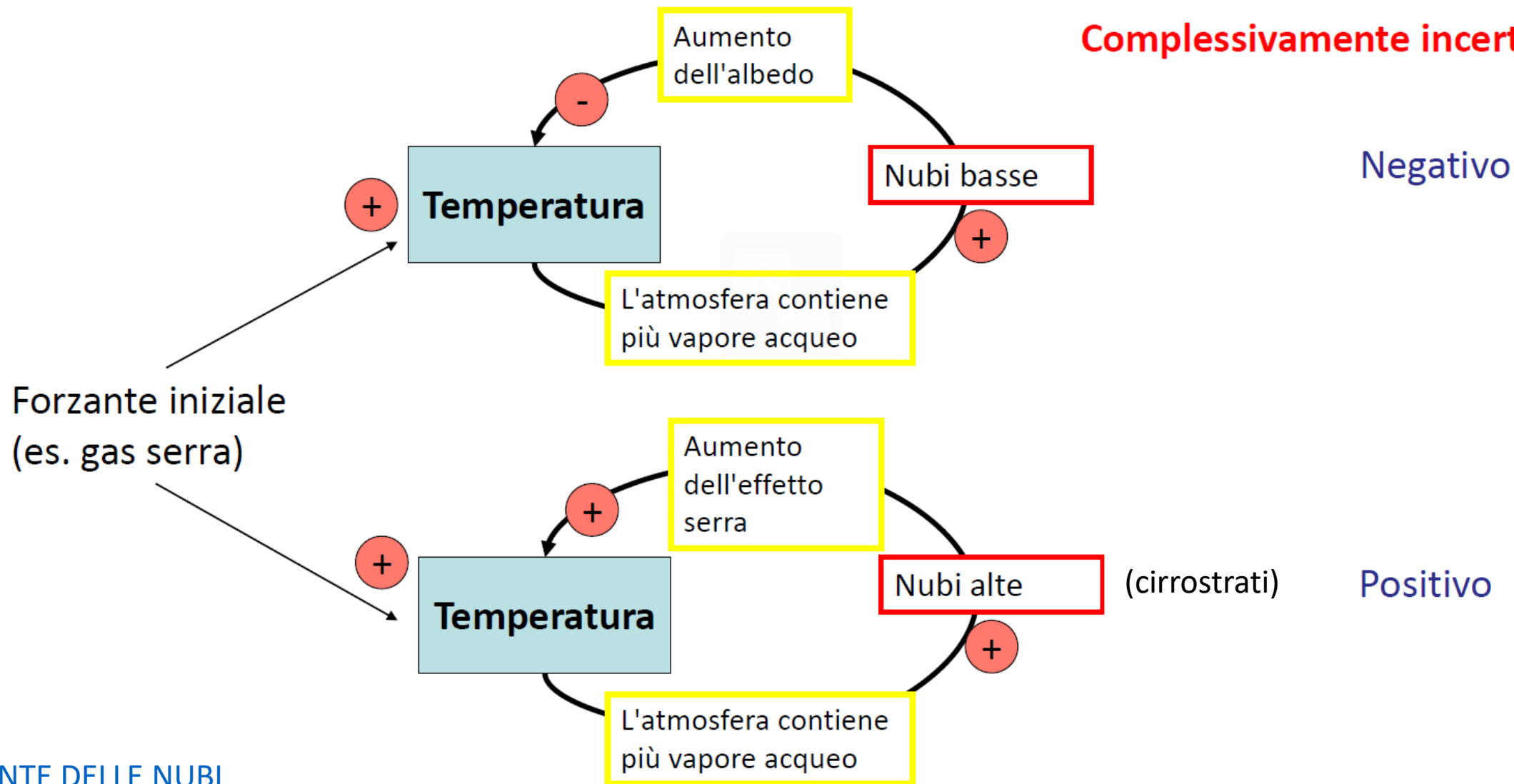
<https://www.astrogeo.va.it/nuvole2/classificazione.htm>

(Bagliani, 2019)

