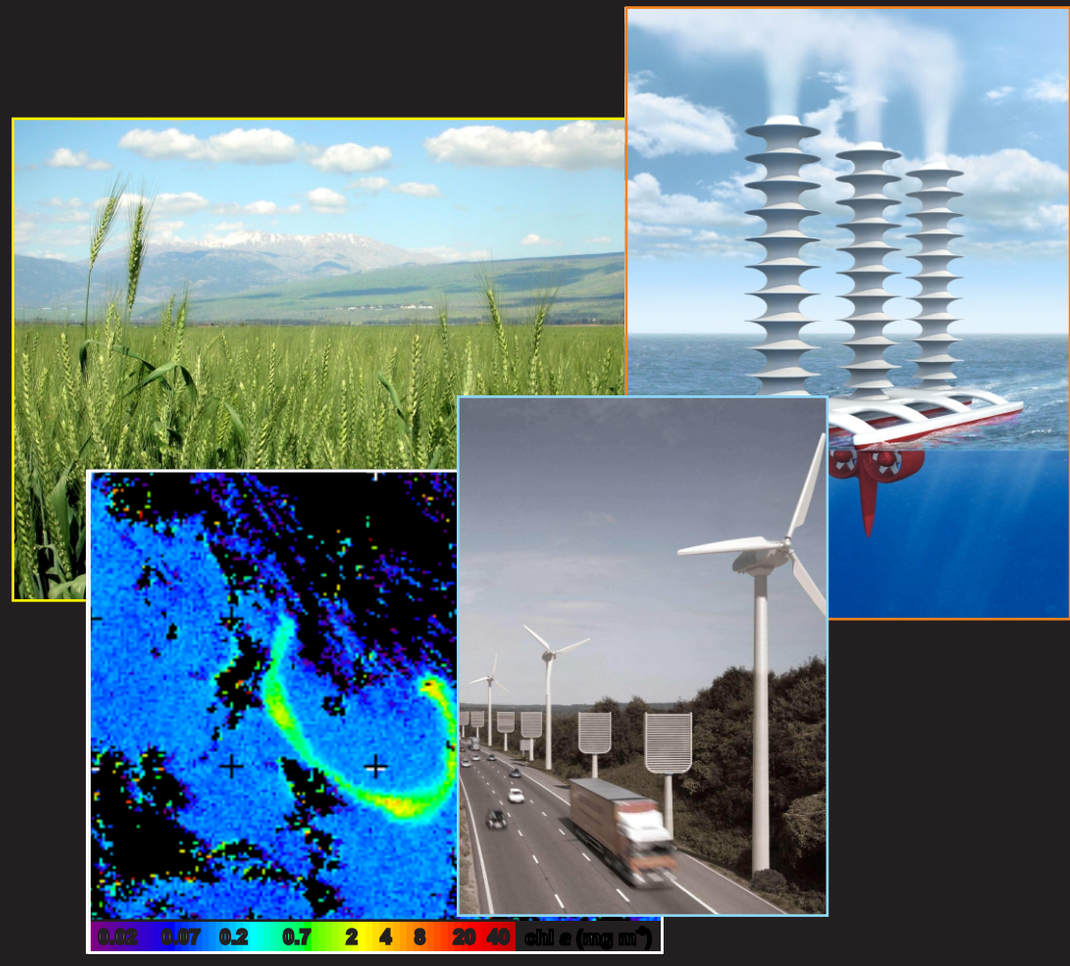
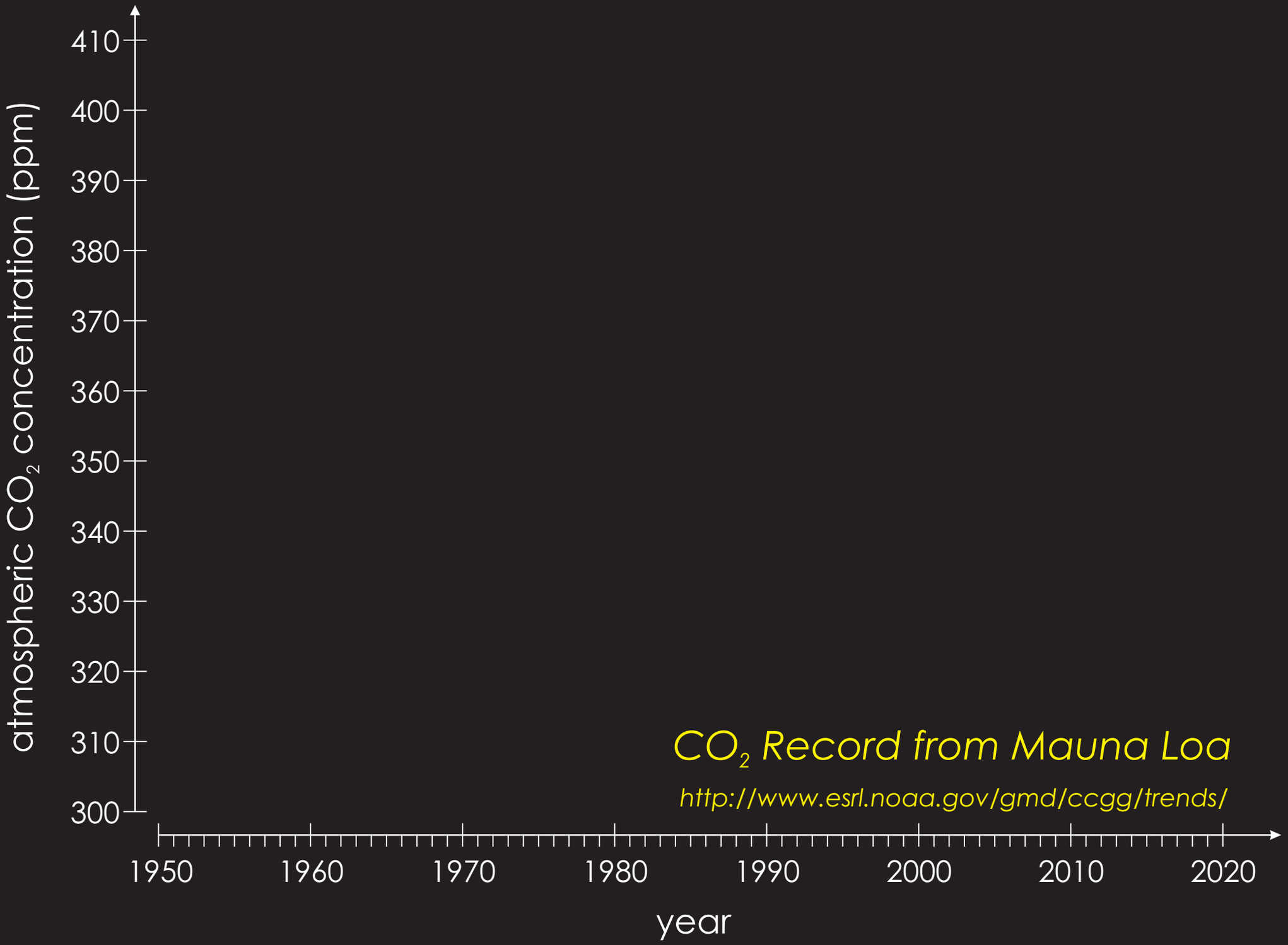
Earth 2.0

Geoengineering and global-scale climate change mitigation

Andy Ridgwell



UCR University of BRISTOL THE ROYAL SOCIETY CELEBRATING 350 YEARS European Research Council Established by the European Commission erc


