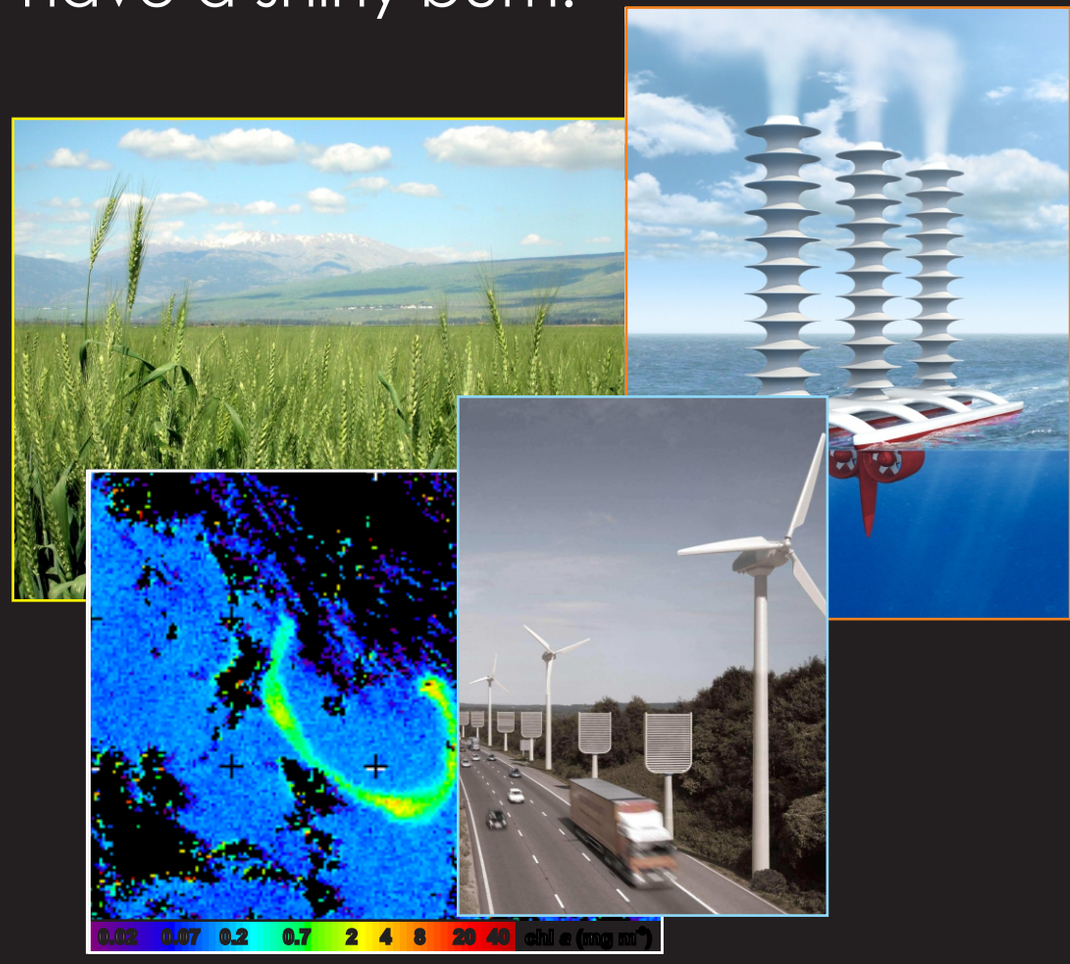
Earth 2.0

Or:

If you are going to stick your head in the sand and not reduce personal emissions, you'd better have a shiny bum.