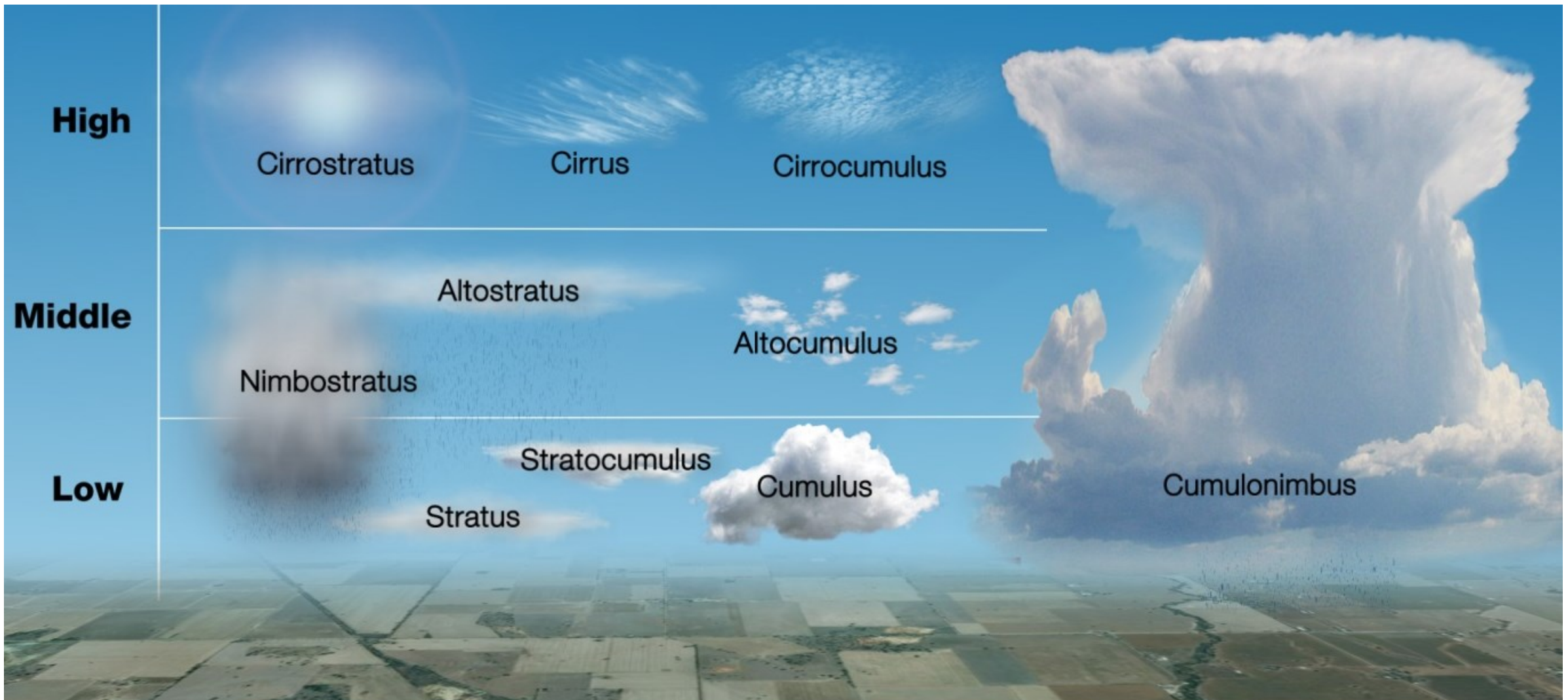
[ATLANTE DELLE NUBI](#)

Feedback loops delle nubi

Complessivamente incerto!



Feedback loops delle nubi (+ o -)