atmospheric CO_2 concentration (ppm)
410
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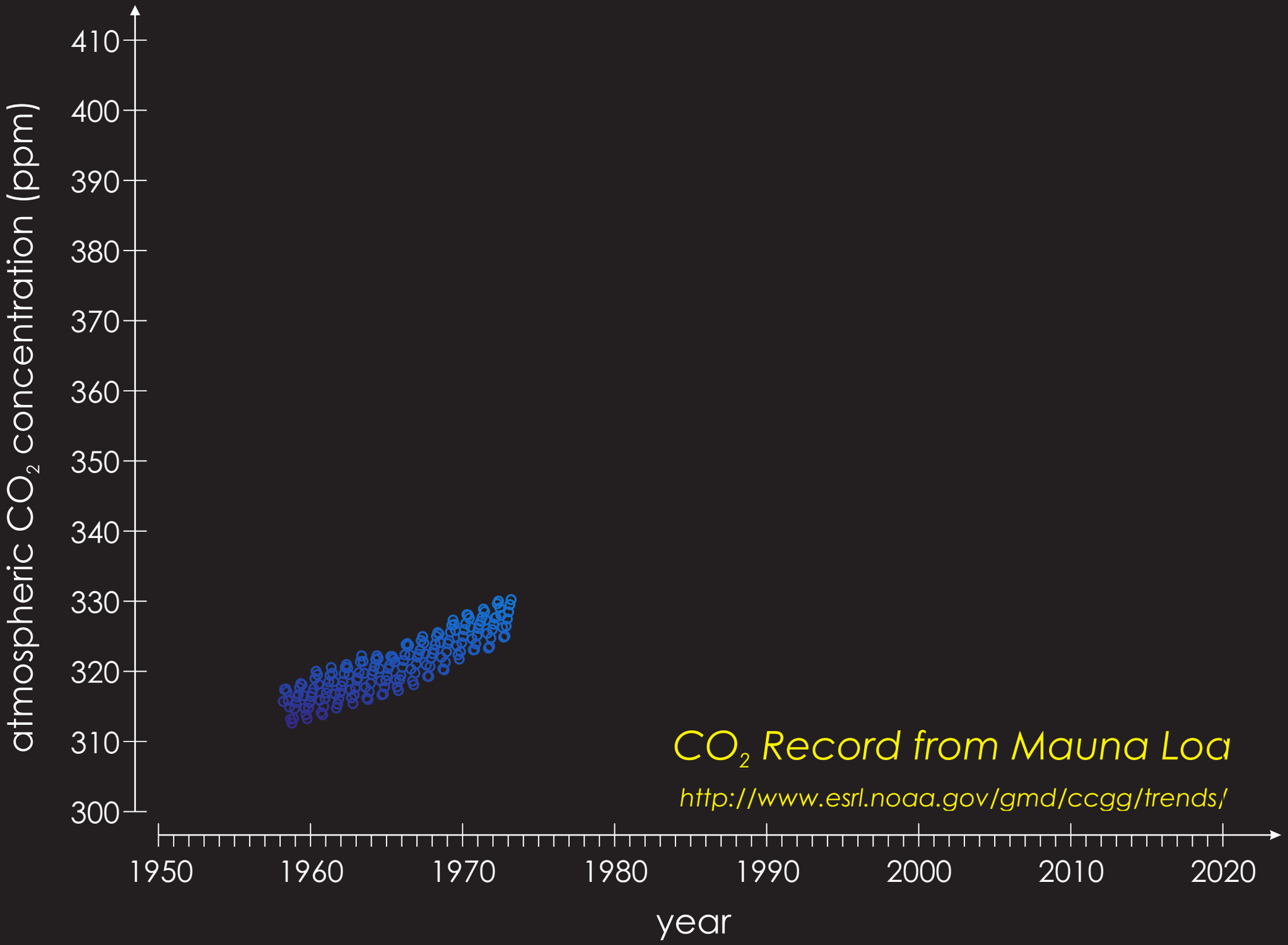
year
CO_2 Record from Mauna Loa
http://www.esrl.noaa.gov/gmd/ccgg/trends/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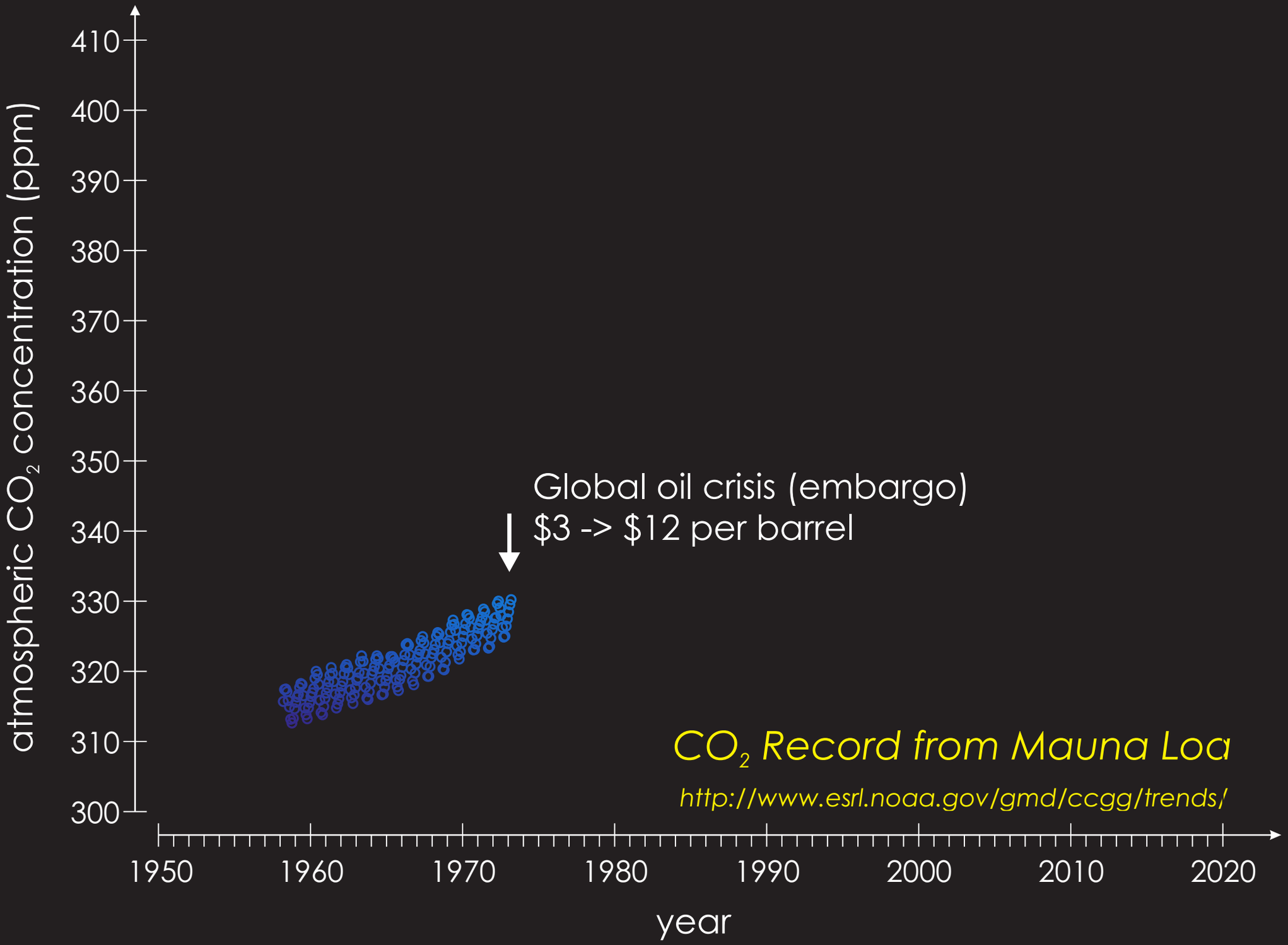
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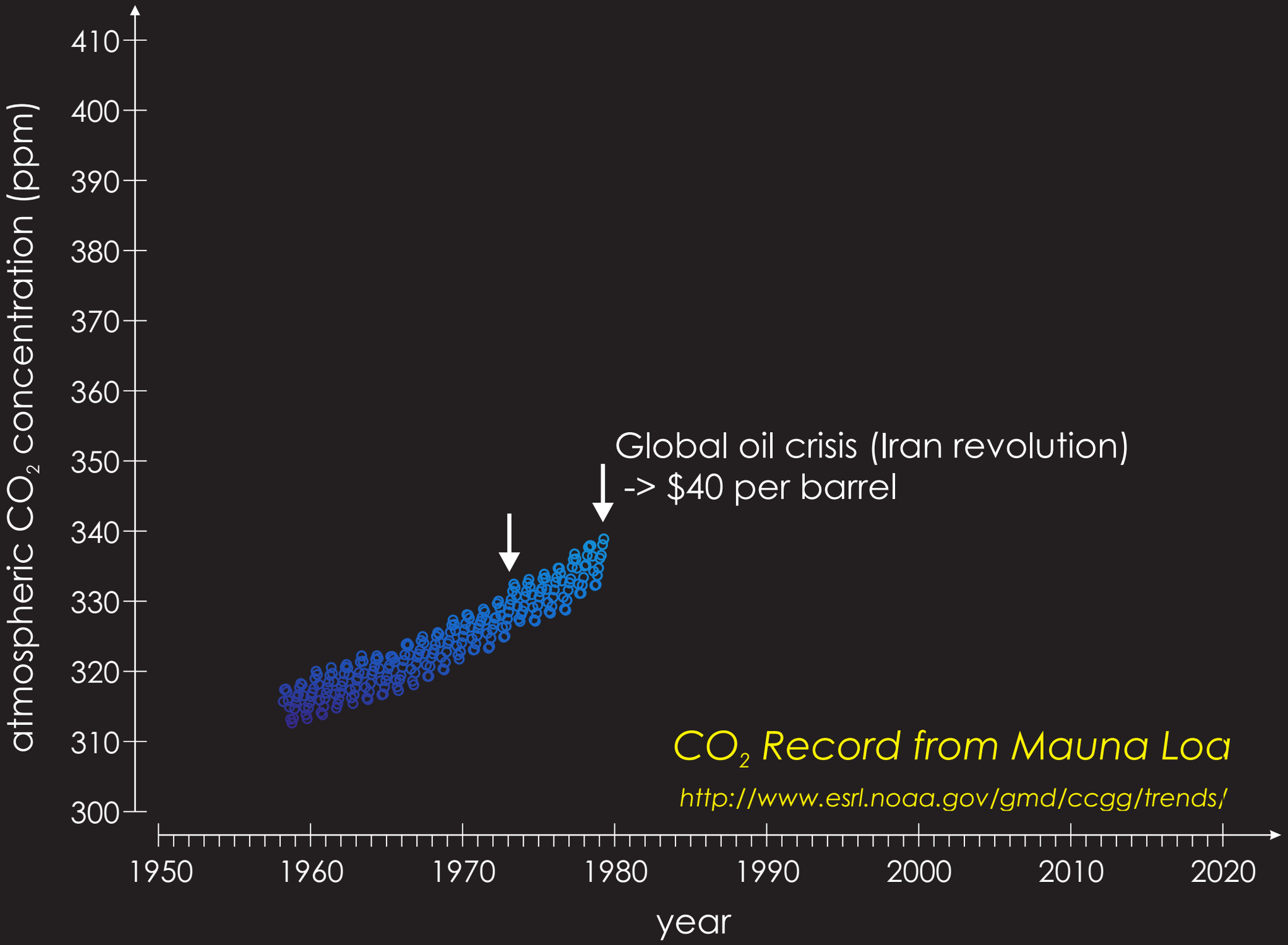