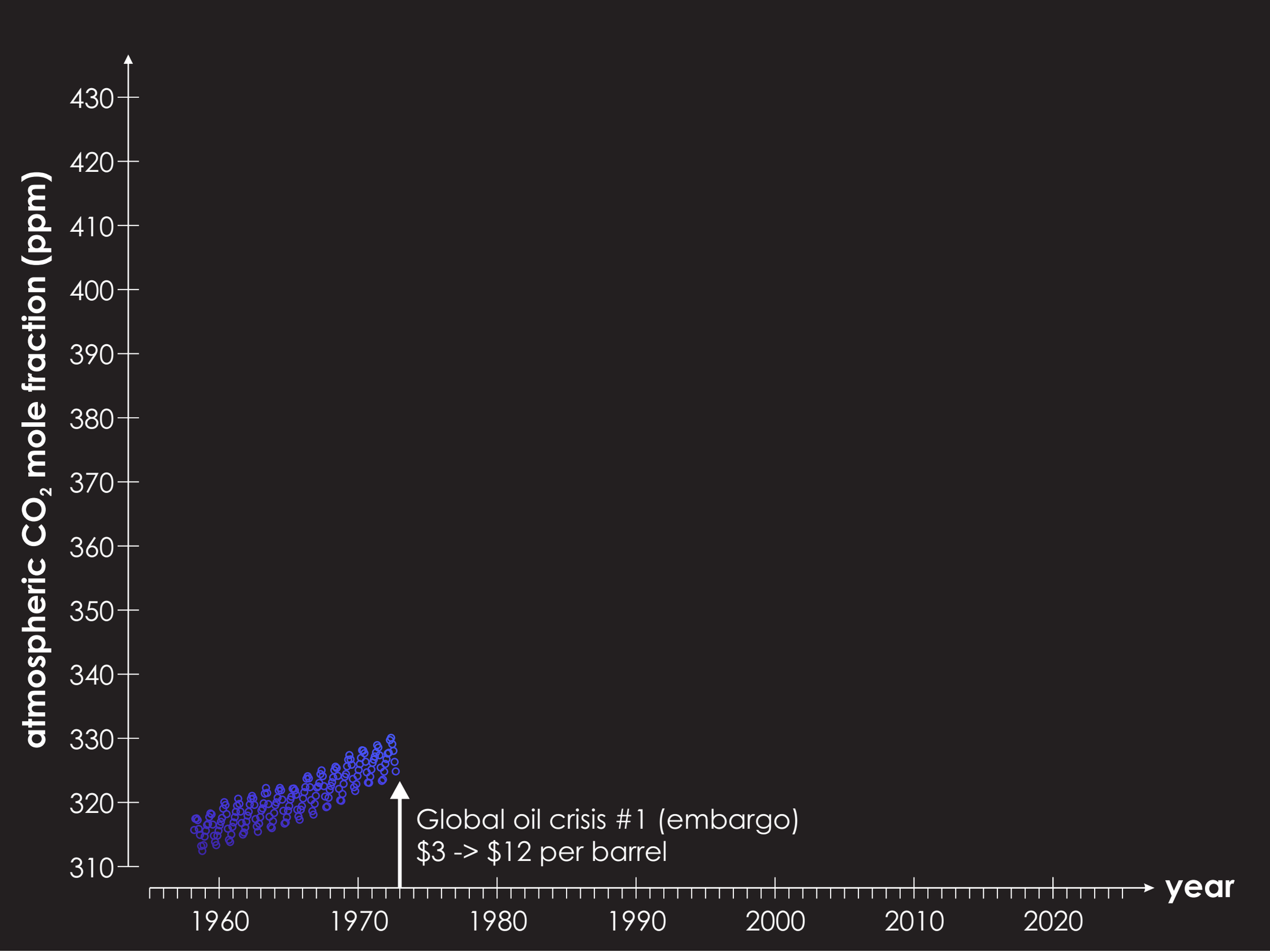
Andy Ridgwell

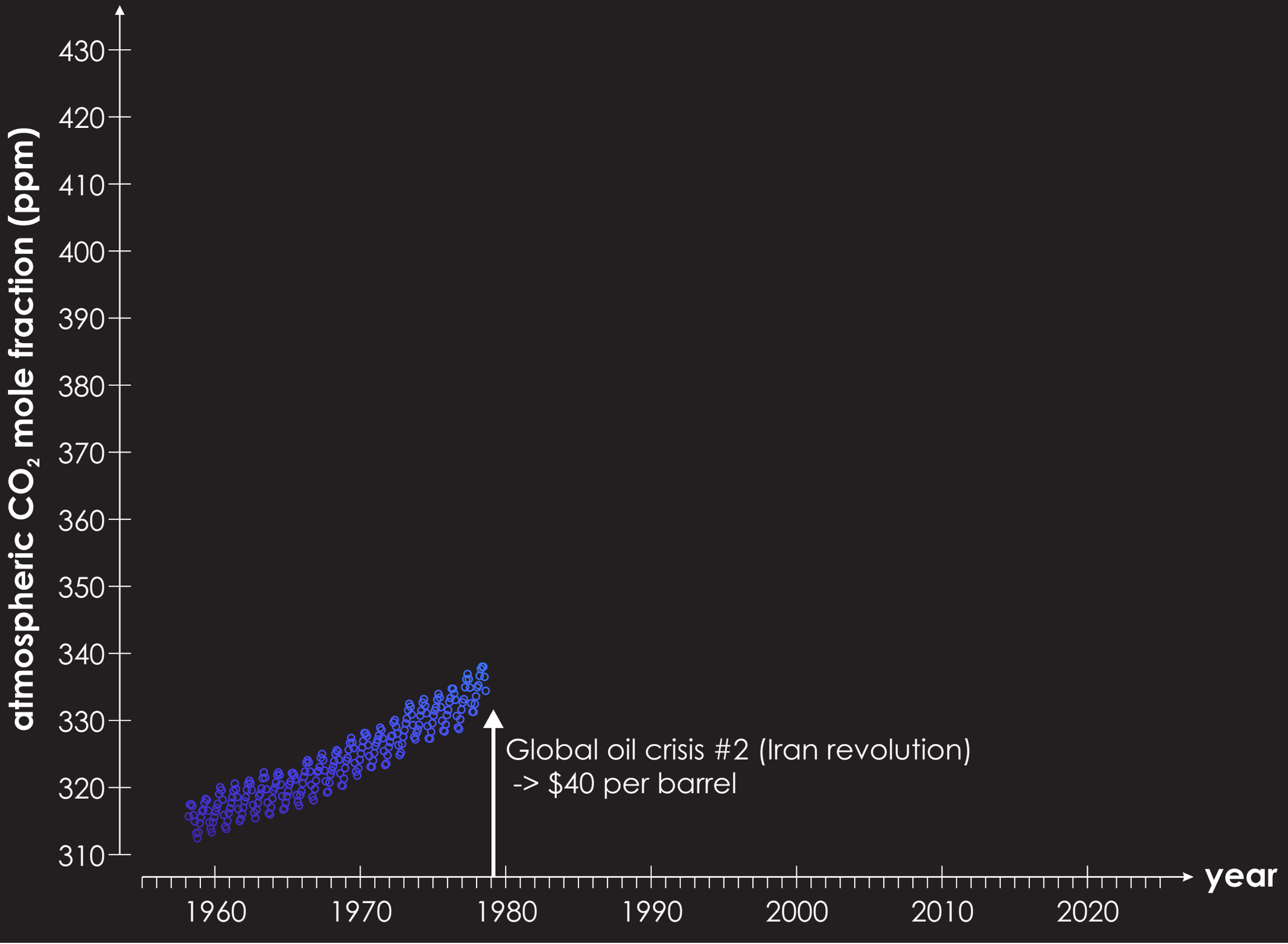


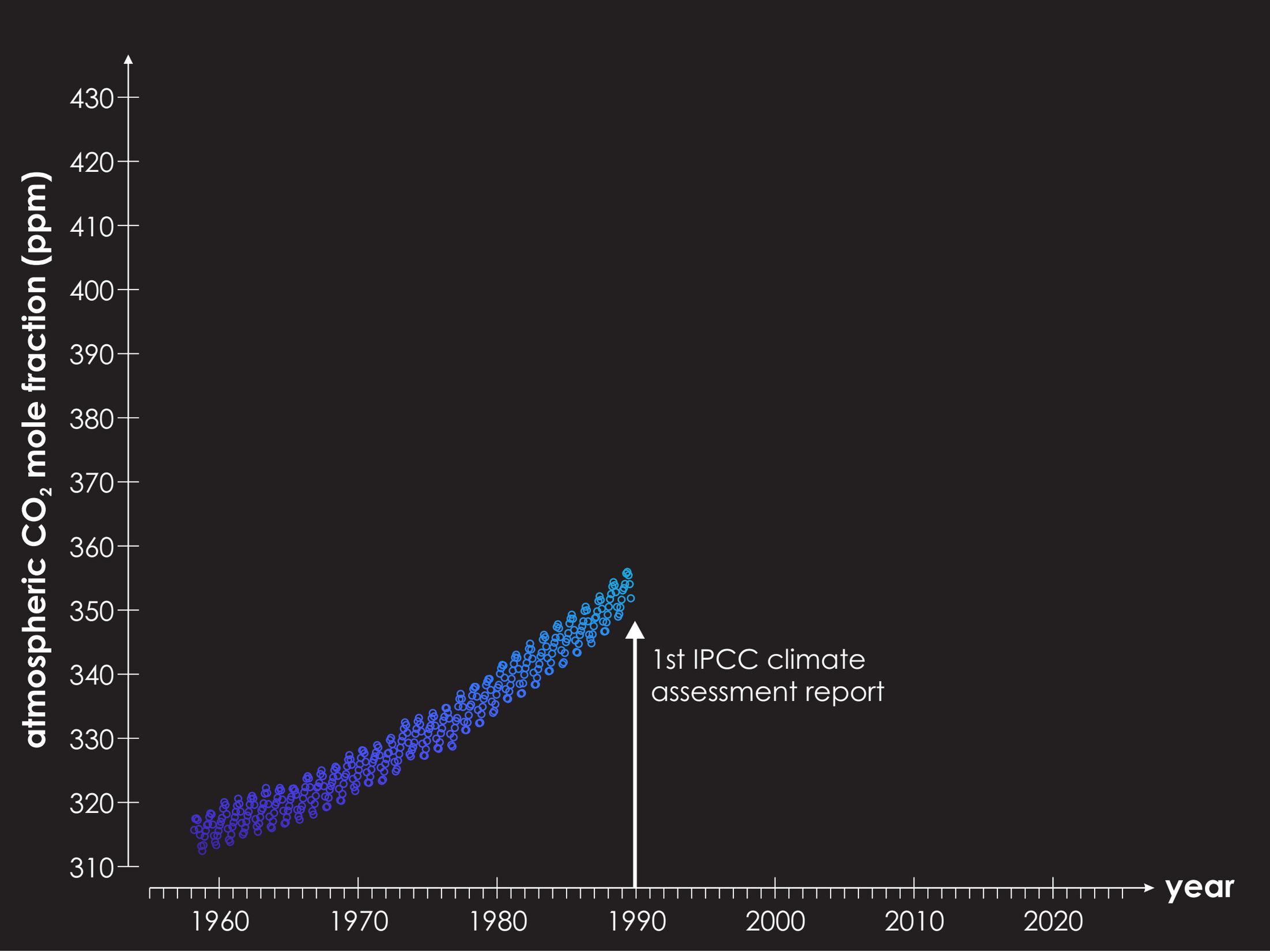
UCR

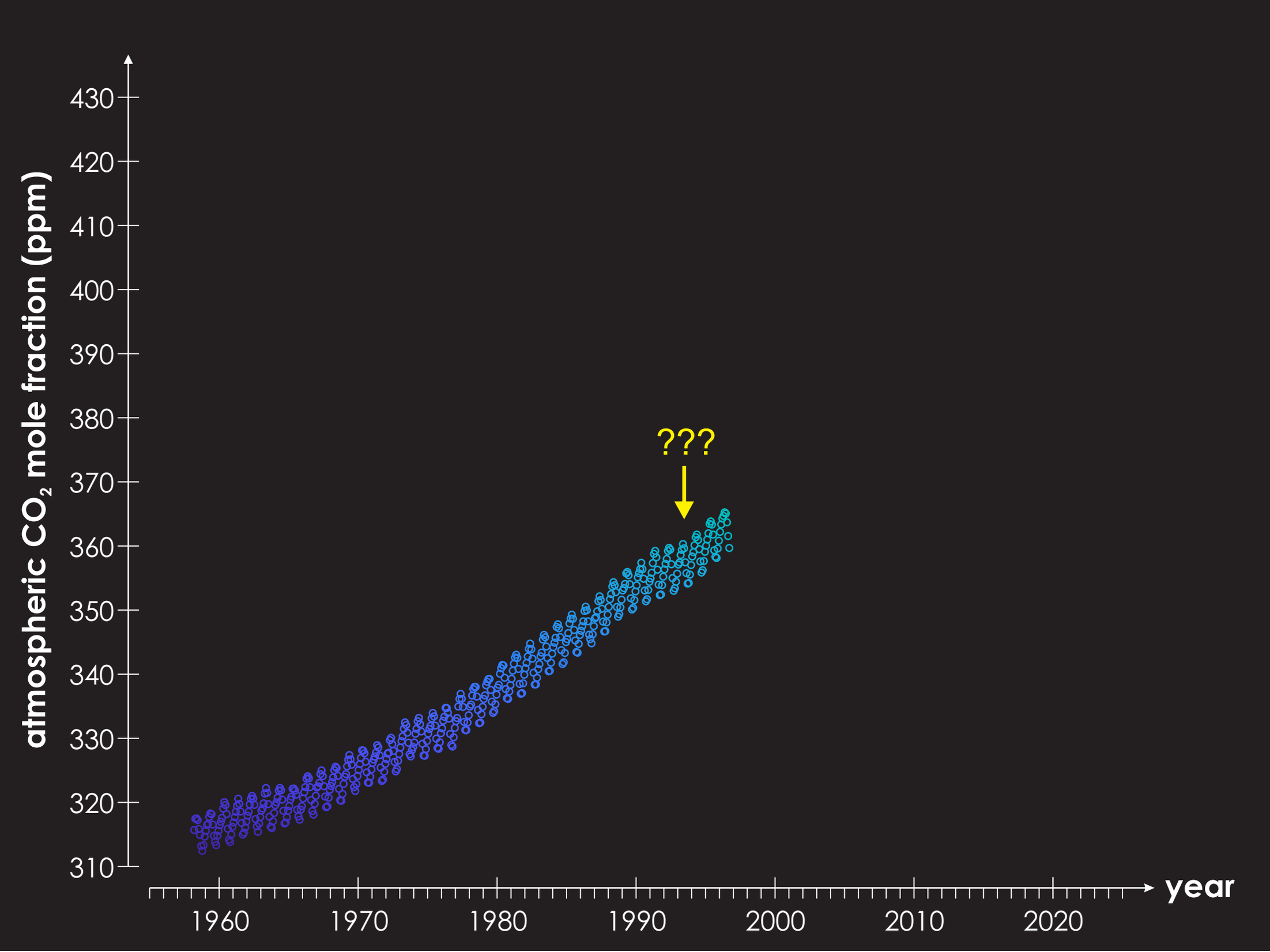
VARIOUSLY: SeaWiFS data provided by NASA DAAC/GSFC (copyright of Orbital Imaging Corps and the NASA SeaWiFS project) and processed at CCMS-PML. Institution of Mechanical Engineers [2009]. John MacNeill, www.johnmacneill.com [2009].

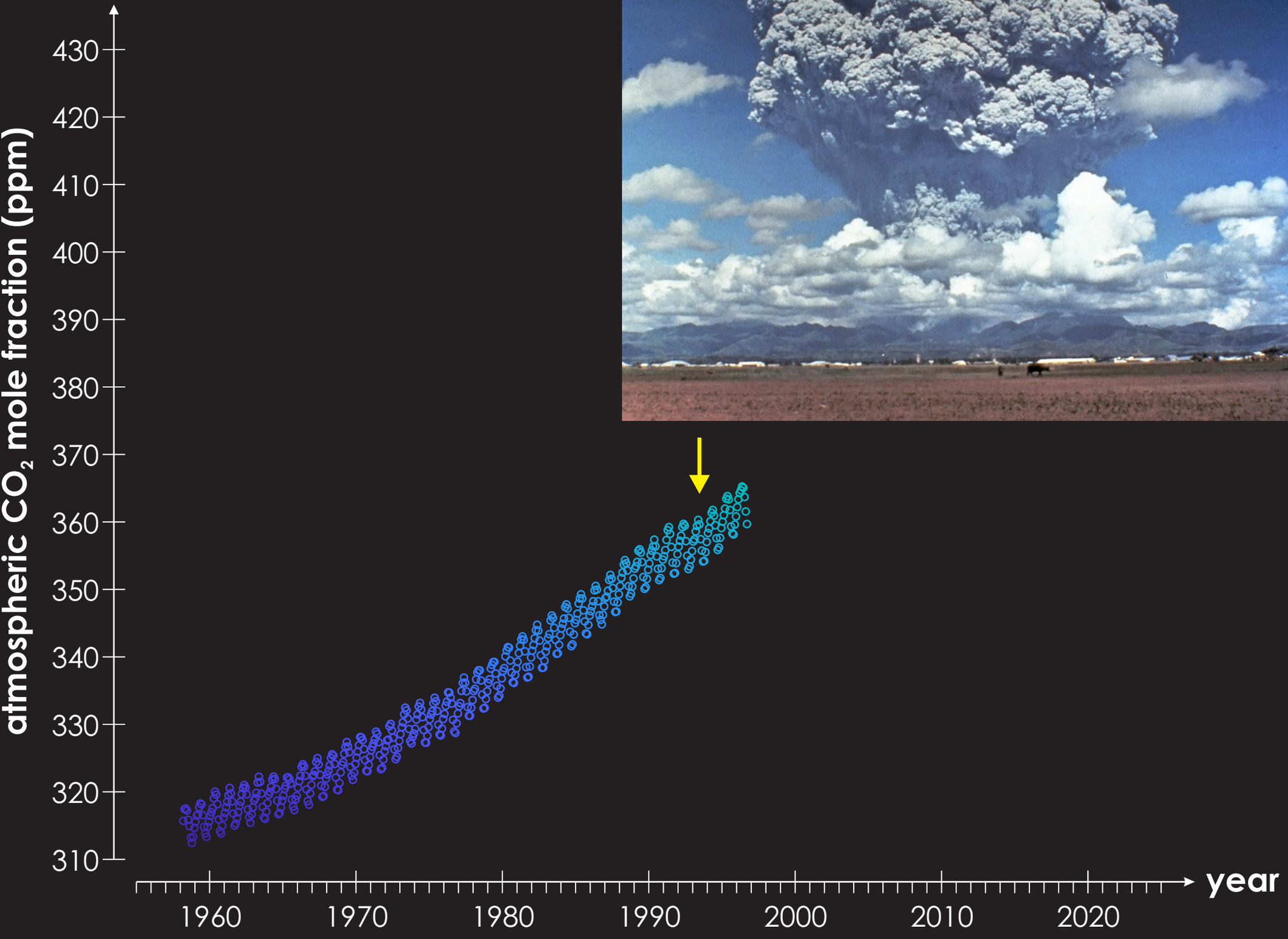
'What happened next?'

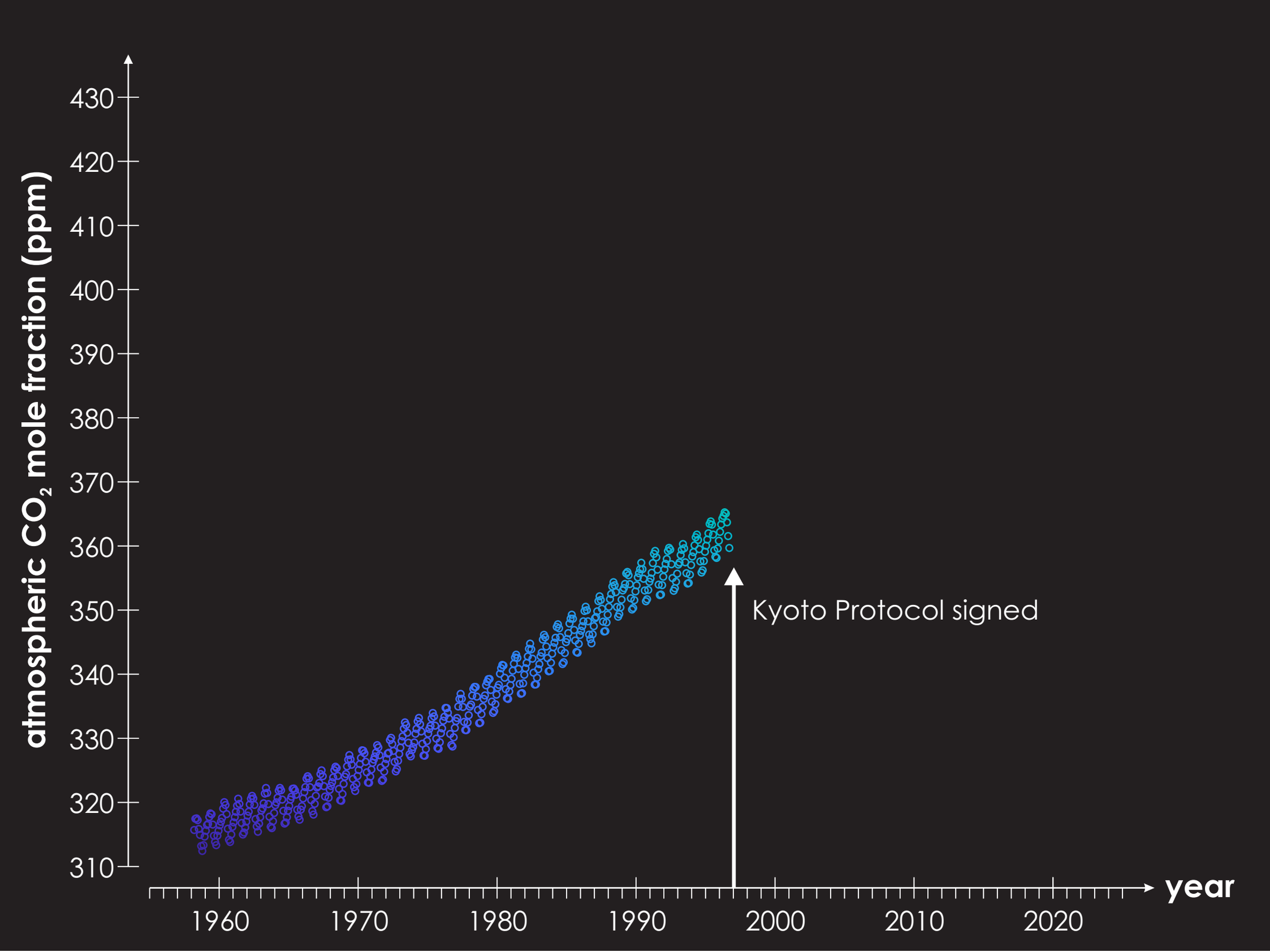

atmospheric CO_2 mole fraction (ppm)
430
420
410
400
390
380
370
360
350
340
330
320
310
Global oil crisis #1 (embargo)
$3 -> $12 per barrel
year
1960
1970
1980
1990
2000
2010
2020

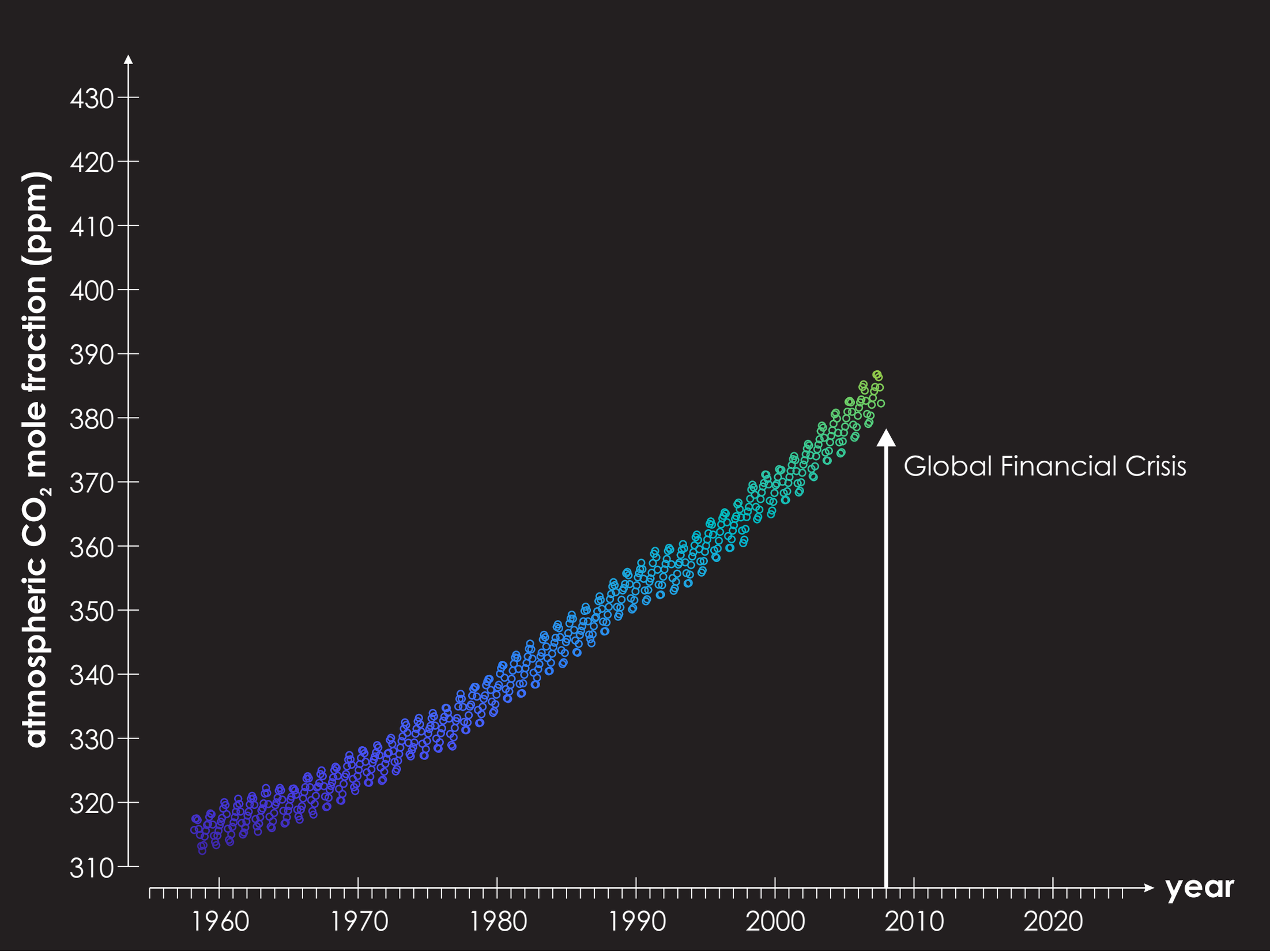

atmospheric CO_2 mole fraction (ppm)
430
420
410
400
390
380
370
360
350
340
330
320
310
Global oil crisis #2 (Iran revolution)
-> $40 per barrel
year
1960
1970
1980
1990
2000
2010
2020