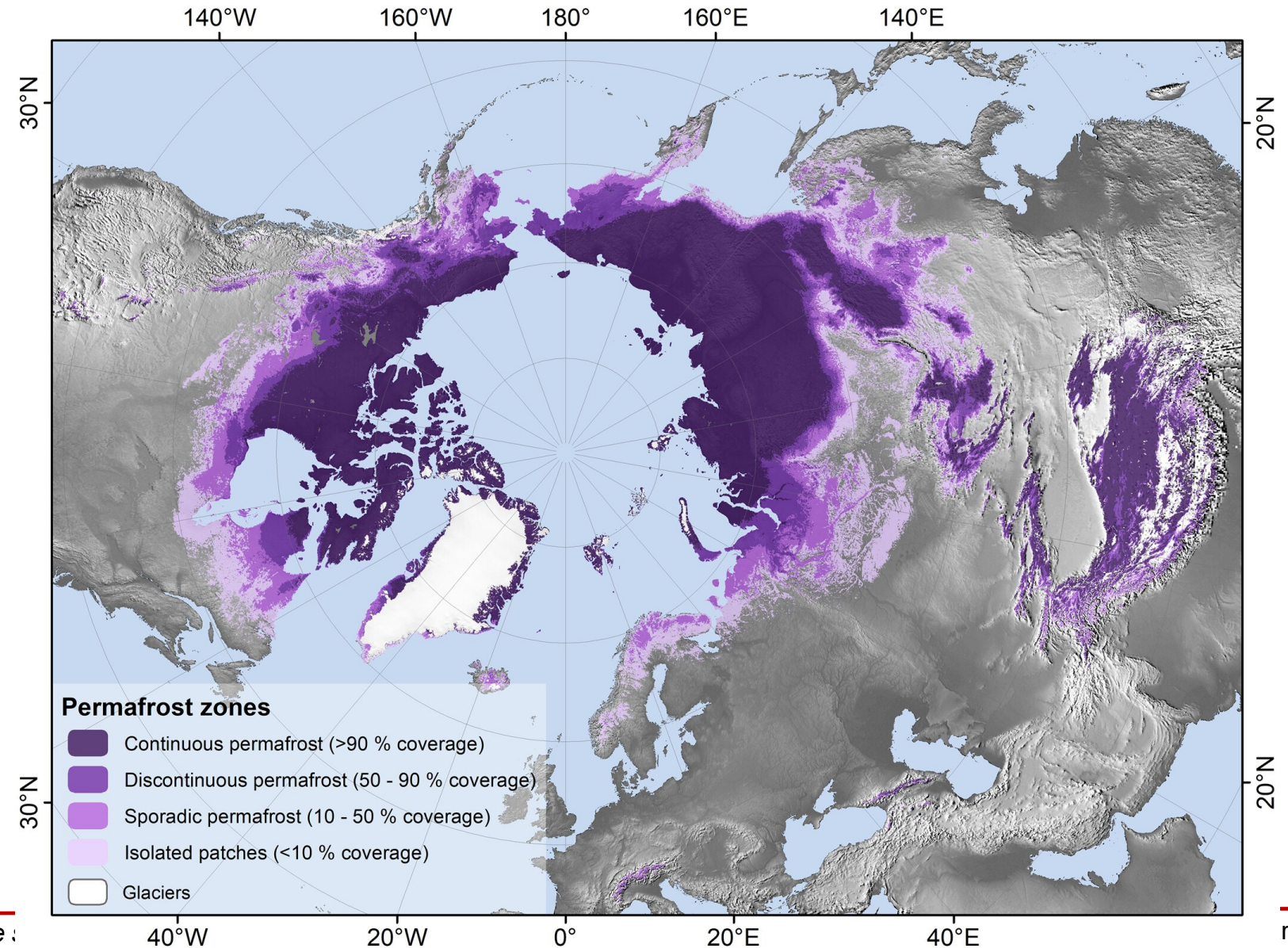


<https://media.bom.gov.au/social/blog/895/whats-that-cloud/>

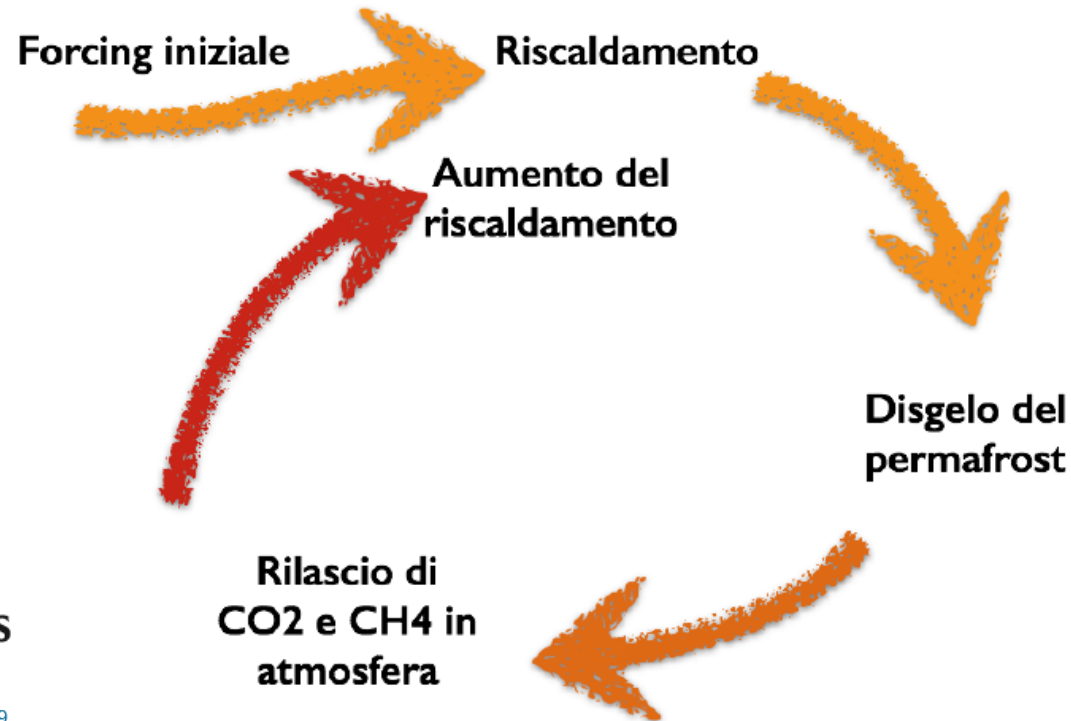
Feedback loop (+) metano-permafrost

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<https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2021JF006123>



Feedback loop (+) metano-permafrost



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<https://e360.yale.edu/features/how-melting-permafrost-is-beginning-to-transform-the-arctic>