year
Global oil crisis (embargo)
$3 -> $12 per barrel
CO_2 Record from Mauna Loa
http://www.esrl.noaa.gov/gmd/ccgg/trends/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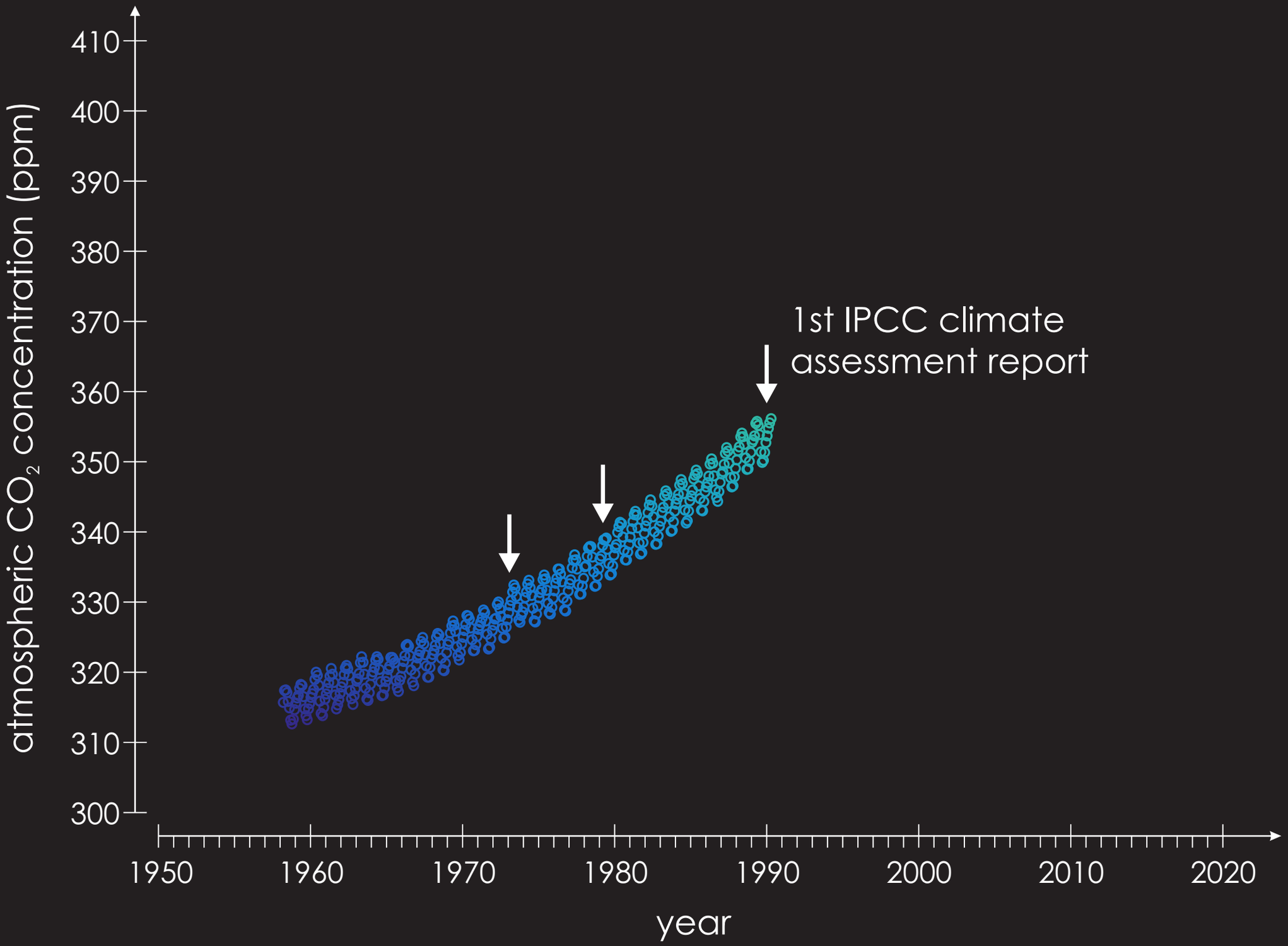
year
Global oil crisis (Iran revolution)
-> $40 per barrel
CO_2 Record from Mauna Loa