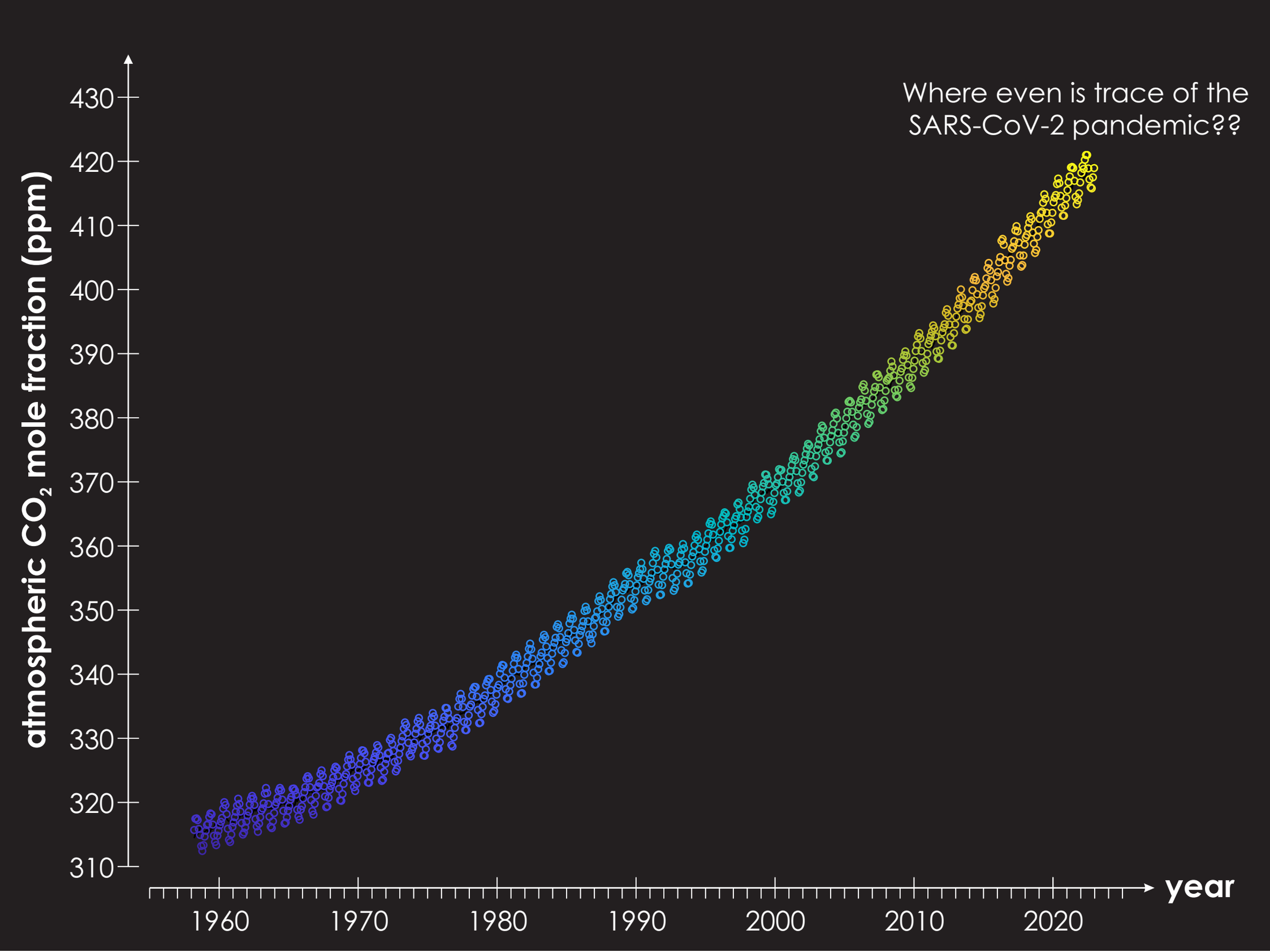

atmospheric CO_2 mole fraction (ppm)
430
420
410
400
390
380
370
360
350
340
330
320
310
1st IPCC climate assessment report
year
1960
1970
1980
1990
2000
2010
2020

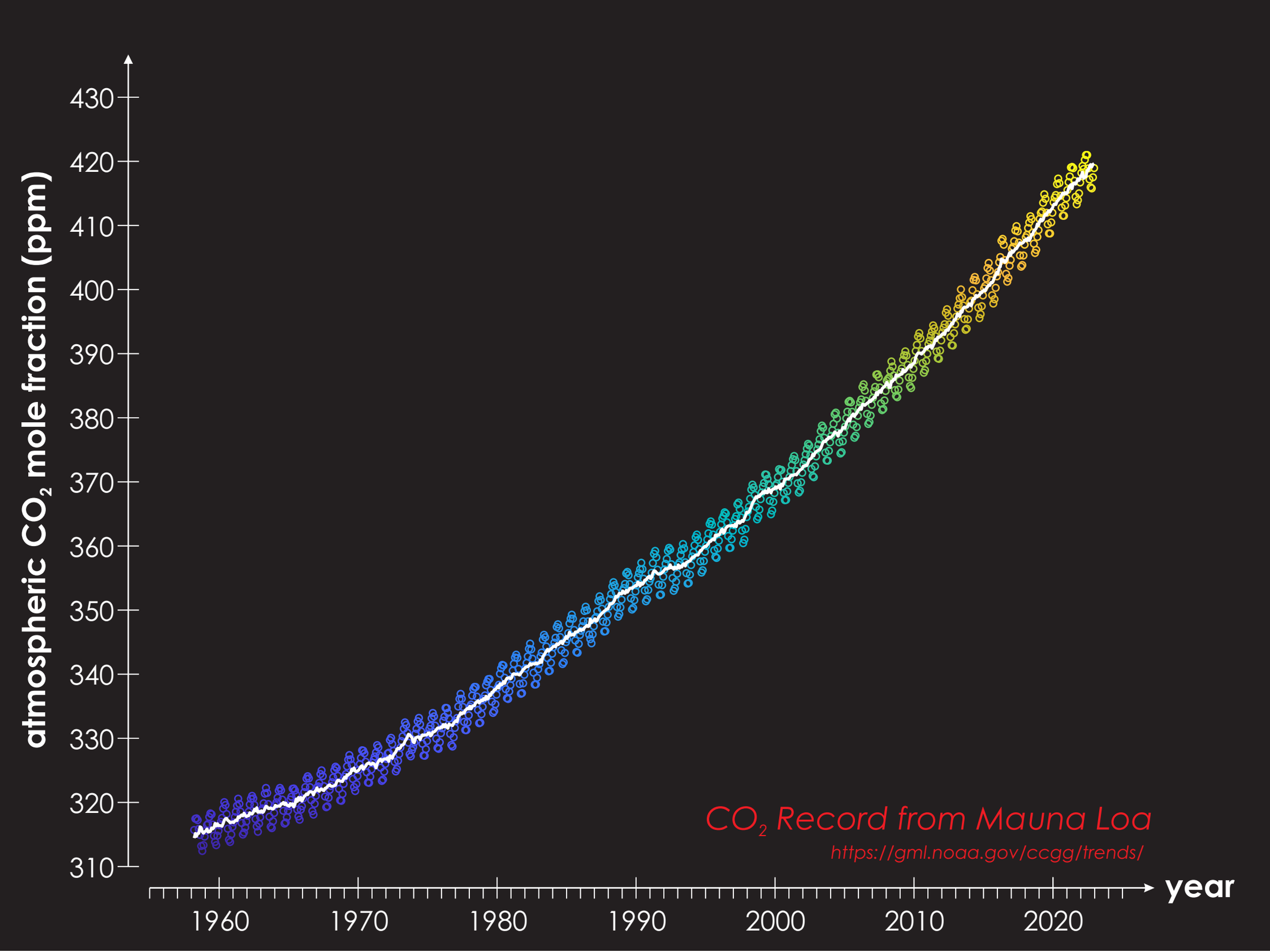

atmospheric CO_2 mole fraction (ppm)
430
420
410
400
390
380
370
360
350
340
330
320
310
???
year
1960
1970
1980
1990
2000
2010
2020


atmospheric CO_2 mole fraction (ppm)
430
420
410
400
390
380
370
360
350
340
330
320
310
year
1960
1970
1980
1990
2000
2010
2020


atmospheric CO_2 mole fraction (ppm)
430
420
410
400
390
380
370
360
350
340
330
320
310
Kyoto Protocol signed
year
1960
1970
1980
1990
2000
2010
2020

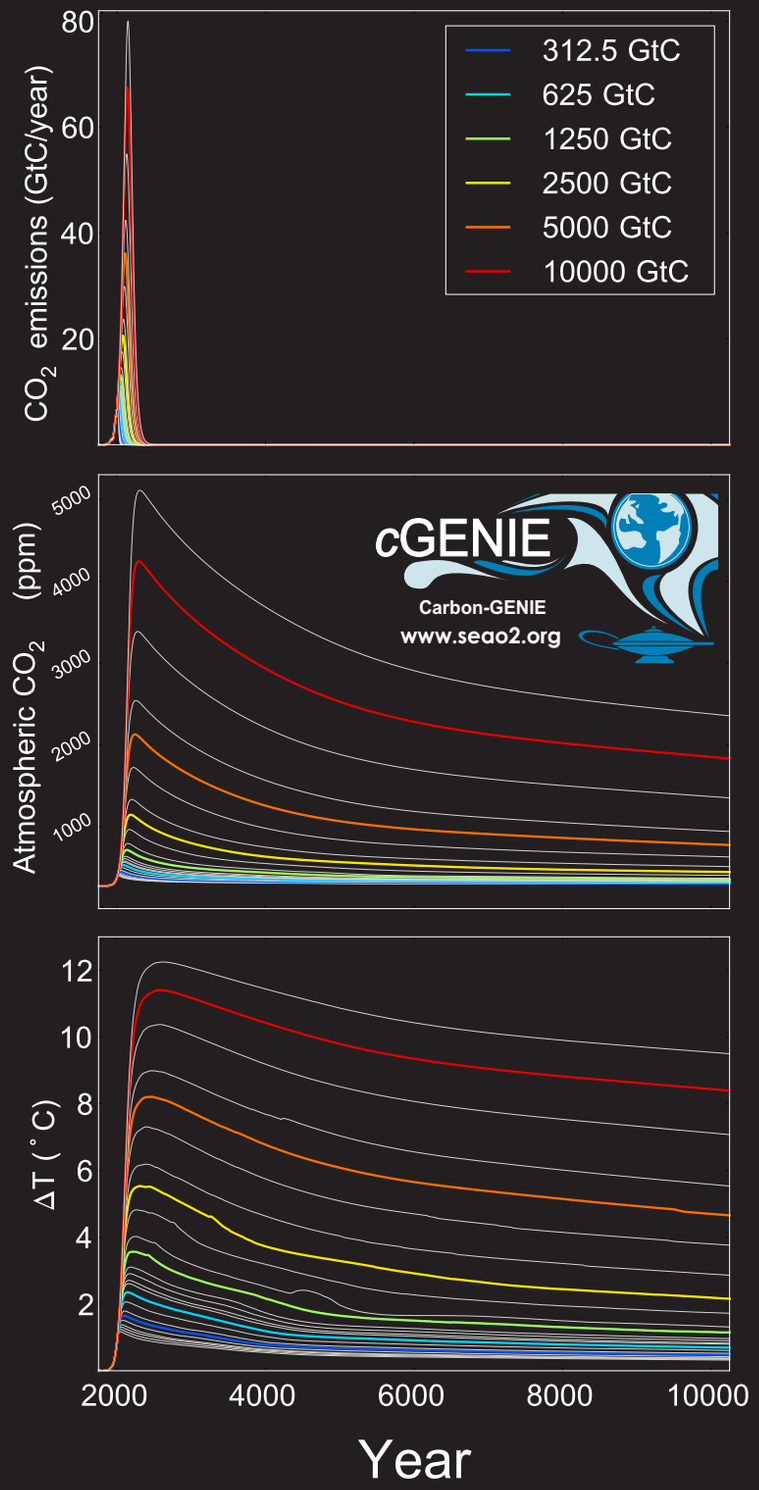

atmospheric CO_2 mole fraction (ppm)
430
420
410
400
390
380
370
360
350
340
330
320
310
Global Financial Crisis
year
1960
1970
1980
1990
2000
2010
2020


Where even is trace of the
SARS-CoV-2 pandemic??
atmospheric CO_2 mole fraction (ppm)
430
420
410
400
390
380
370
360
350
340
330
320
310
year
1960
1970
1980
1990
2000
2010
2020


atmospheric CO_2 mole fraction (ppm)
430
420
410
400
390
380
370
360
350
340
330
320
310
1960
1970
1980
1990
2000
2010
2020
year
CO_2 Record from Mauna Loa
https://gml.noaa.gov/ccgg/trends/

‘Melting Antarctica’

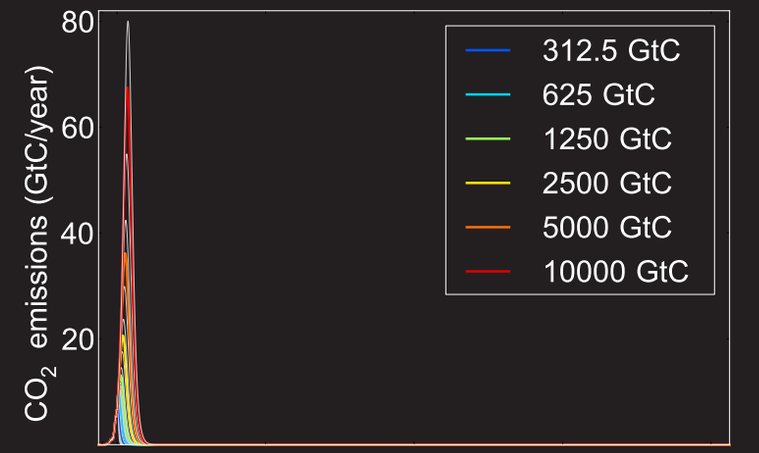
EDGE.2023

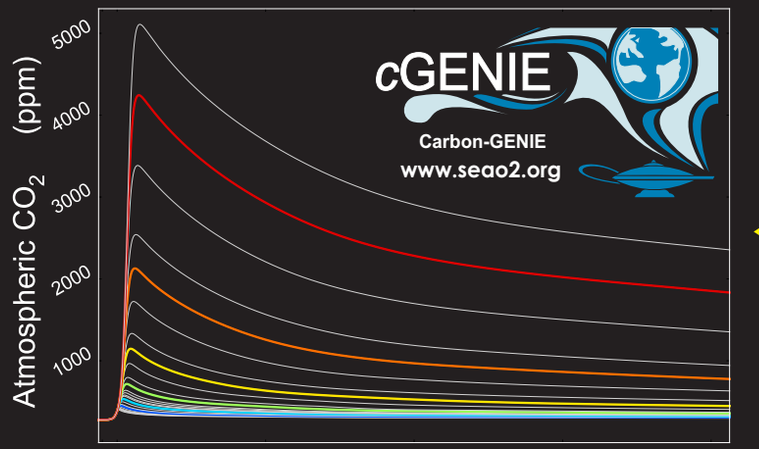


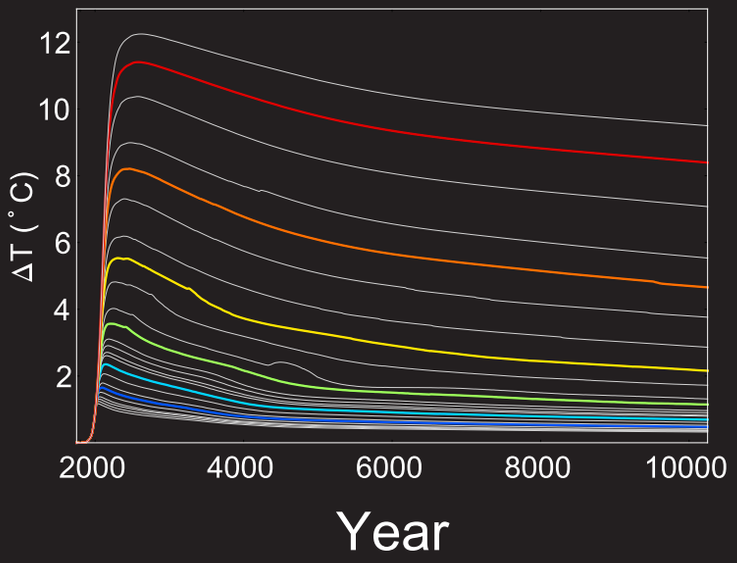
Winkelmann, R., A. Levermann, A. Ridgwell, and K. Caldeira, Combustion of available fossil-fuel resources sufficient to eliminate the Antarctic Ice Sheet, Science Advances, DOI: 10.1126/sciadv.1500589 (2015).