http://www.esrl.noaa.gov/gmd/ccgg/trends/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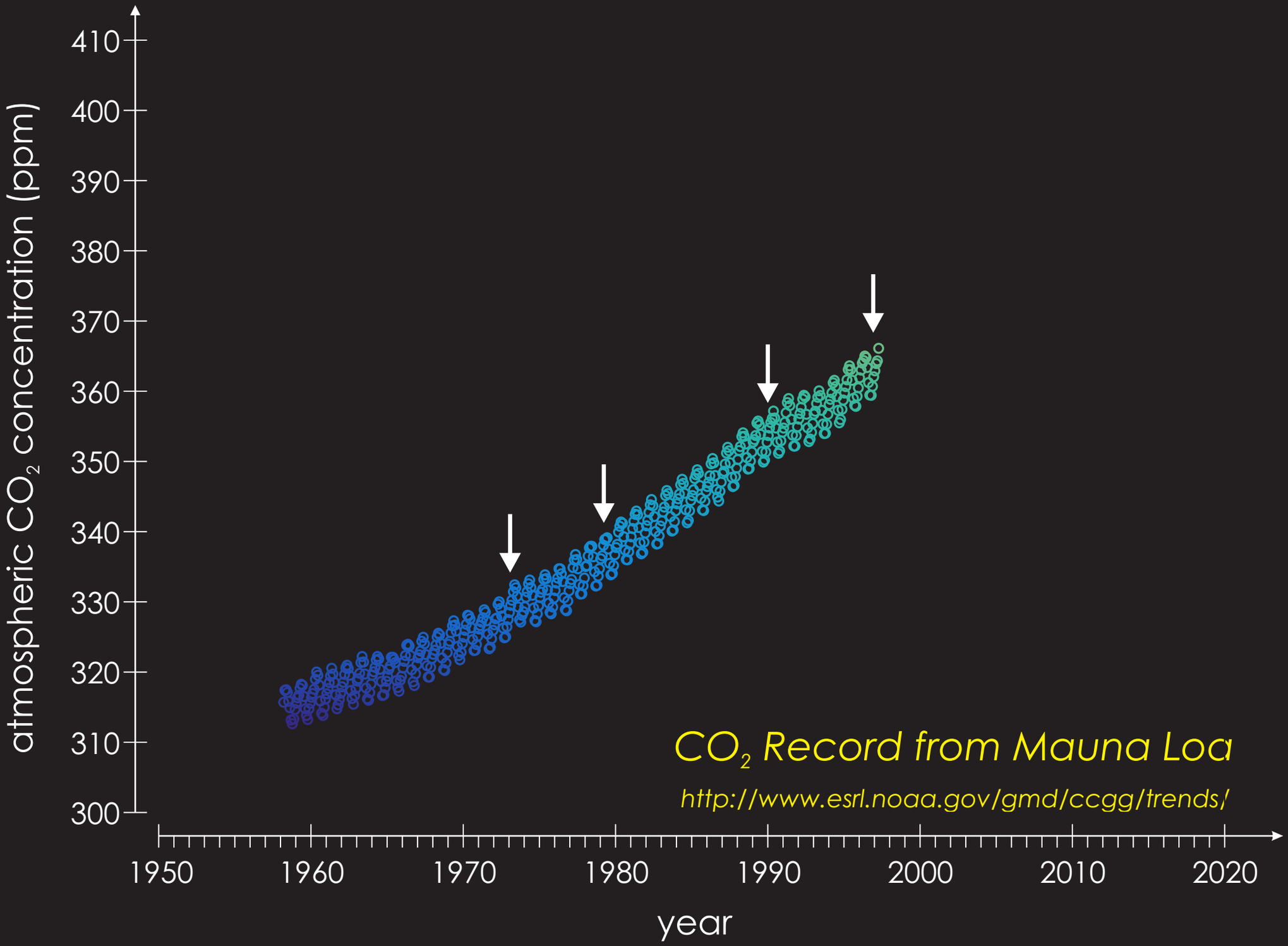
year
1st IPCC climate assessment report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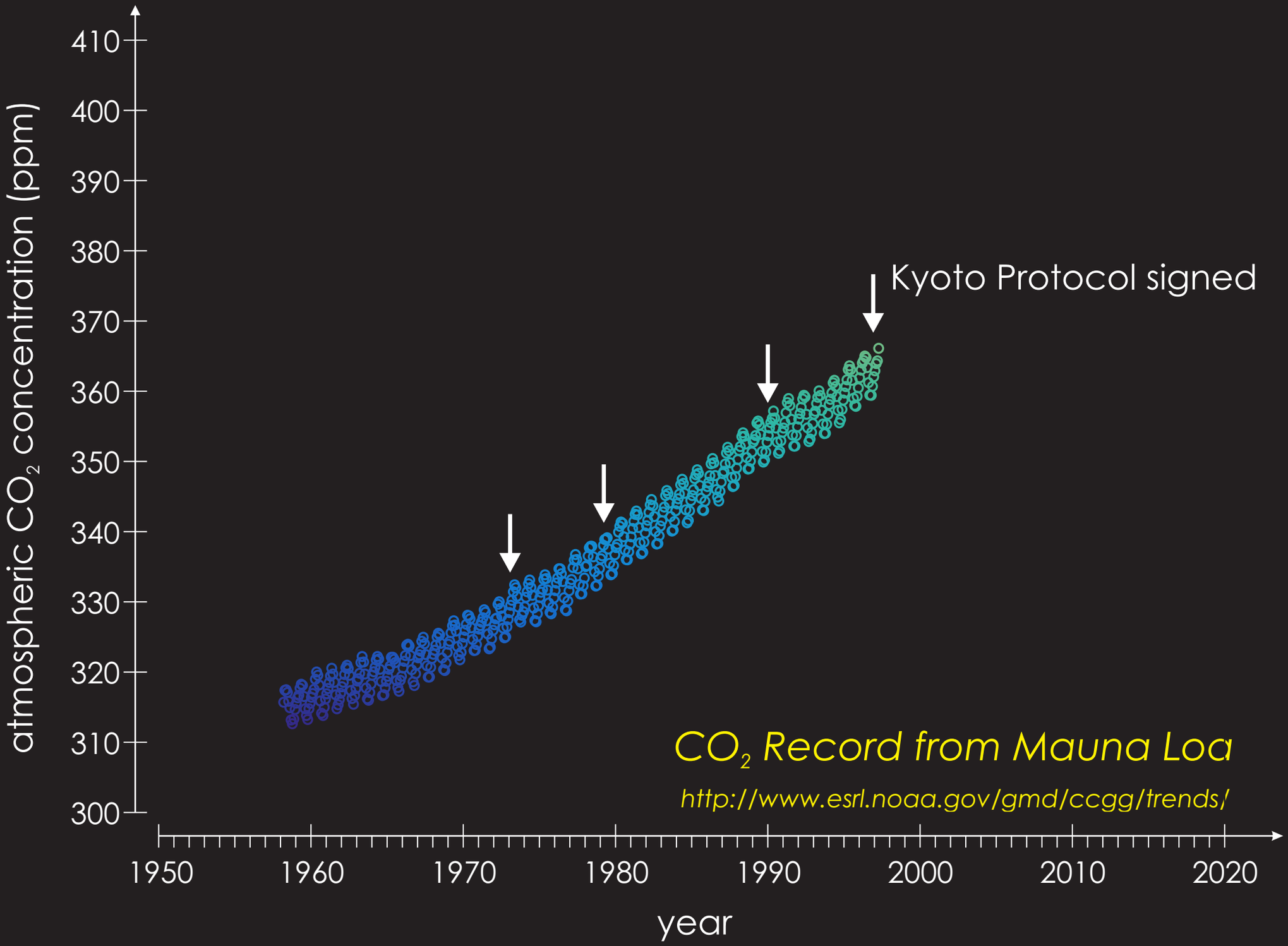
atmospheric CO_2 concentration (ppm)
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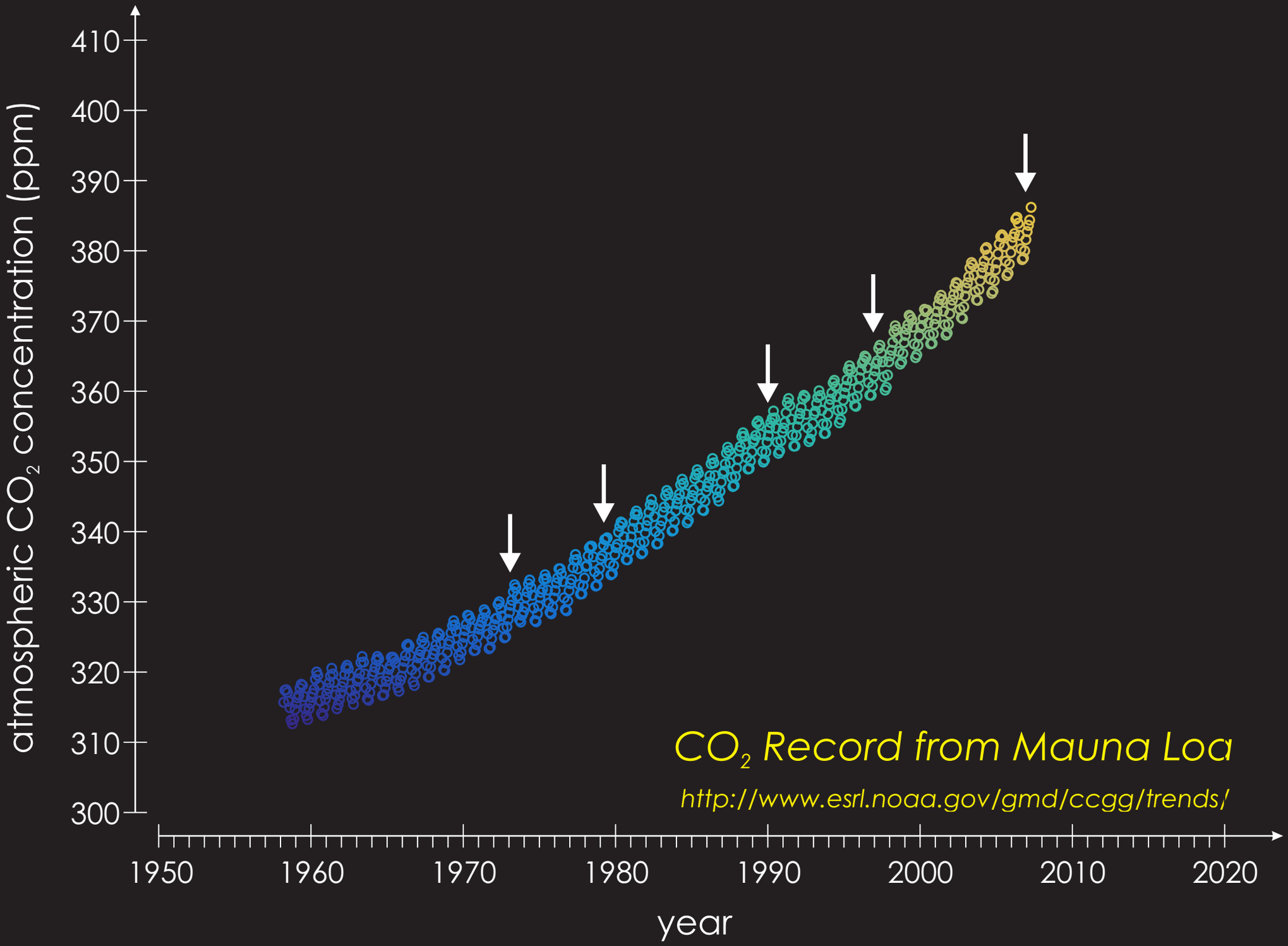
year
Kyoto Protocol signed