‘Melting Antarctica’

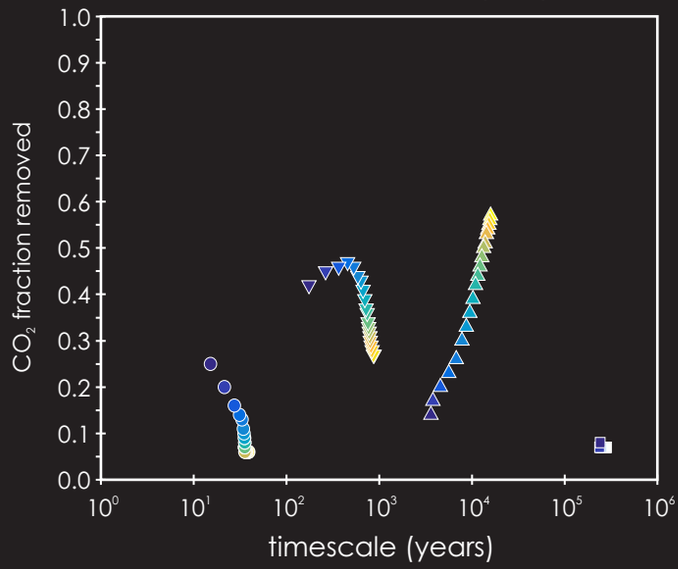
EDGE.2023





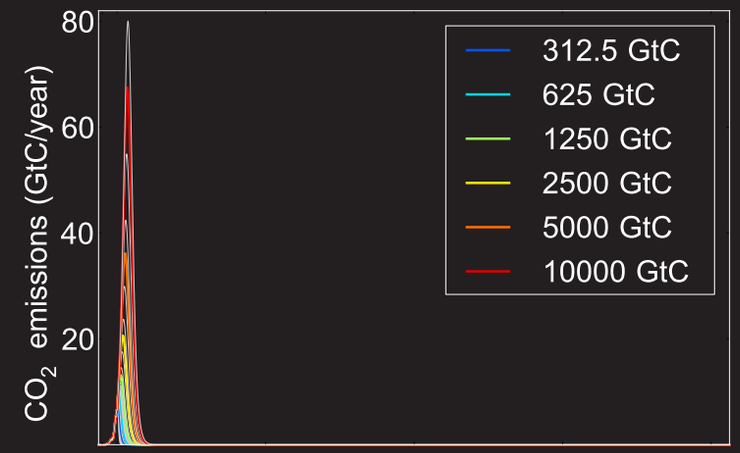


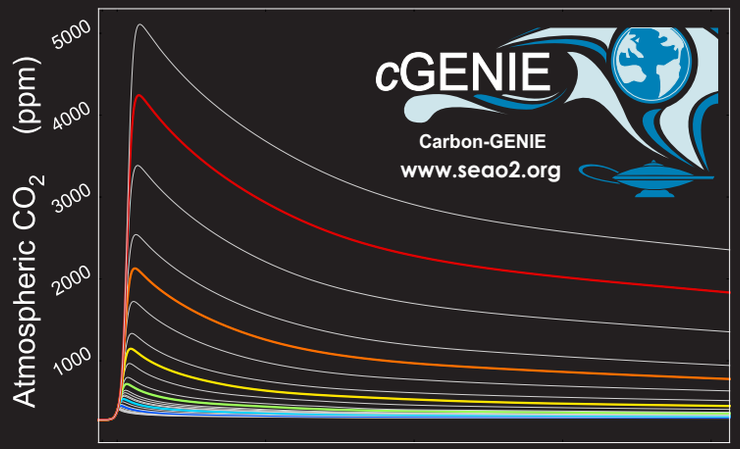
Lord, N.S., A. Ridgwell, M.C. Thorne, and D.J. Lunt, An impulse response function for the ‘long tail’ of excess atmospheric CO2 in an Earth system model, GBC DOI: 10.1002/2014GB005074 (2015).

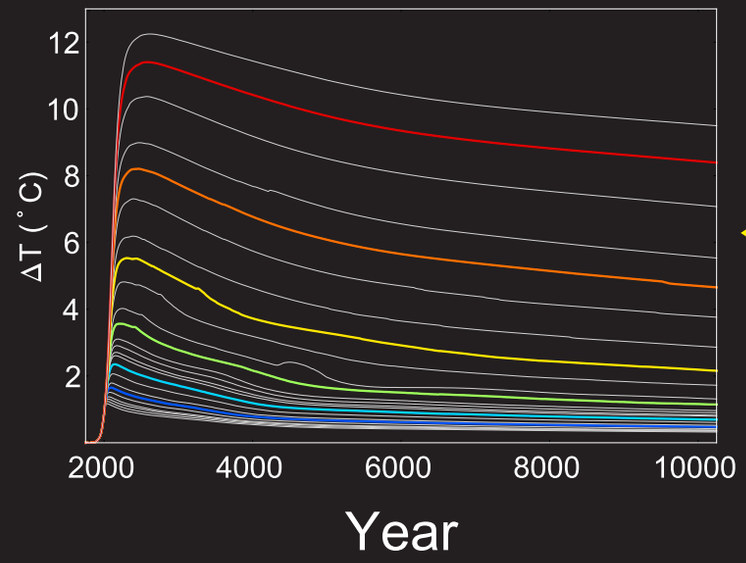


'Melting Antarctica'