CO_2 Record from Mauna Loa
http://www.esrl.noaa.gov/gmd/ccgg/trends/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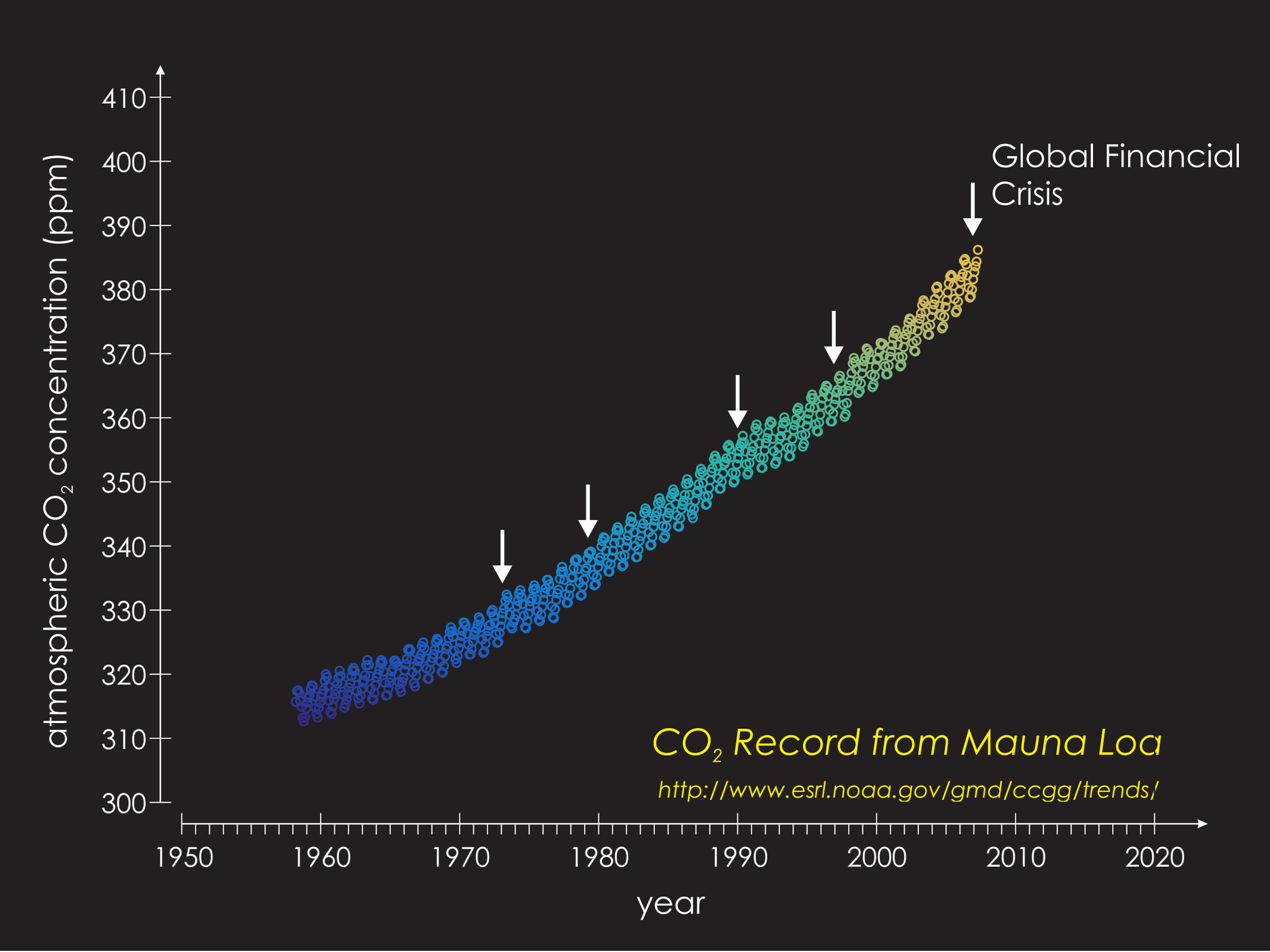
http://www.esrl.noaa.gov/gmd/ccgg/trends/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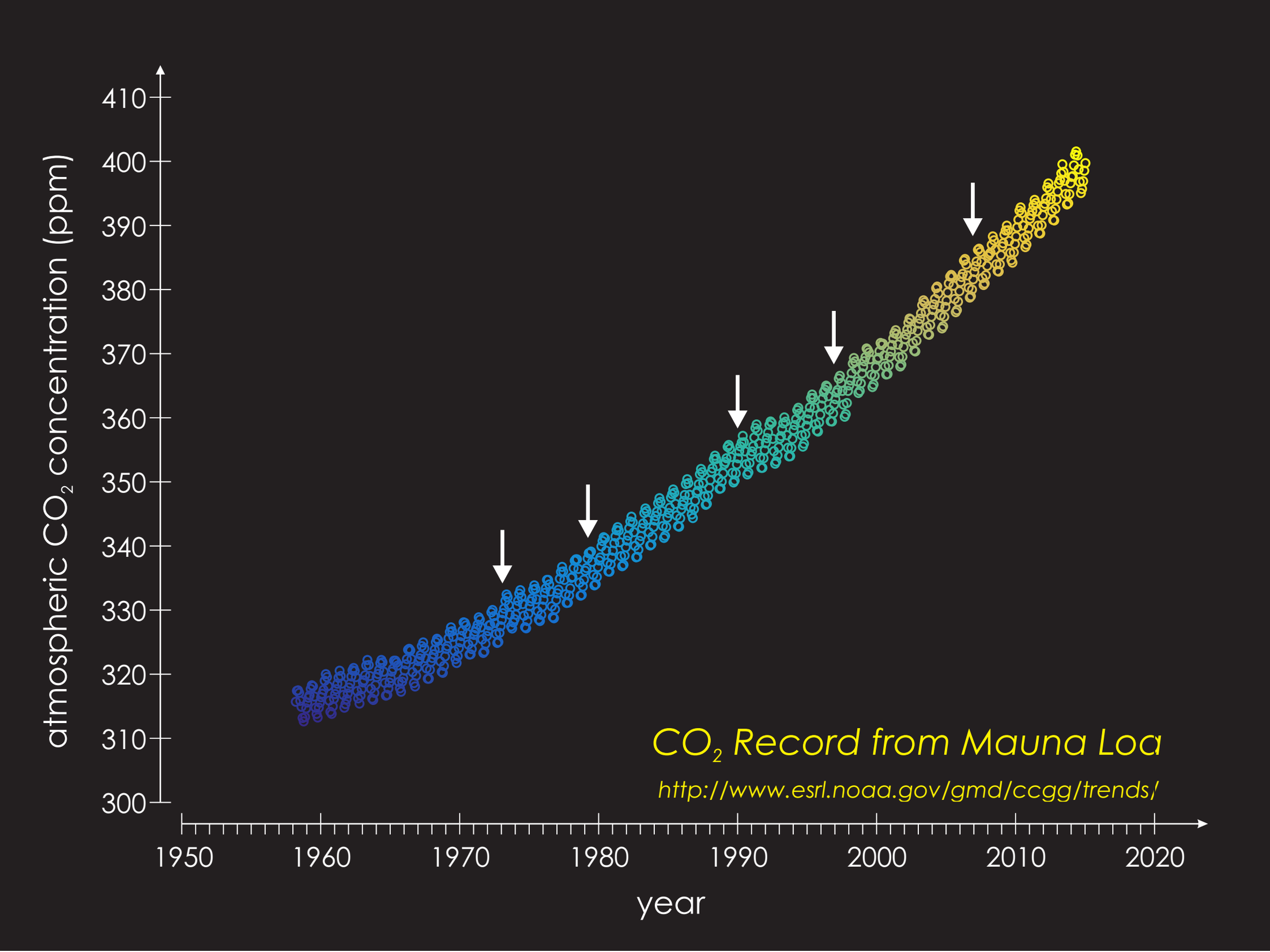
Global Financial Crisis
CO_2 Record from Mauna Loa
http://www.esrl.noaa.gov/gmd/ccgg/trends/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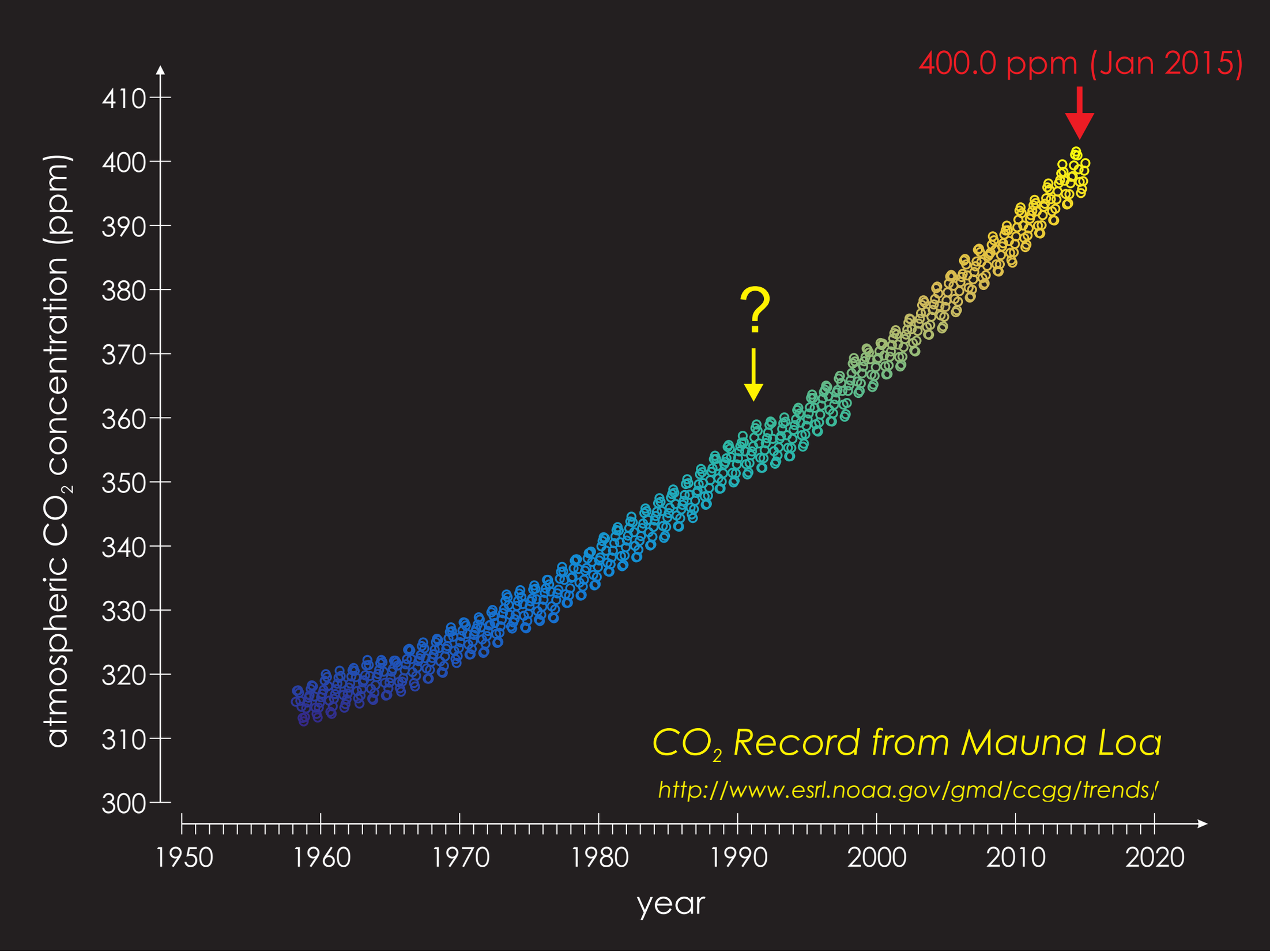
400.0 ppm (Jan 2015)
?
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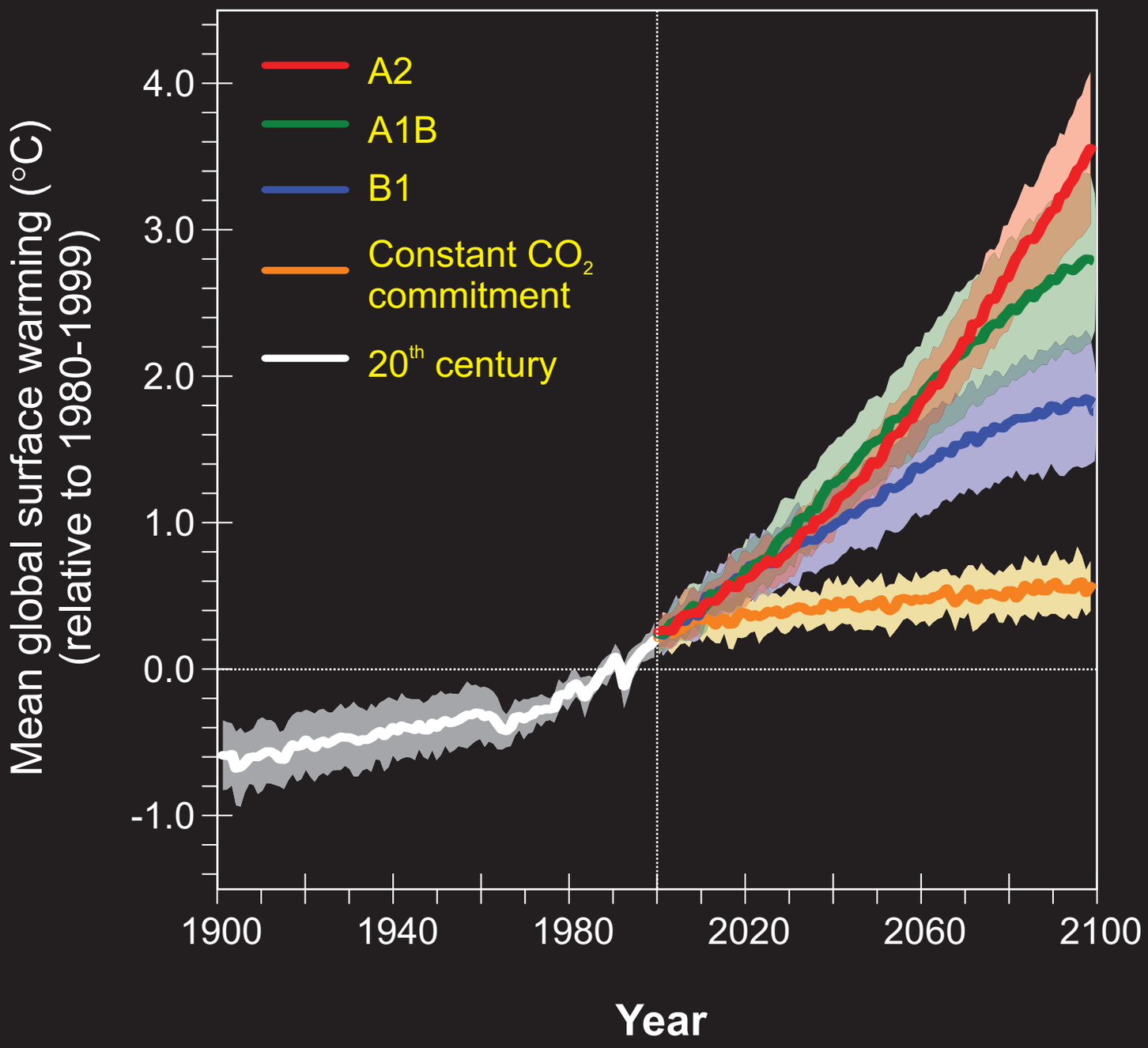
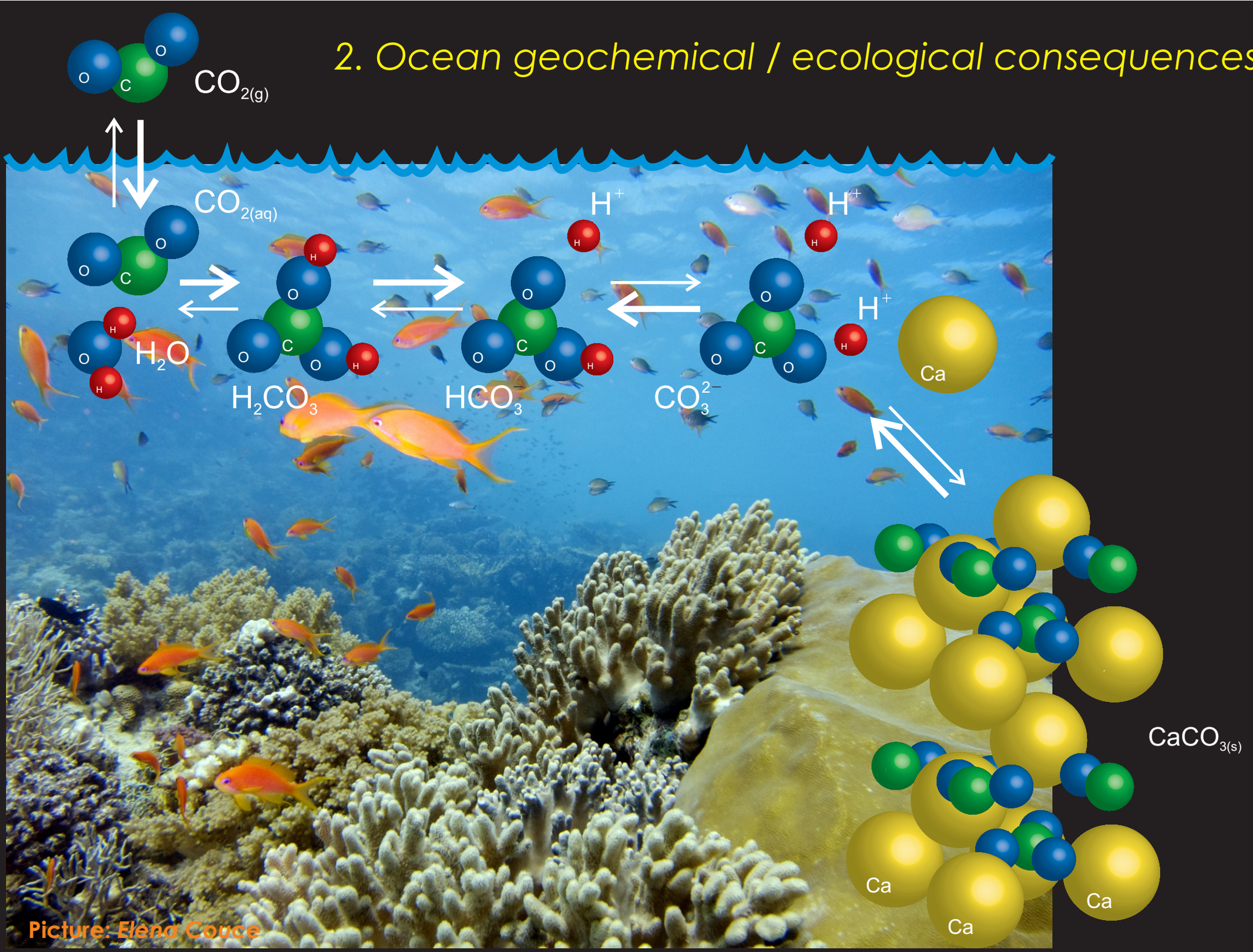
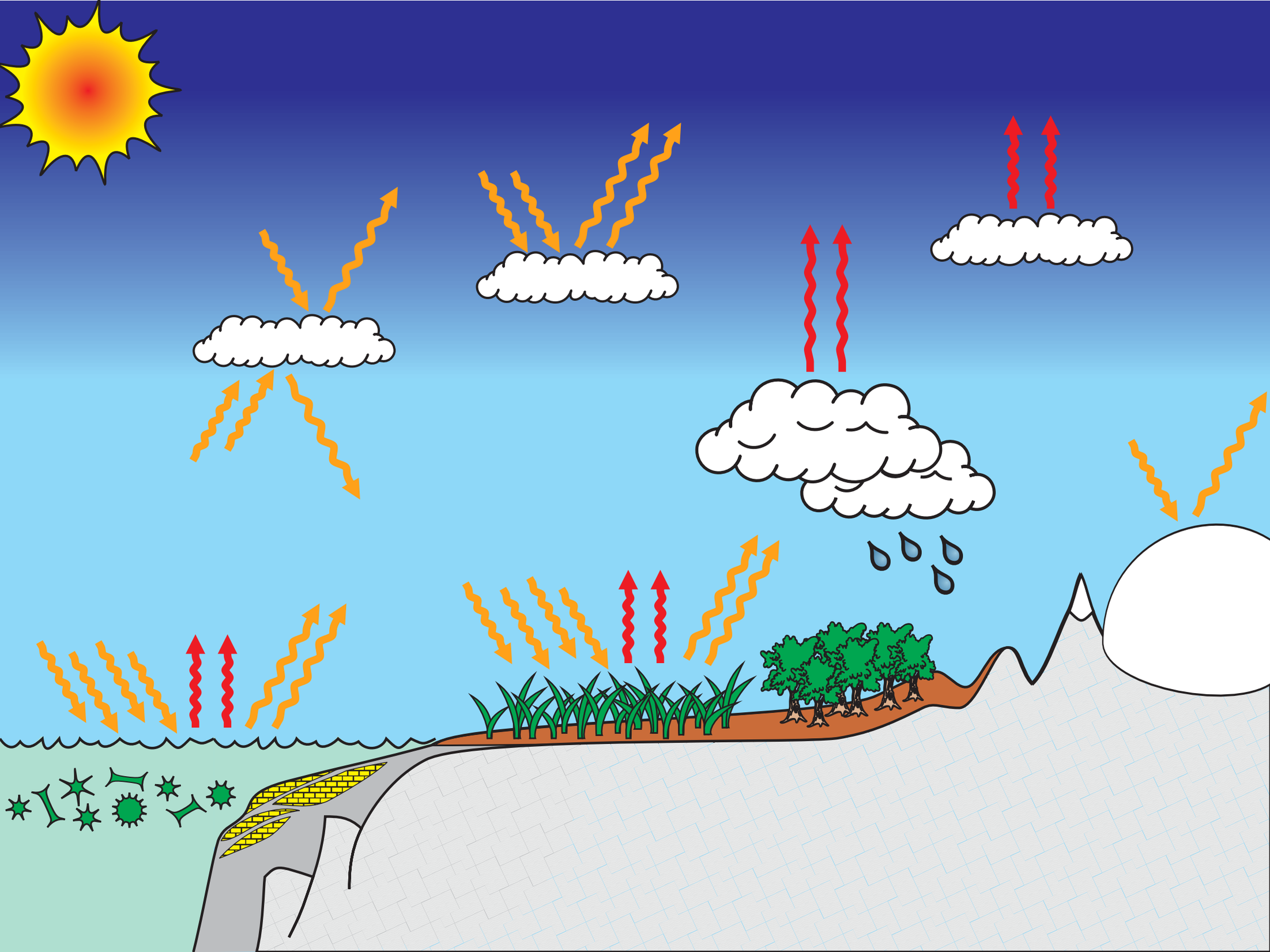
year
CO_2 Record from Mauna Loa
http://www.esrl.noaa.gov/gmd/ccgg/trends/