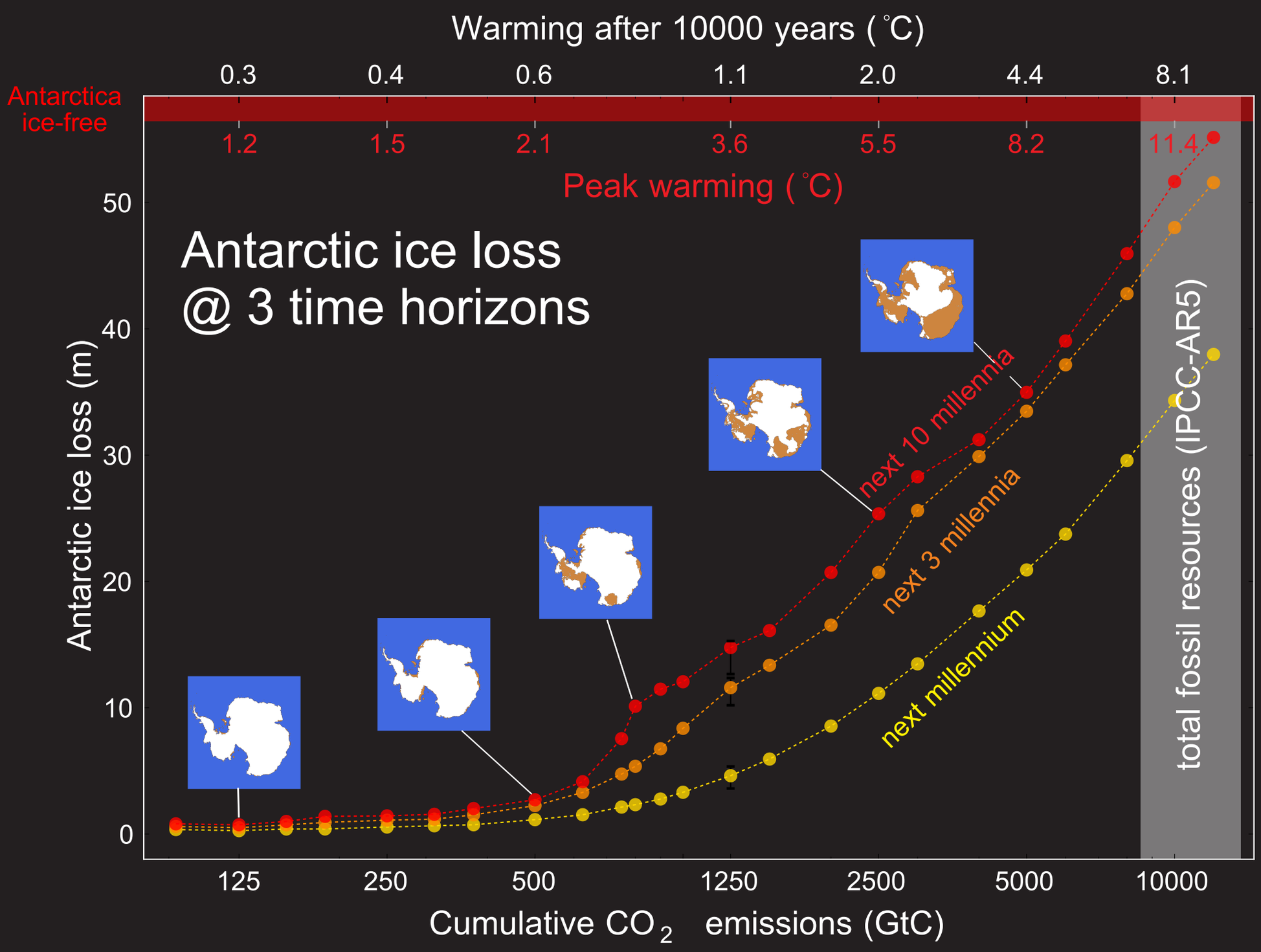
EDGE.2023

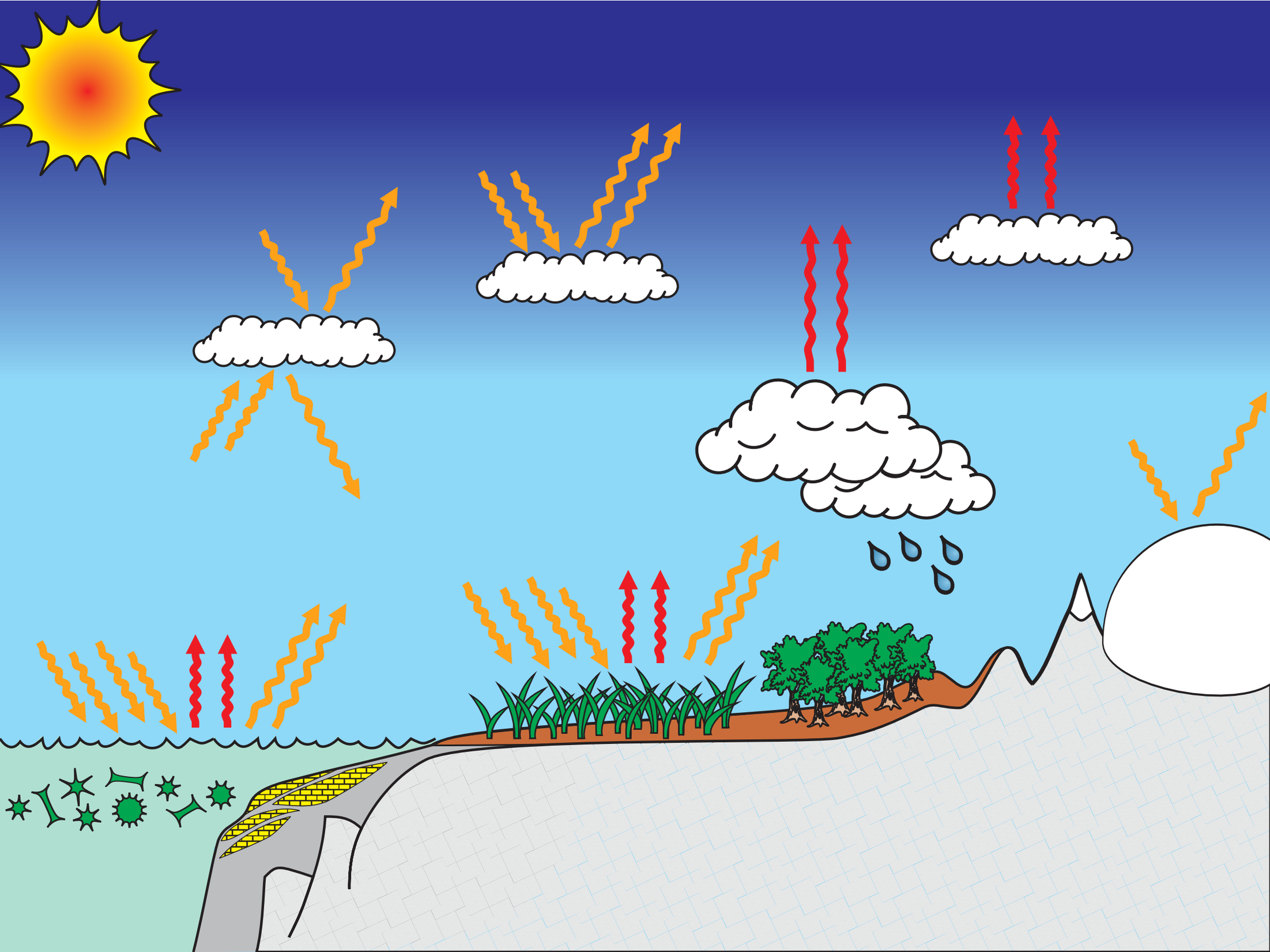


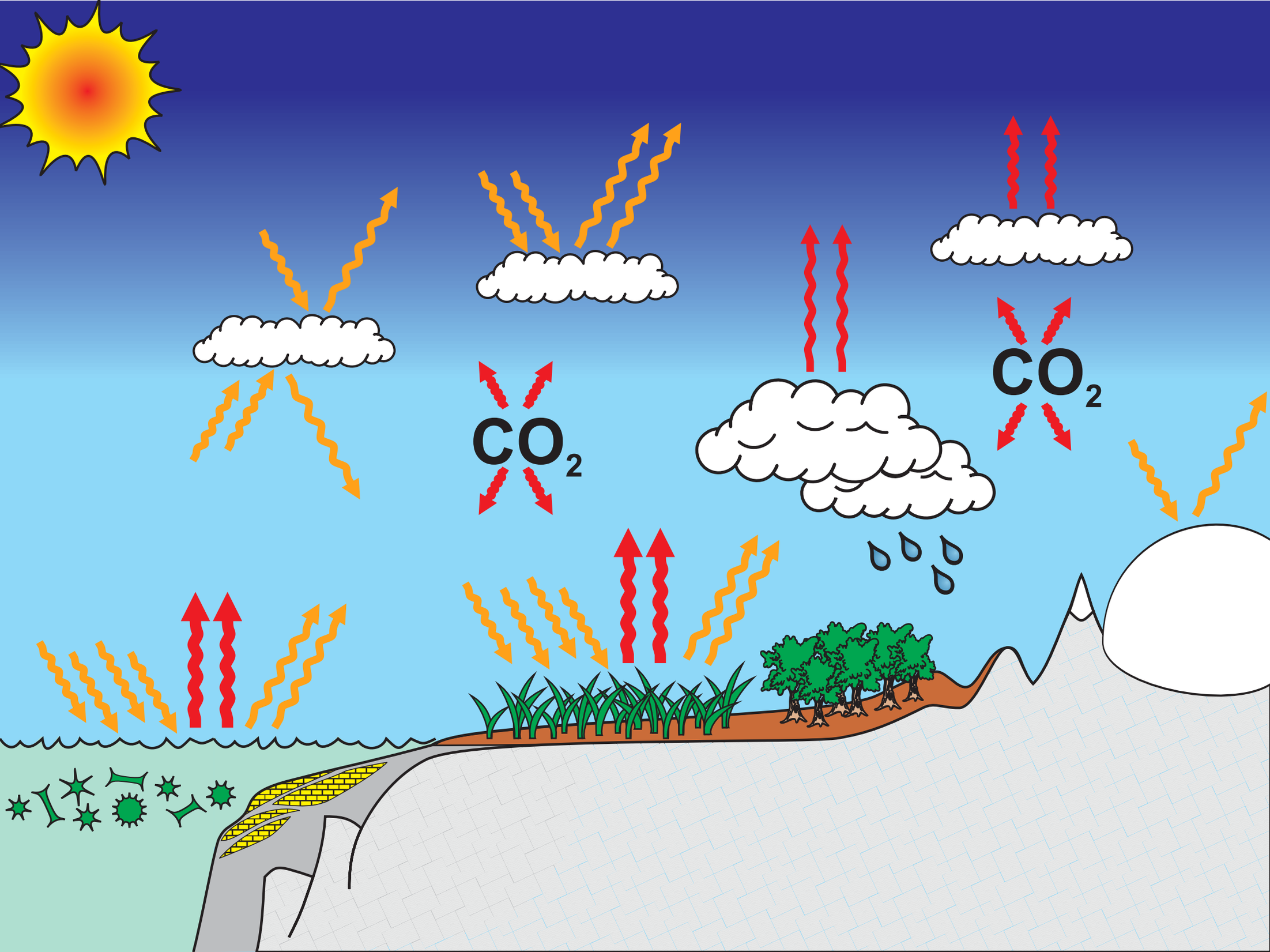




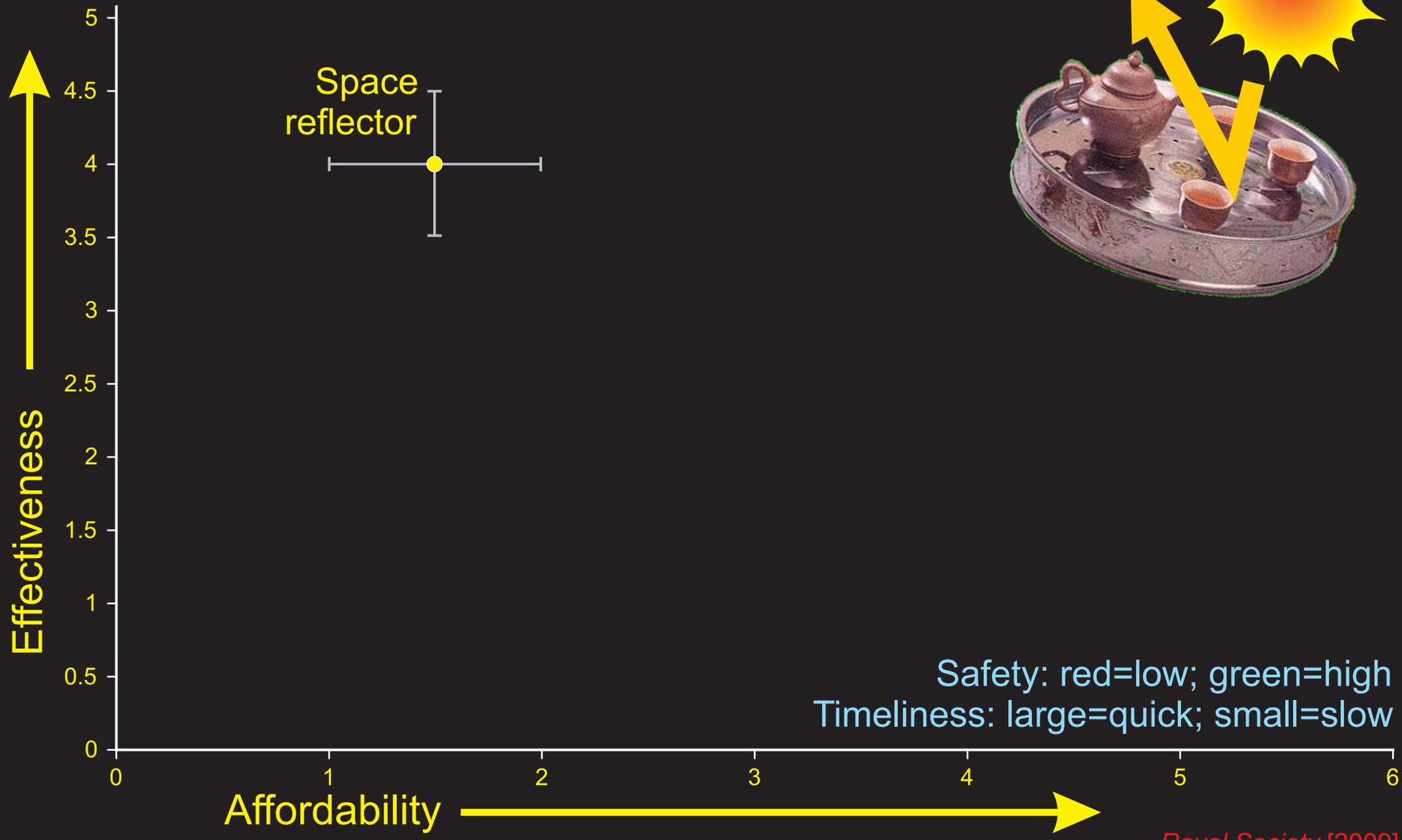
$\longleftrightarrow \Delta F \propto \ln(C/C_o)$


Warming after 10000 years (˚C)
0.3
0.4
0.6
1.1
2.0
4.4
8.1
Antarctica ice-free
1.2
1.5
2.1
3.6
5.5
8.2
11.4
Peak warming (˚C)
Antarctic ice loss @ 3 time horizons
Antarctic ice loss (m)
0
10
20
30
40
50
next 10 millennia
next 3 millennia
next millennium
total fossil resources (IPCC-AR5)
125
250
500
1250
2500
5000
10000
Cumulative CO2 emissions (GtC)

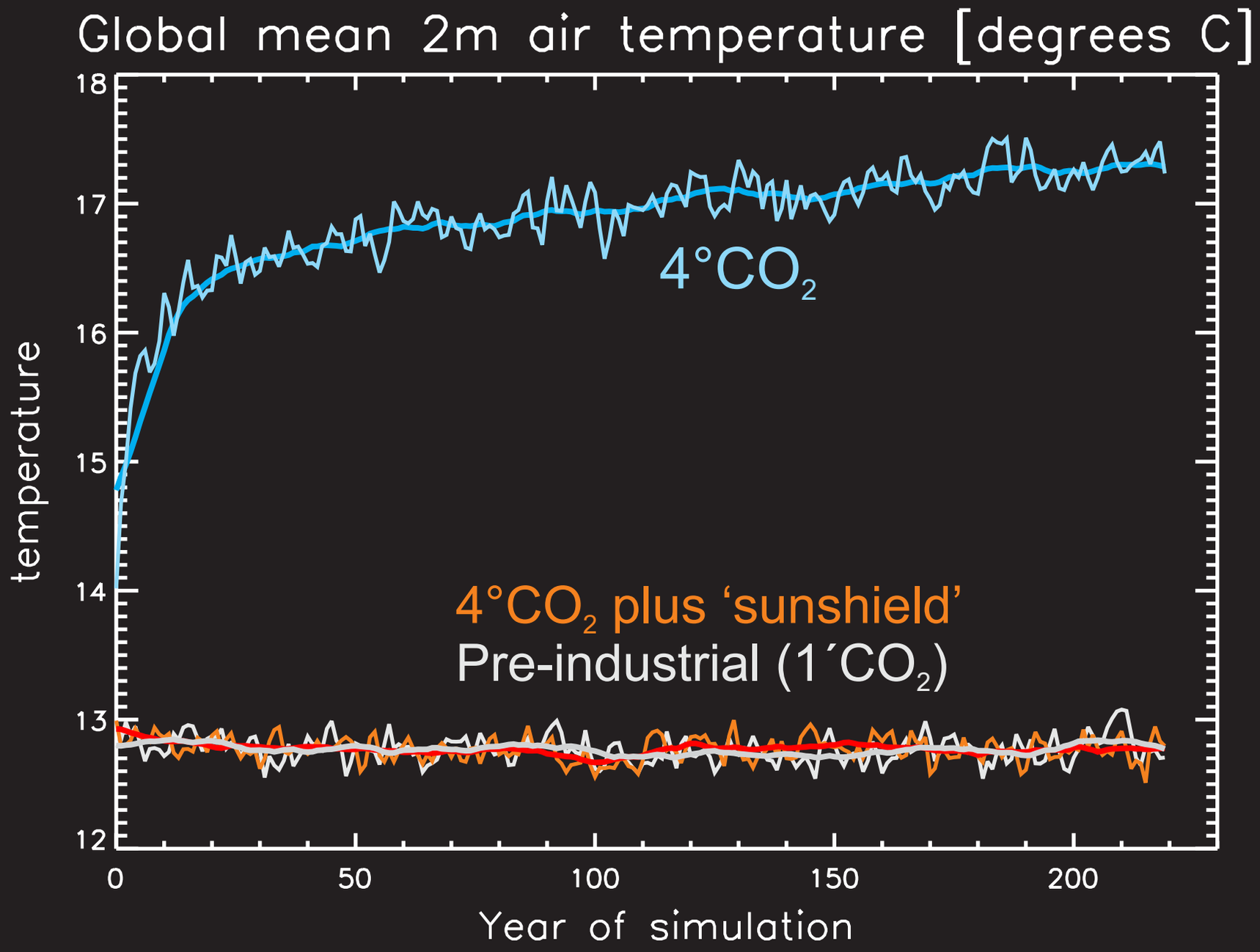



CO_2
CO_2

'Sunshield' geoengineering



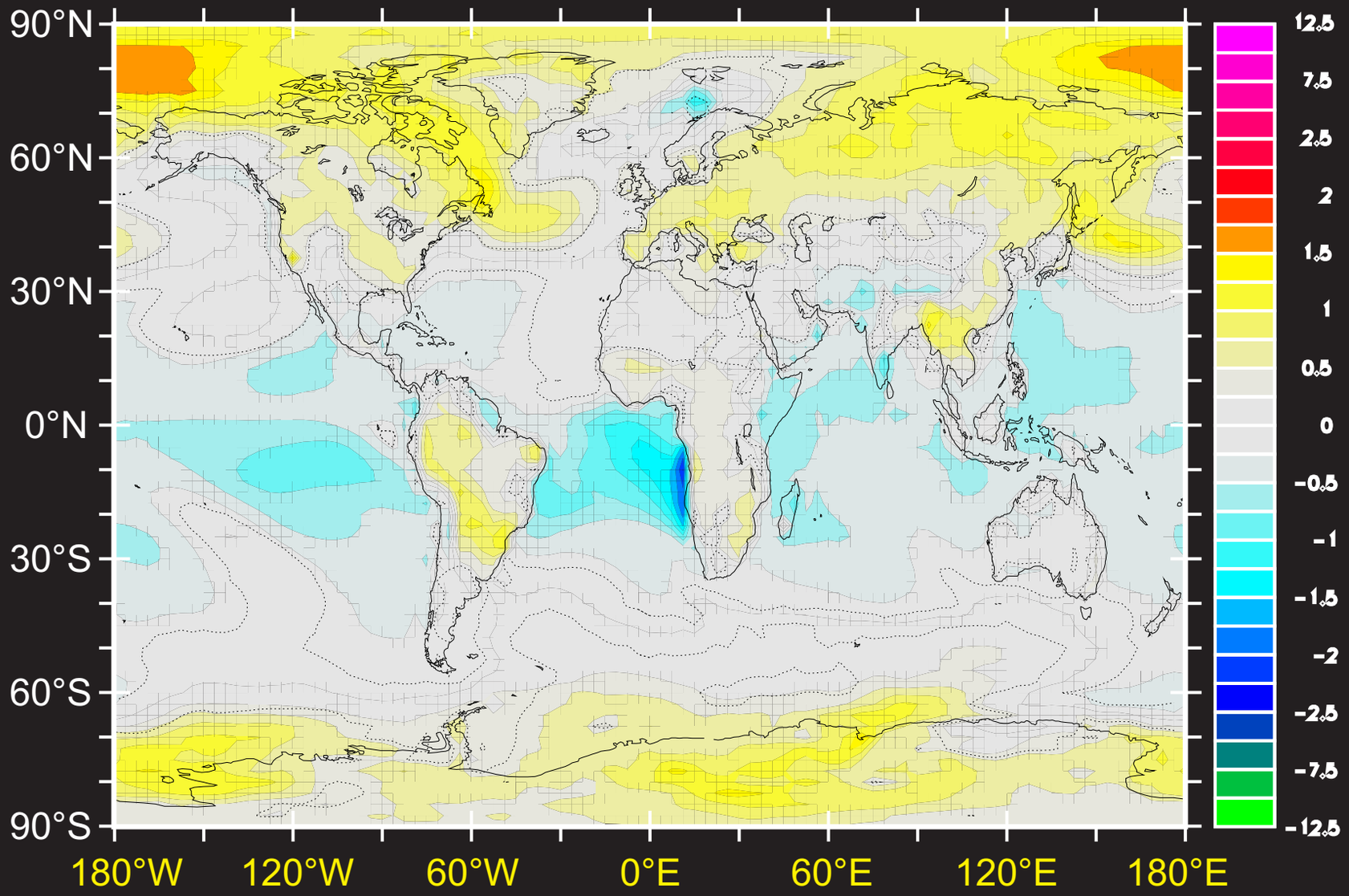
Royal Society [2009]



Lunt et al. [2008] (*GRL* **35**)

'Sunshield' geoengineering

Difference between 4xCO_2 in the atmosphere with a 'sunshield' (4.2% reduced incident solar intensity) and Pre-industrial (1xCO_2) control.



Lunt et al. [2008] (*GRL* **35**)

Increasing the reflectiveness of crops (no, really)

EDGE.2023

Space reflector

crops

Effectiveness

0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5

Affordability

0 1 2 3 4 5 6

Safety: red=low; green=high

Timeliness: large=quick; small=slow

Royal Society [2009]

'Cloud brightening' (no, really)

John MacNeill, www.johnmacneill.com [2009]