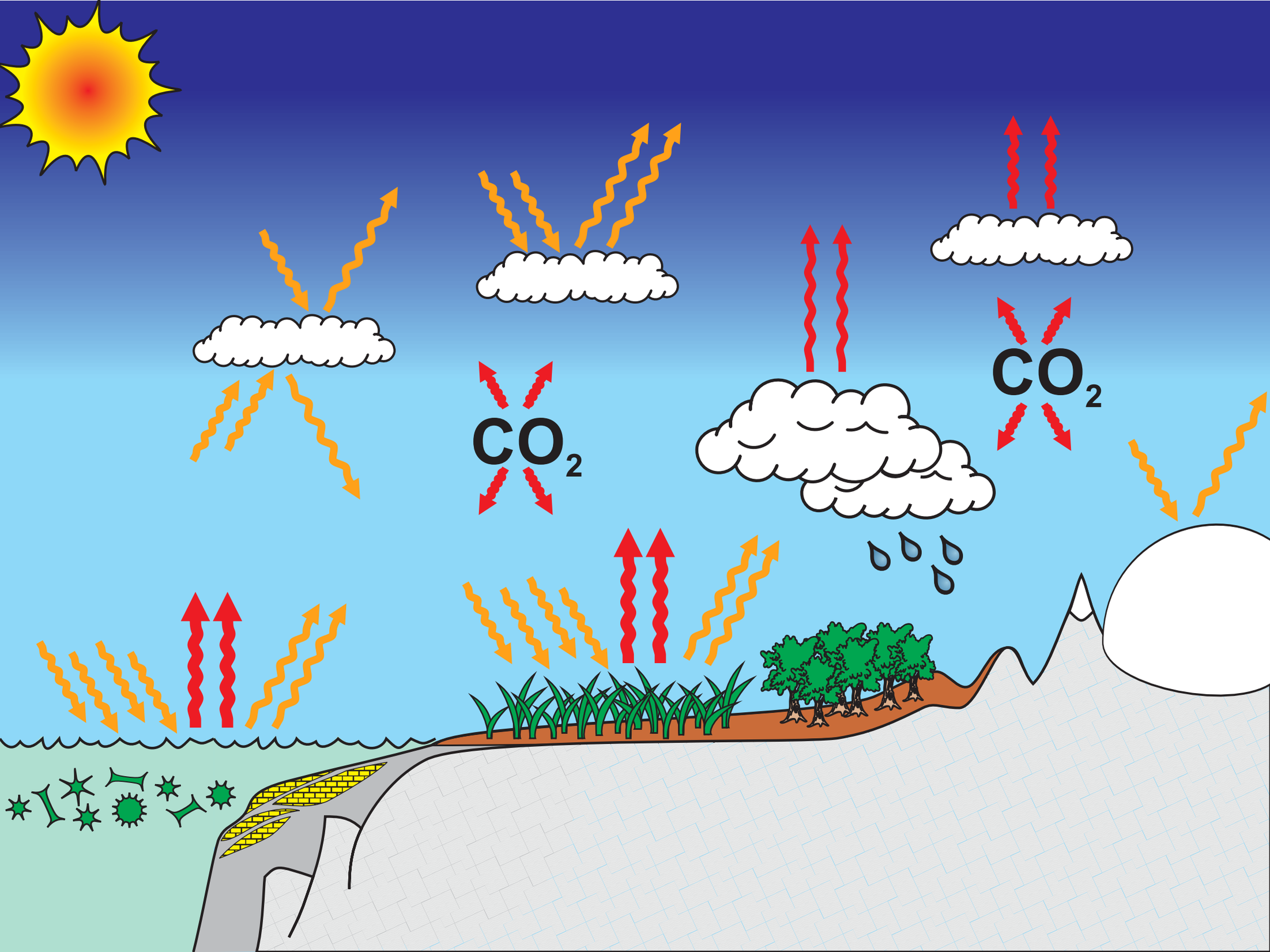
1. (projected) climatic consequences

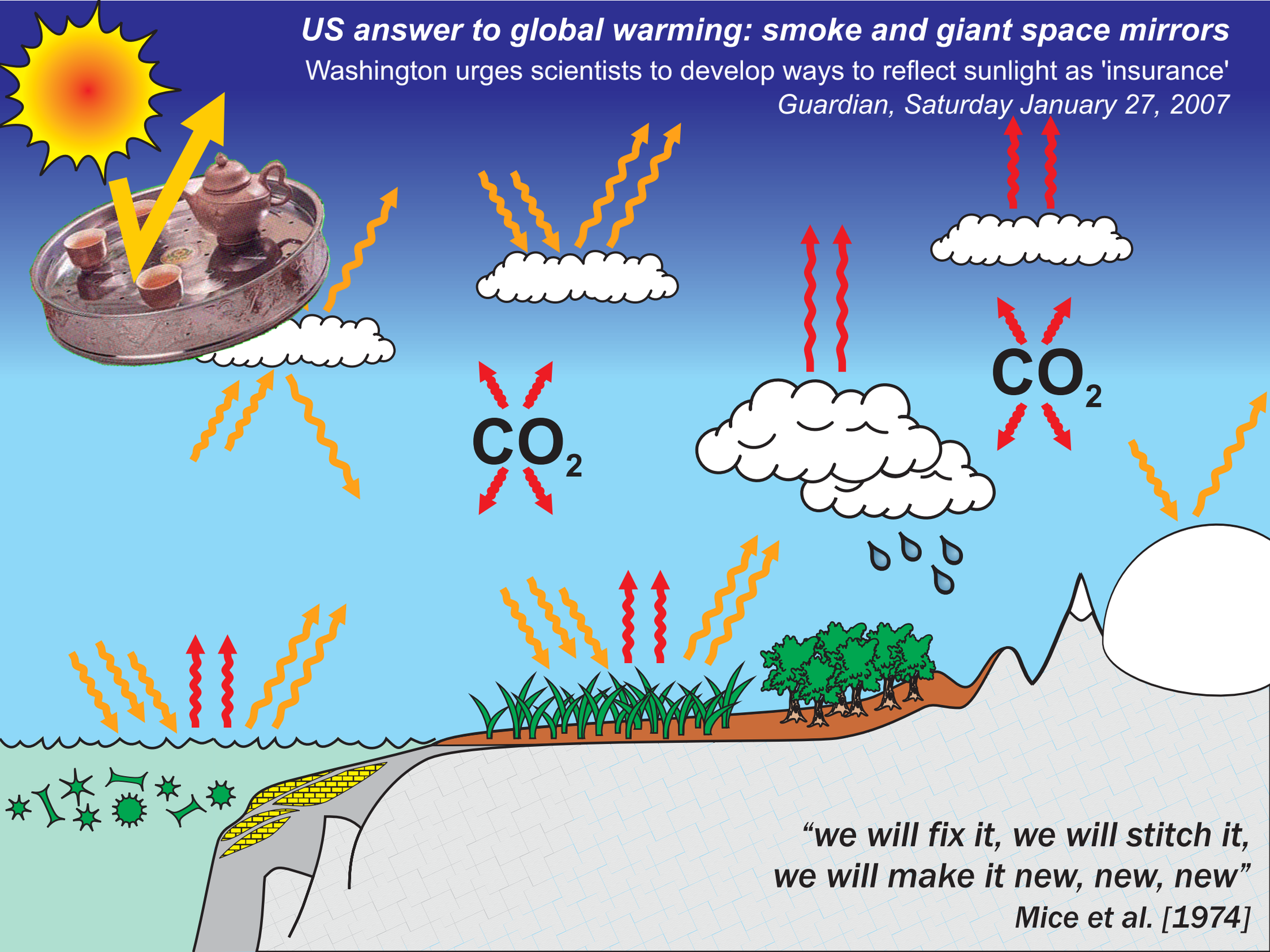


2. Ocean geochemical / ecological consequences






CO_2
CO_2


US answer to global warming: smoke and giant space mirrors
Washington urges scientists to develop ways to reflect sunlight as 'insurance'
Guardian, Saturday January 27, 2007
CO2
CO2
"we will fix it, we will stitch it,
we will make it new, new, new"
Mice et al. [1974]

'Sunshield' geoengineering

Space reflector

Effectiveness

Affordability

0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5

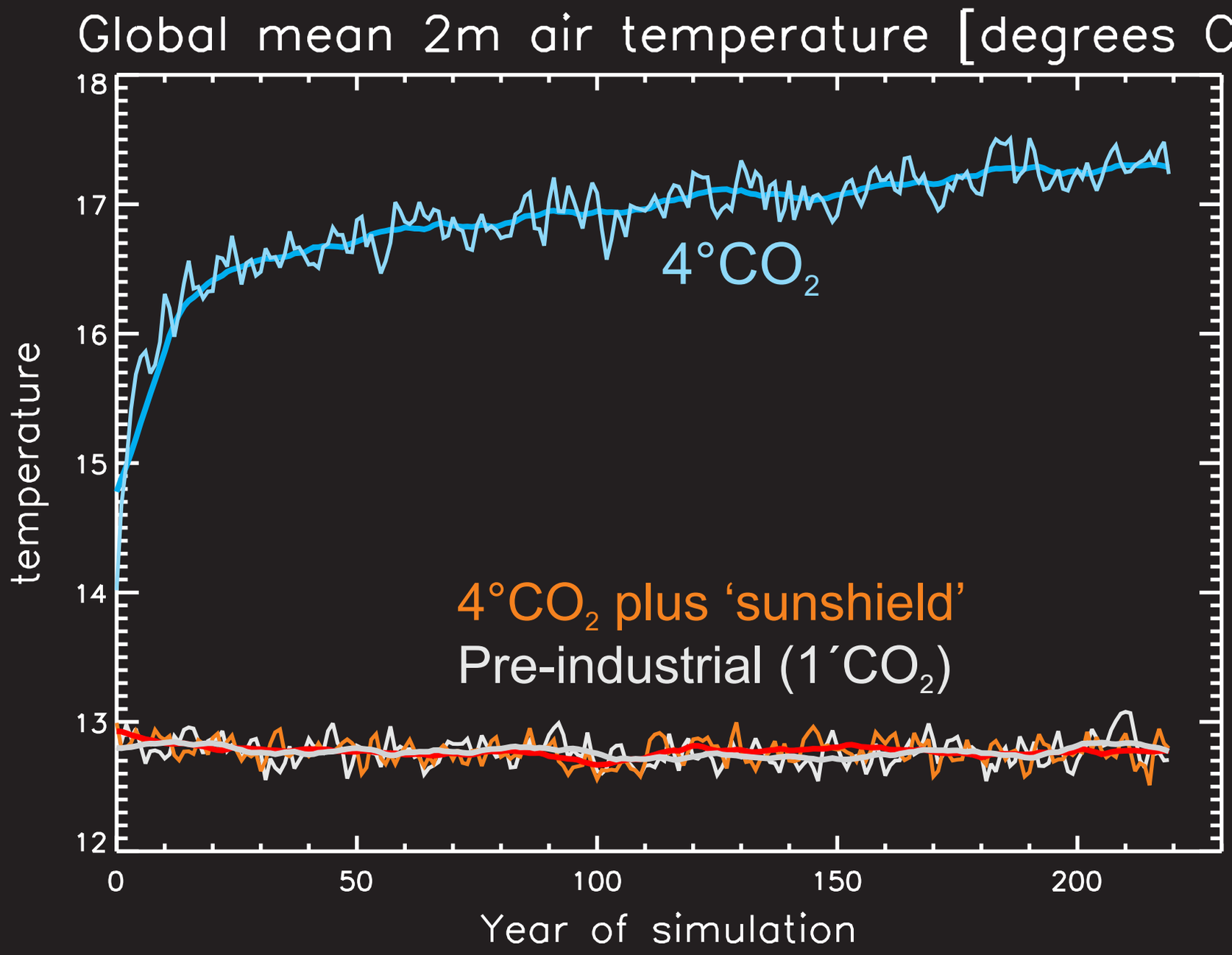
0 1 2 3 4 5 6

Safety: red=low; green=high

Timeliness: large=quick; small=slow

Royal Society [2009]

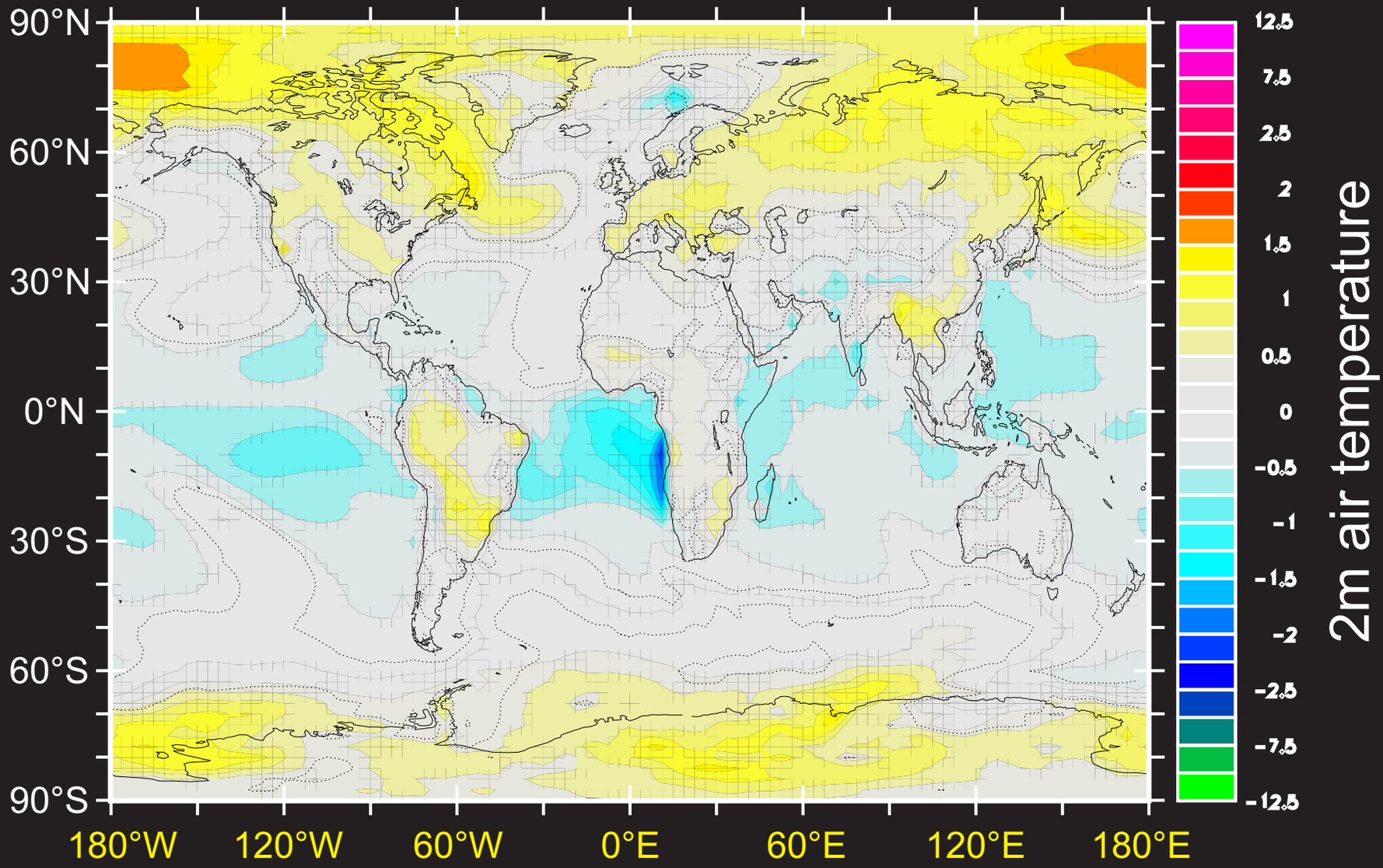
'Sunshield' geoengineering



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

'Sunshield' geoengineering

Difference between 4×CO_2 in the atmosphere with a 'sunshield' (4.2% reduced incident solar intensity) and Pre-industrial (1×CO_2) control.