Space reflector

Cloud albedo

Crops

Effectiveness

0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5

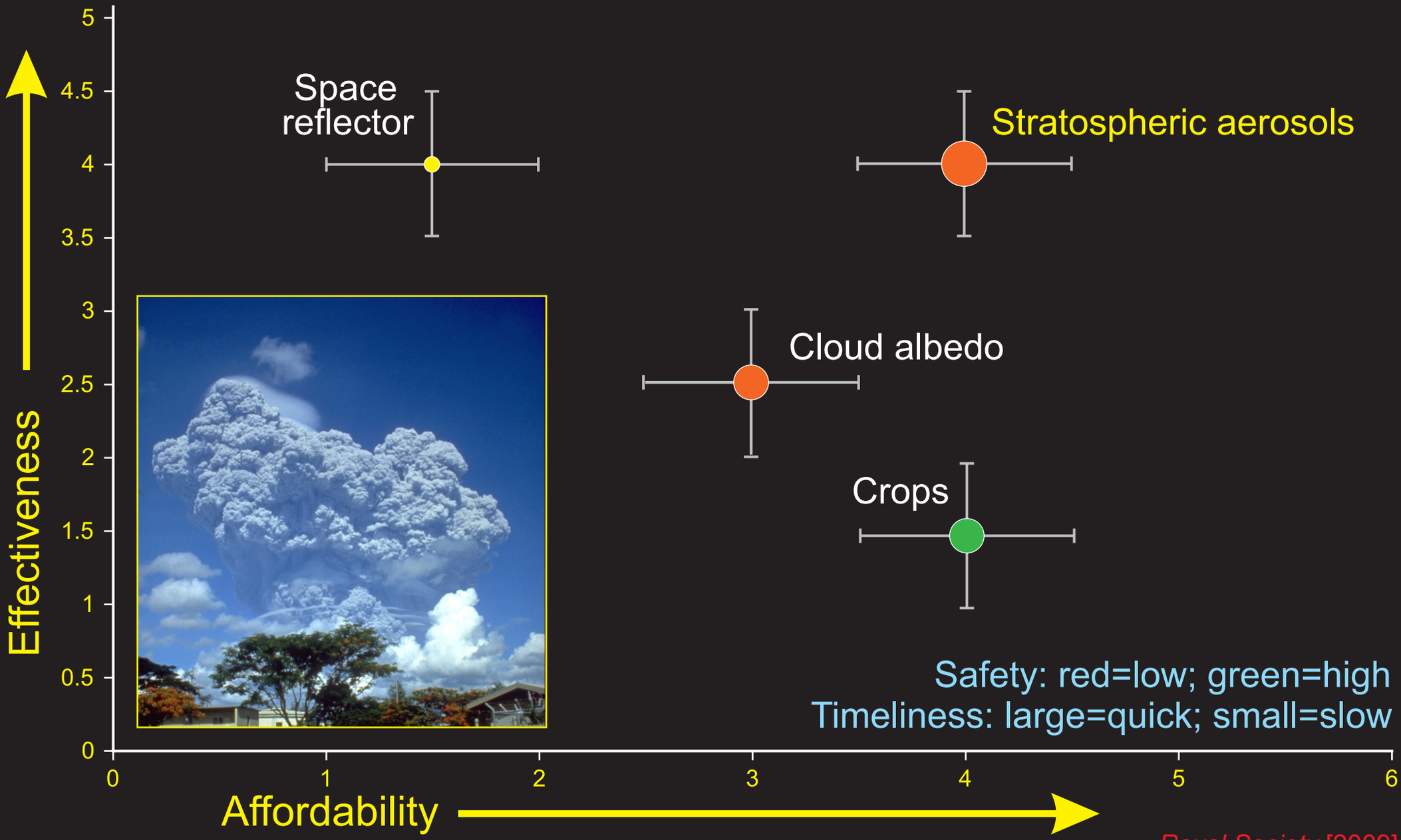
Affordability

0 1 2 3 4 5 6

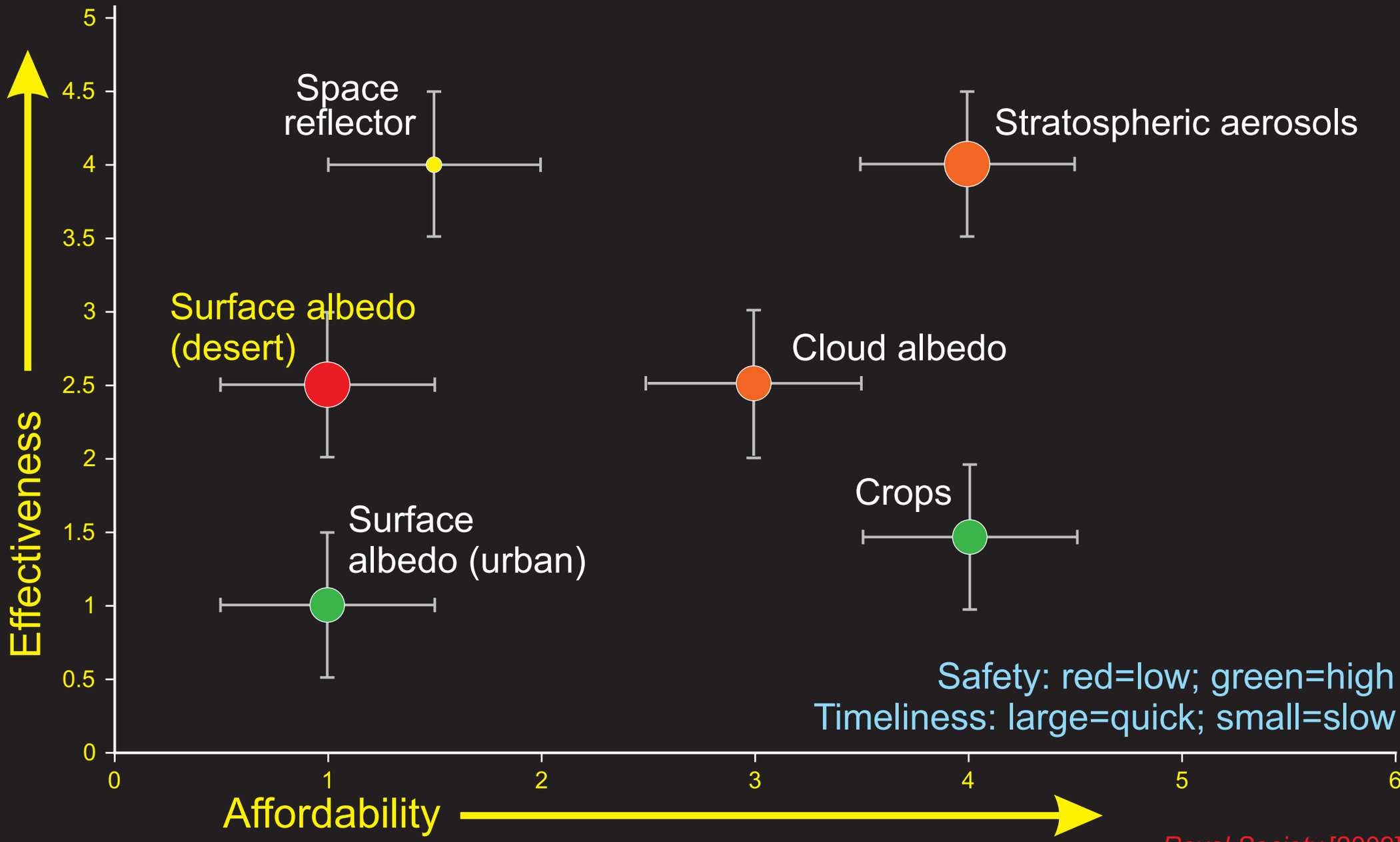
Safety: red=low; green=high

Timeliness: large=quick; small=slow

Royal Society [2009]

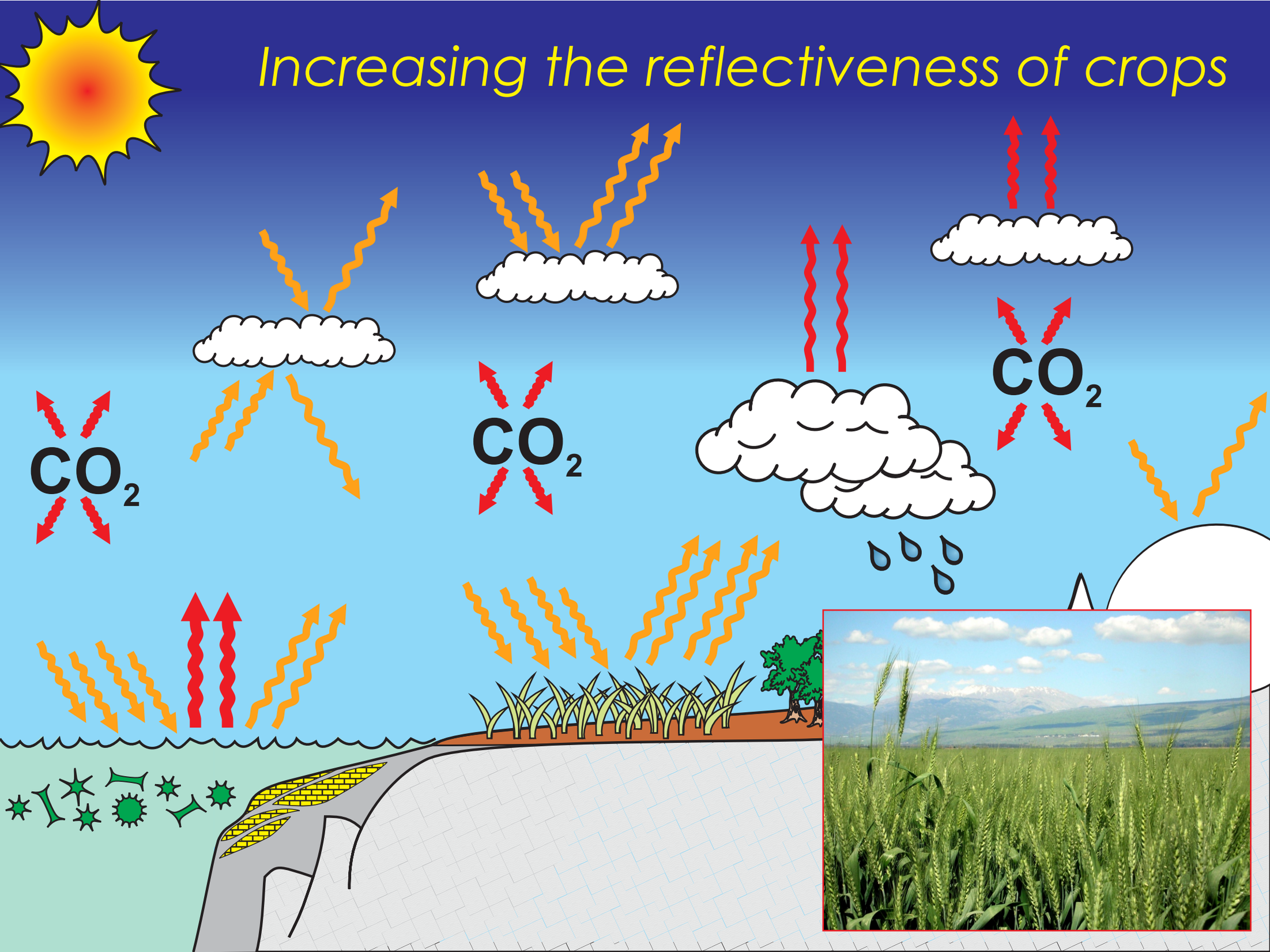


Royal Society [2009]



Royal Society [2009]

Increasing the reflectiveness of crops



Increasing the reflectiveness of crops (no, really)

albedo ~ 0.23
(77% absorption)

albedo ~ 0.18
(82% absorption)

albedo ~ 0.16
(84% absorption)

Decreasing albedo

Increasing reflectivity

Increasing the reflectiveness of crops (no, really)

albedo ~ 0.26
(74% absorption)

sugar beet

albedo ~ 0.23
(77% absorption)

barley

Decreasing albedo

Increasing reflectivity

Increasing the reflectiveness of crops (no, really)

albedo ~ 0.25
(75% absorption)

albedo ~ 0.23
(77% absorption)

albedo ~ 0.21
(79% absorption)

Decreasing albedo

Increasing reflectivity

Controls on (intra) variety crop albedo:

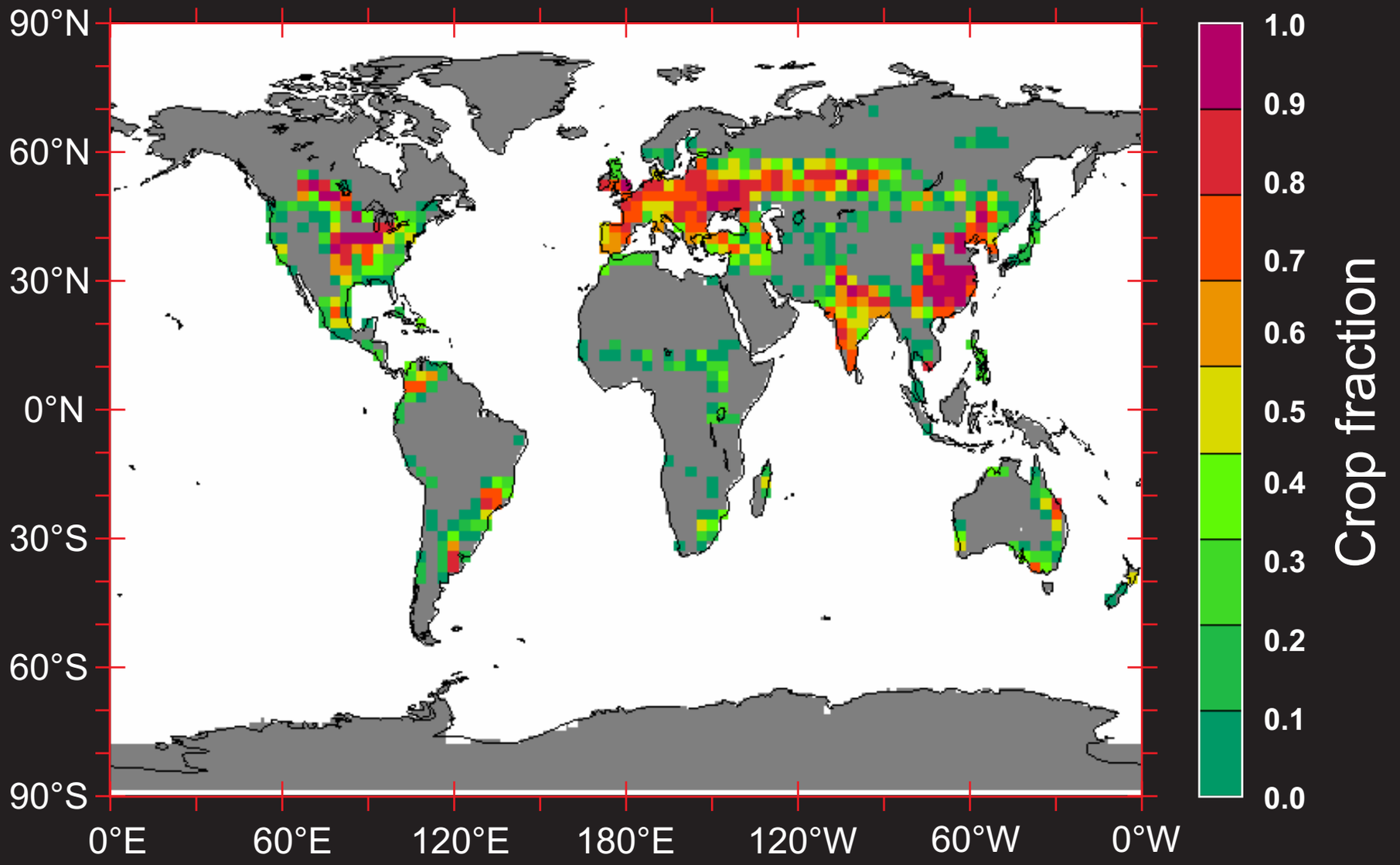
leaf waxiness

leaf/stem hairs

canopy structure

Increasing the reflectiveness of crops (no, really)

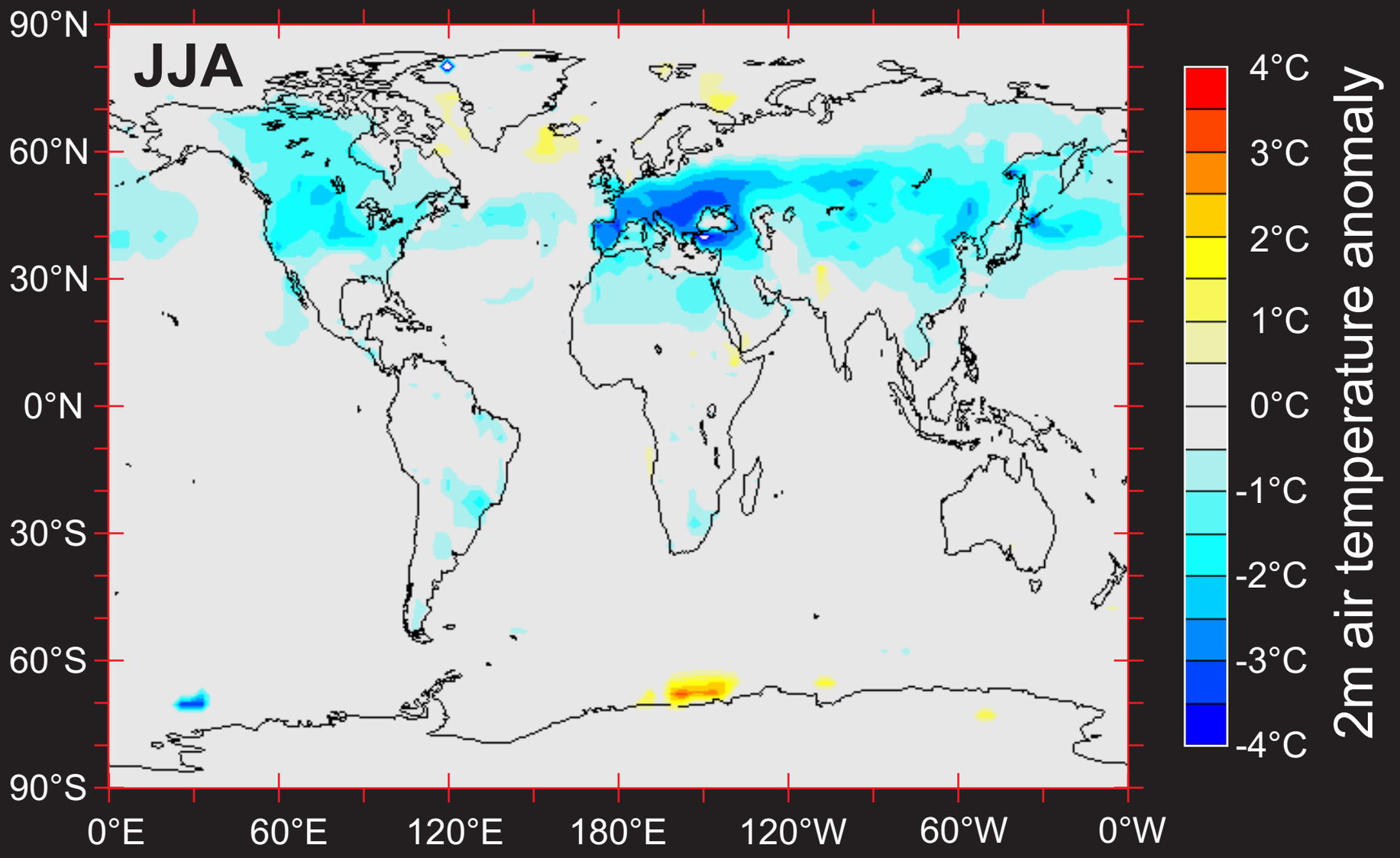
EDGE.2023



Ridgwell et al. [2009] (*Current Biology* **19**)

Increasing the reflectiveness of crops (no, really)

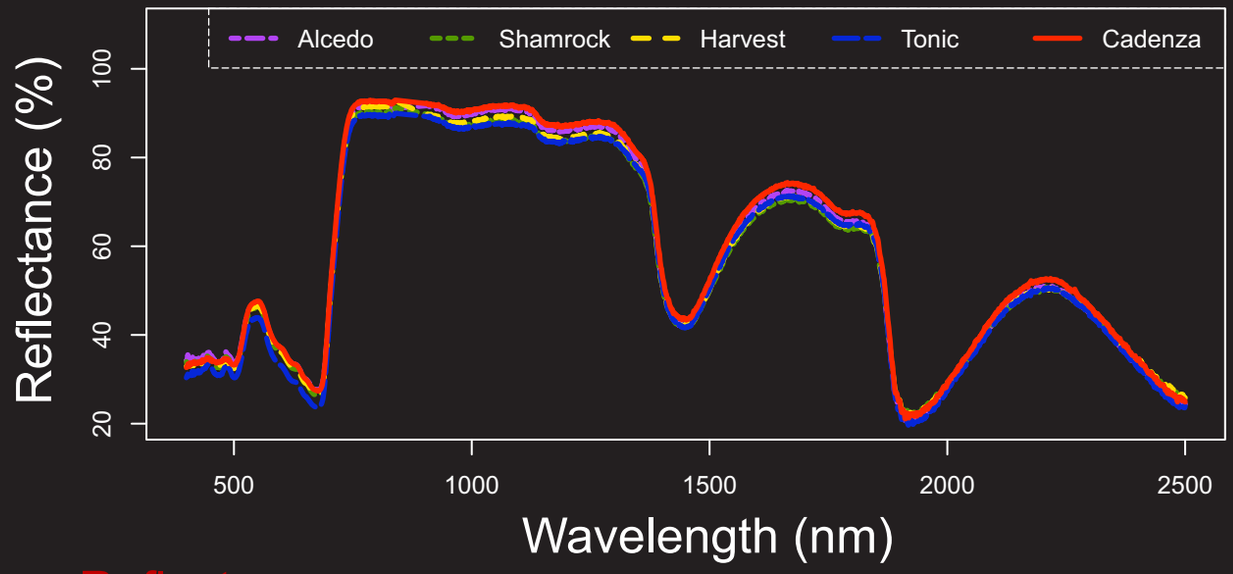
EDGE.2023

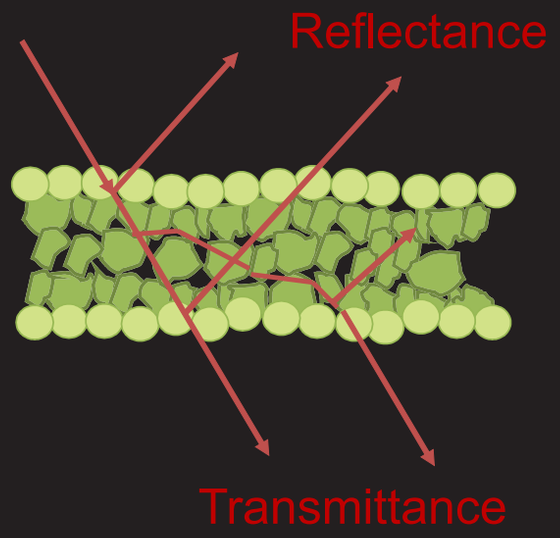


Ridgwell et al. [2009] (*Current Biology* **19**)

#1 Growing range of commercially available strains of wheat.

#2 Measuring reflectance and transmissivity of the leaves.





#1 Growing range of commercially available strains of wheat.

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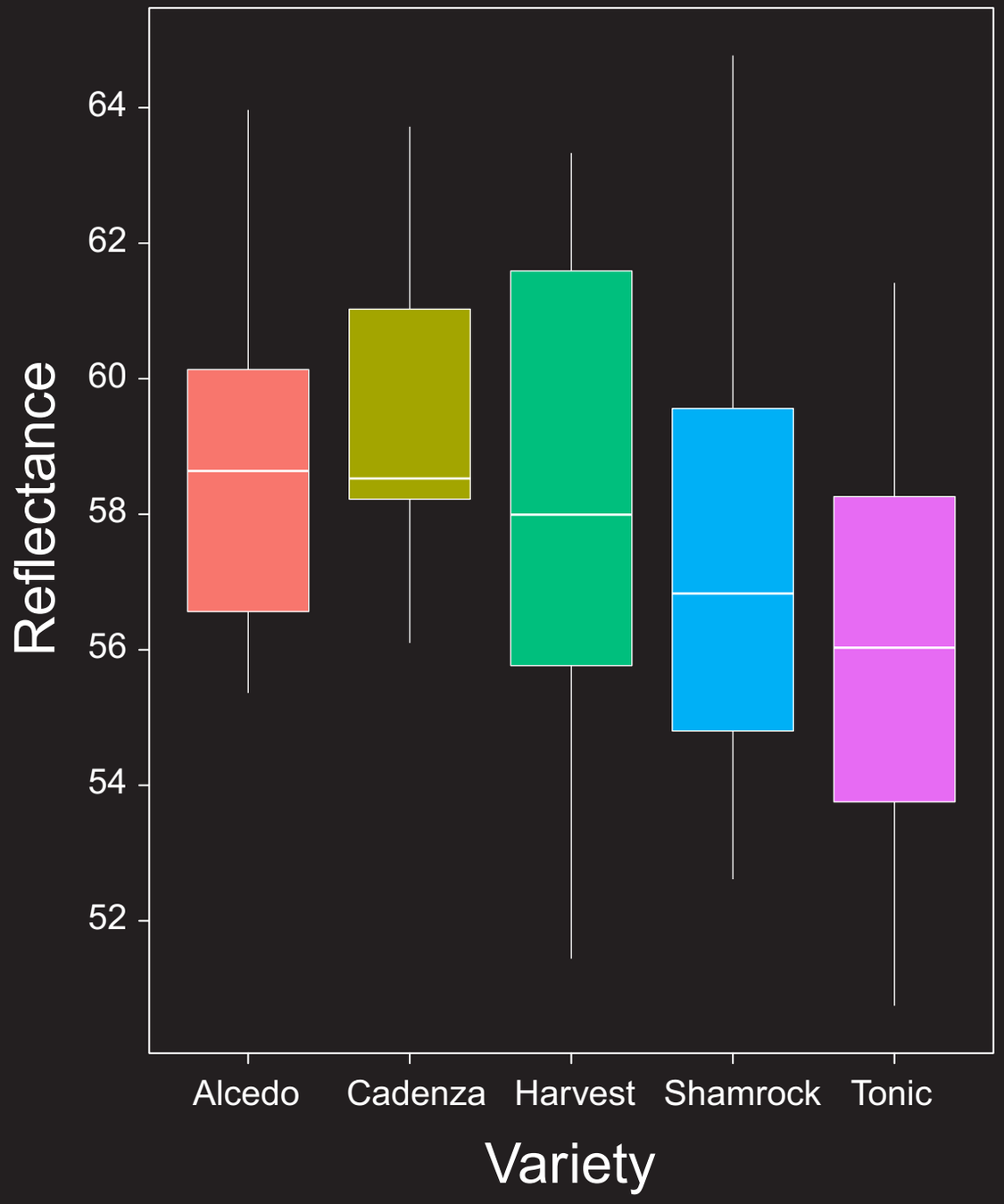


#1 Growing range of commercially available strains of wheat.

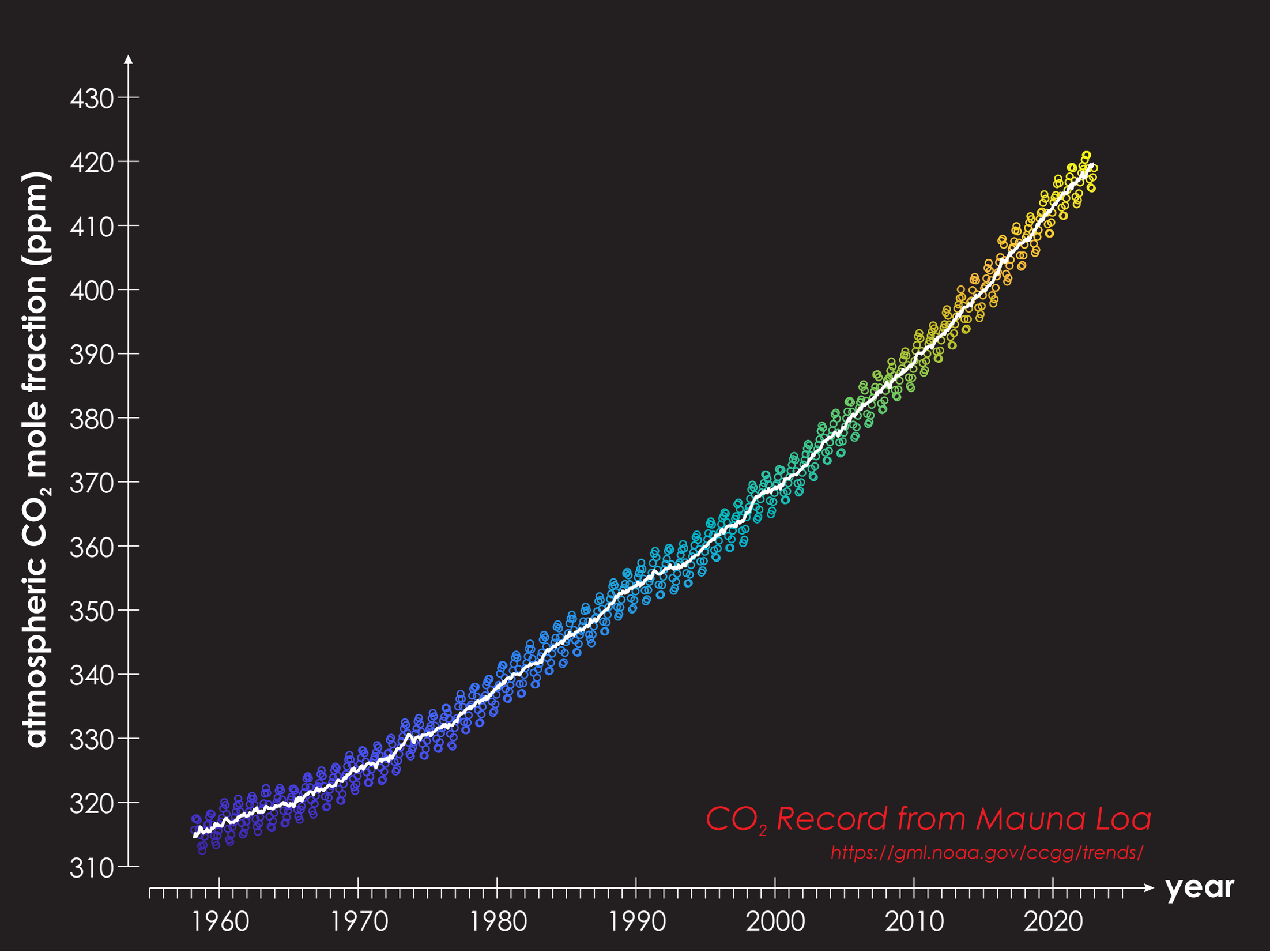
#2 Measuring reflectance and transmissivity of the leaves.

#3 Calculation of yield in crop models.

#4 Up-scaling to canopy level in climate models.

#5 Field measurements.

#6 ...


atmospheric CO_2 mole fraction (ppm)
430
420
410
400
390
380
370
360
350
340
330
320
310
1960
1970
1980
1990
2000
2010
2020
year
CO_2 Record from Mauna Loa
https://gml.noaa.gov/ccgg/trends/

Carbon capture from air

EDGE.2023

CO_2 air capture

Effectiveness

Affordability

0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5

0 1 2 3 4 5 6

Safety: red=low; green=high

Timeliness: large=quick; small=slow

Royal Society [2009]

Current global oil consumption = $90{,}136 \times 10^3$ barrels per day

1.0 barrel = 159 l
= 159×10^3 cm^3

$\Rightarrow$ oil consumption
= 5.23×10^{15} cm^3 $year^{-1}$
= 5.23 km^3 $year^{-1}$

Current global oil consumption = $90{,}136 \times 10^3$ barrels per day

1.0 barrel = 159 l
= 159×10^3 cm^3

⇒ oil consumption
= 5.23×10^{15} cm^3 $year^{-1}$
= 5.23 km^3 $year^{-1}$

How many Yosemite Valleys? (equivalent volume)

Current global oil consumption = $90{,}136 \times 10^3$ barrels per day

1.0 barrel = 159 l
= 159×10^3 cm^3

⇒ oil consumption
= 5.23×10^{15} cm^3 $year^{-1}$
= 5.23 km^3 $year^{-1}$

Yosemite Valley (Wikipedia):
1,200m deep × 1,600m across, 12.0 km long
⇒
volume = 1.2×1.6×12.0
= 23.0 km^3

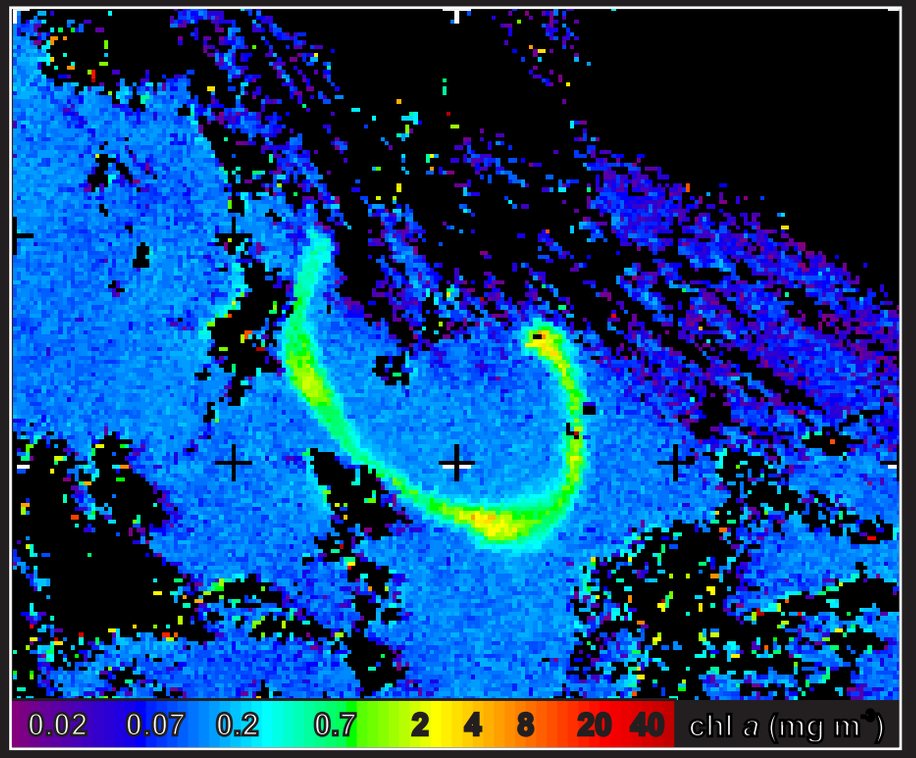
How many Yosemite Valleys? (equivalent volume)

Inject CO2 directly into the ocean … ? (no really!)

Brewer et al. [1999]

Biological manipulation (iron fertilization)

EDGE.2023



Effectiveness

0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

Ocean fertilisation

Safety: red=low; green=high

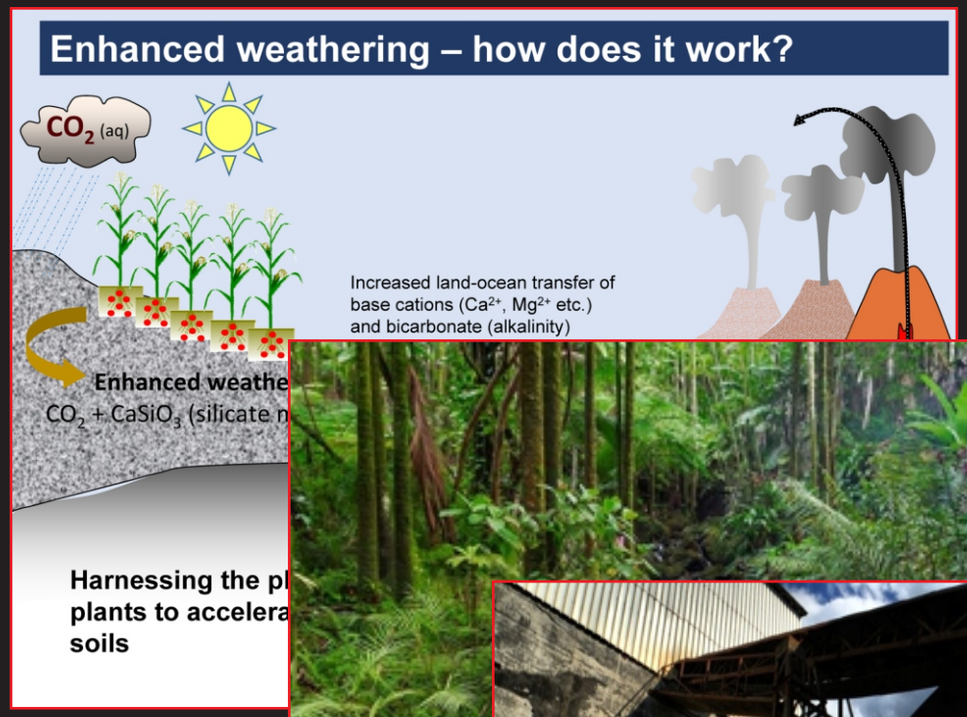
Timeliness: large=quick; small=slow

0
1
2
3
4
5
6

Affordability

Royal Society [2009]

'Enhanced weathering'



David Beerling

~ olivine + pyroxene

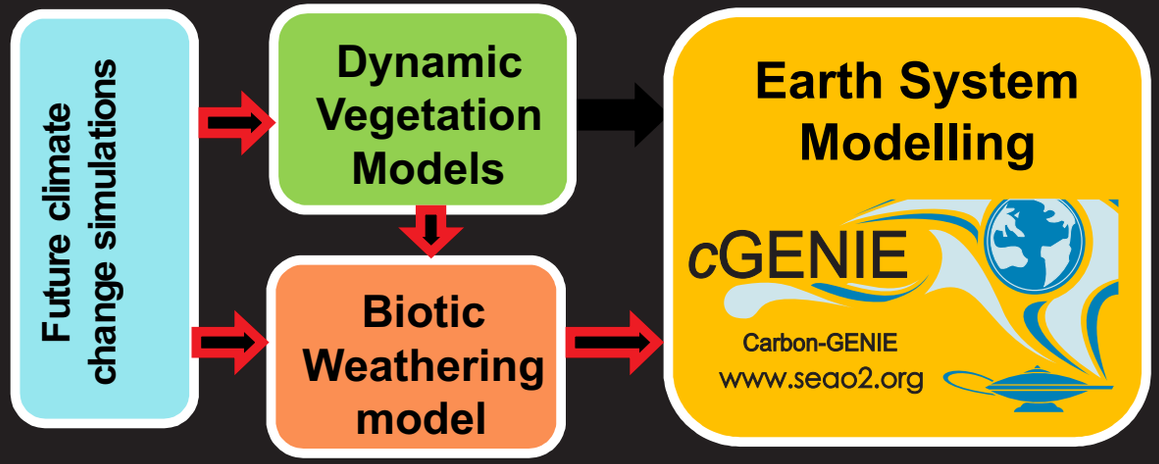
Harzburgite

~ plagioclase + pyroxene (+olivine)

>90% olivine: $(Mg^{+2}, Fe^{+2})2SiO_4$

Dunite

'Enhanced weathering'

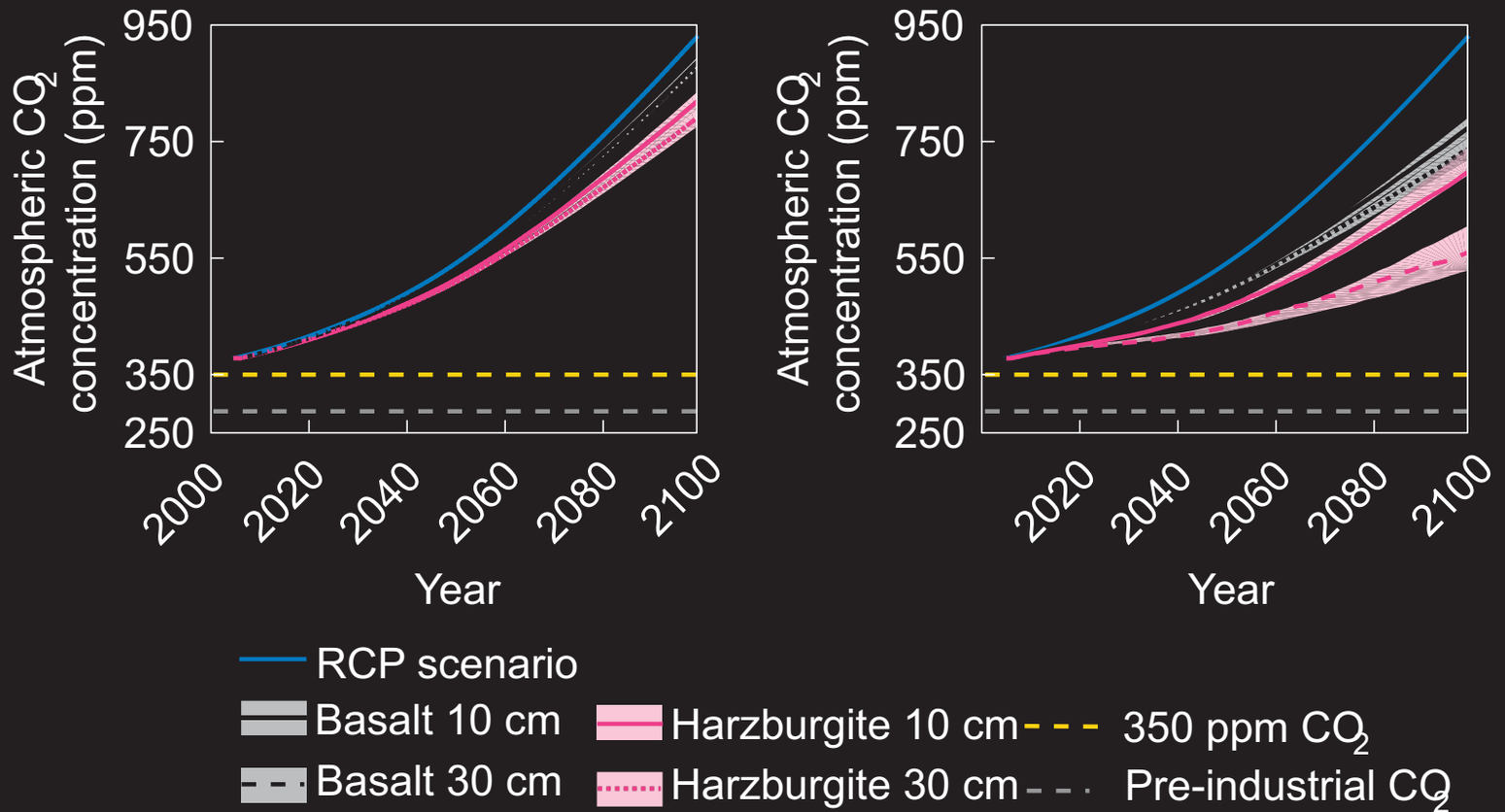


nature climate change LETTERS

Enhanced weathering strategies for stabilizing climate and averting ocean acidification

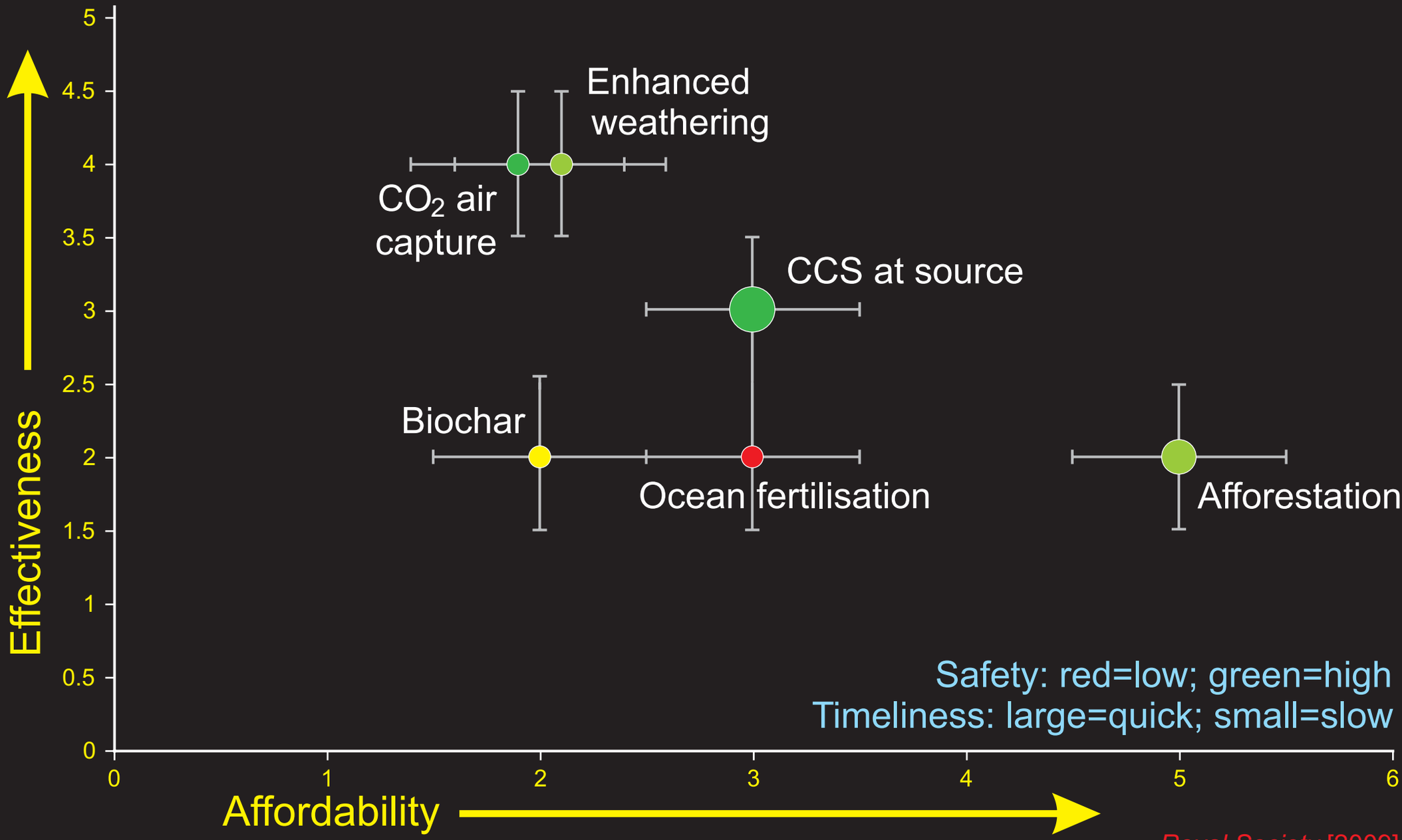
Lyla L. Taylor[1], Joe Quirk[1], Rachel M. S. Thorley[2], Pushker A. Kharecha[3,4], James Hansen[3], Andy Ridgwell[5,6], Mark R. Lomas[6], Steve A. Banwart[1] and David J. Beerling[1]*

Taylor et al. [2015]



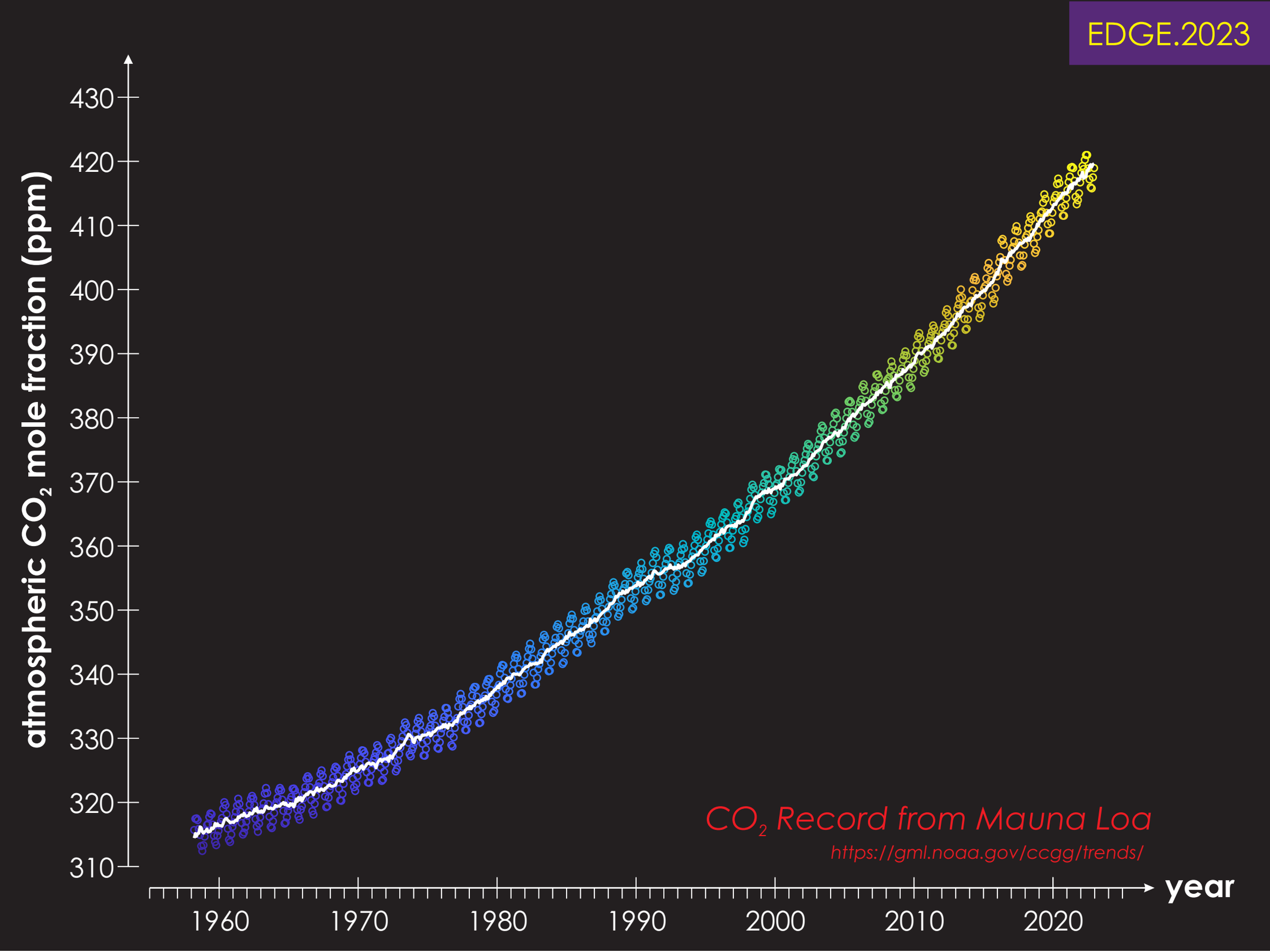
Meaningless CDR summary

EDGE.2023



Royal Society [2009]

EDGE.2023


atmospheric CO_2 mole fraction (ppm)
430
420
410
400
390
380
370
360
350
340
330
320
310
1960
1970
1980
1990
2000
2010
2020
year
CO_2 Record from Mauna Loa
https://gml.noaa.gov/ccgg/trends/