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

Increasing the reflectiveness of crops

Royal Society [2009]

Whitening clouds

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

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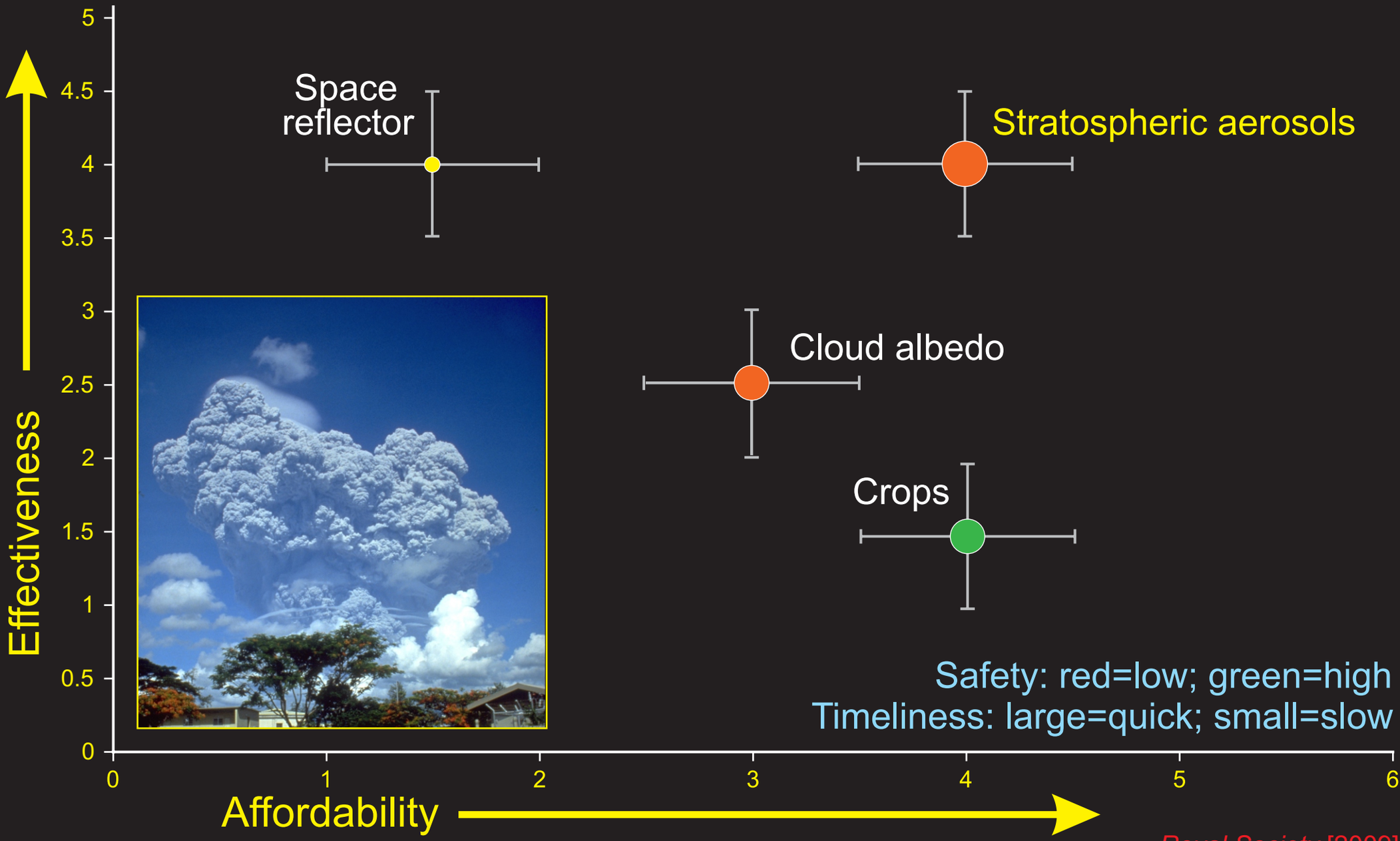
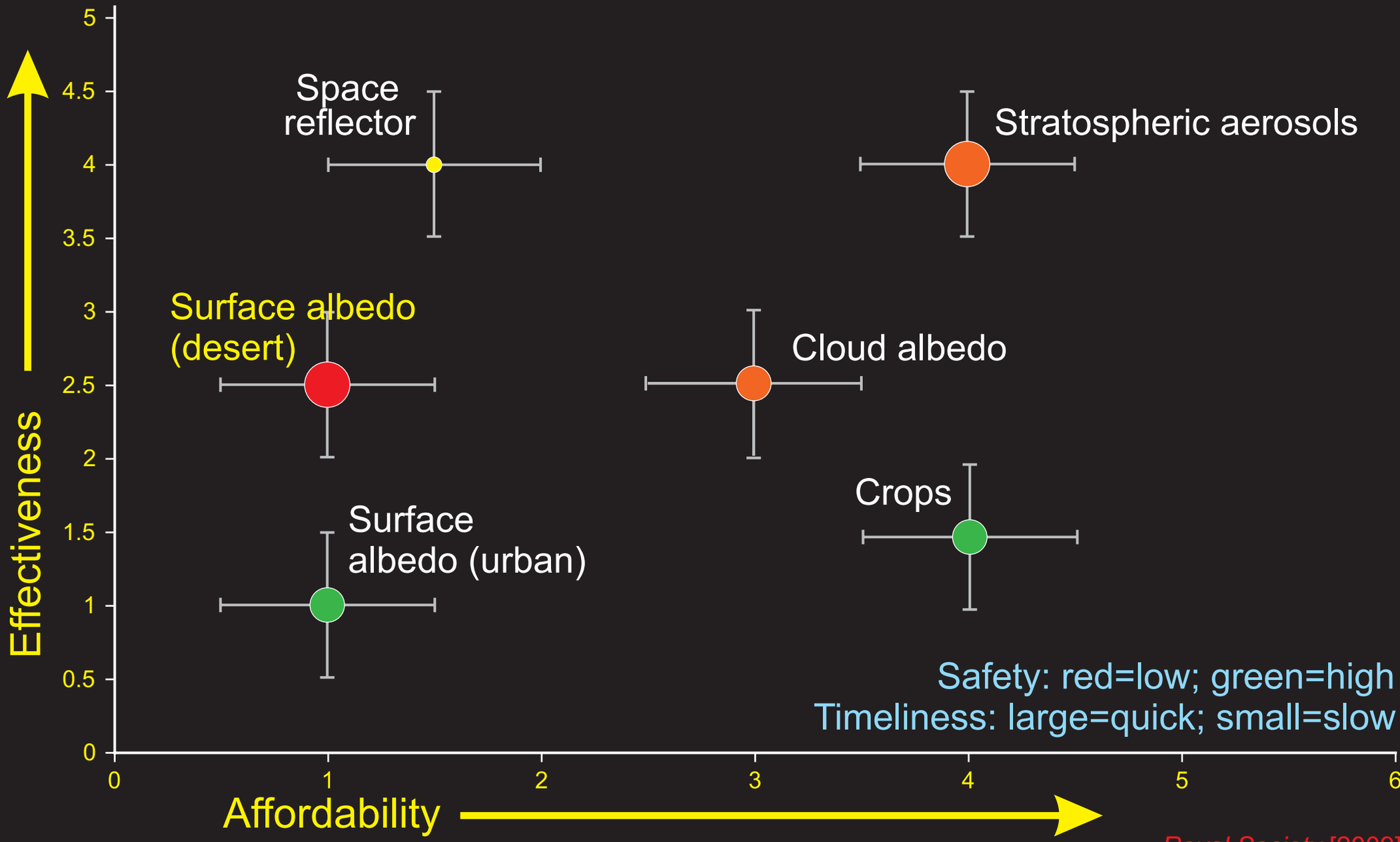
Royal Society [2009]

Stratospheric aerosol geoengineering



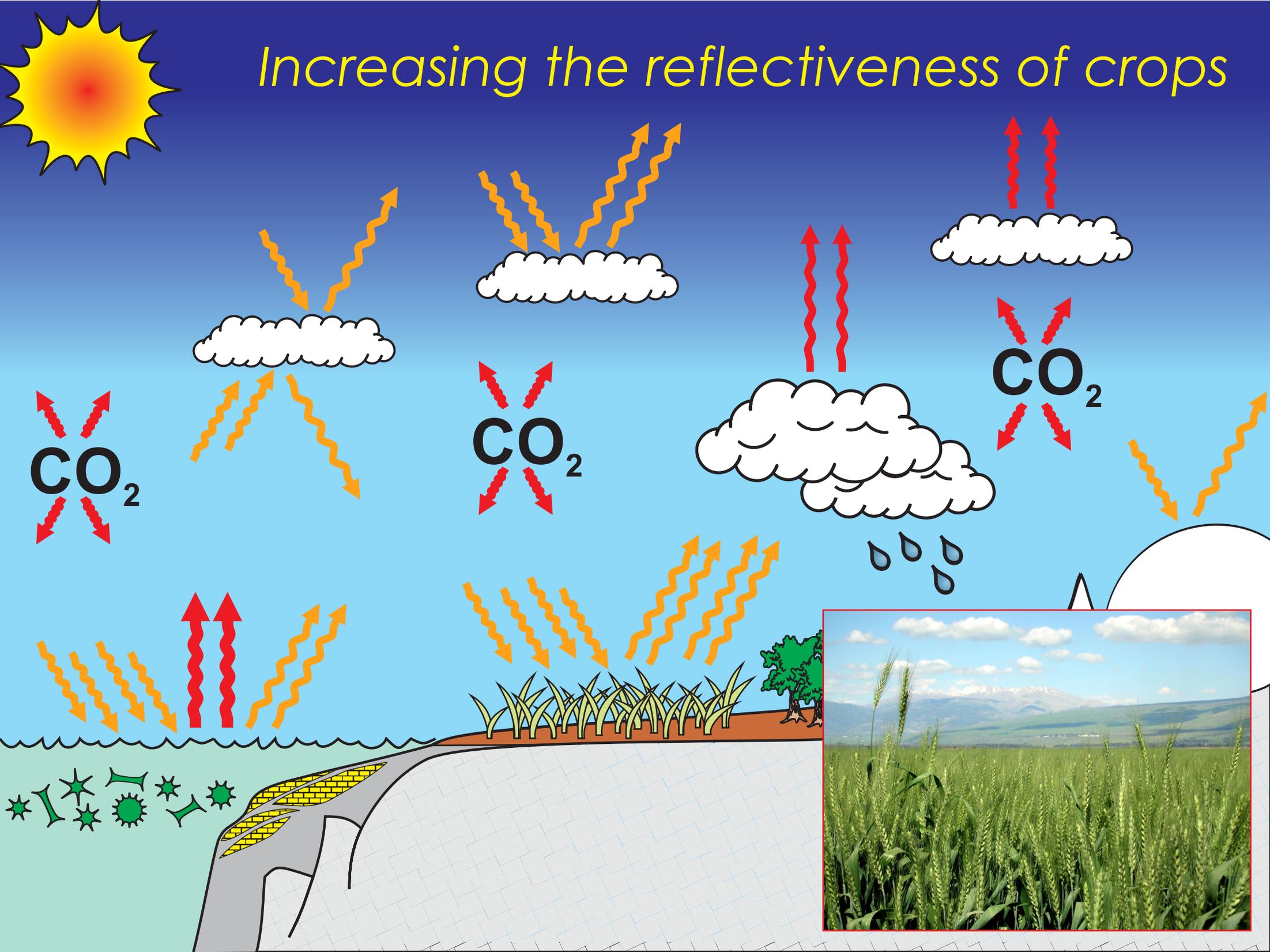
Royal Society [2009]

Solar radiation management geoengineering summary



Royal Society [2009]

Increasing the reflectiveness of crops



Cooling the Planet with Crops (background)

albedo ~ 0.23
(77% absorption)

albedo ~ 0.18
(82% absorption)

albedo ~ 0.16
(84% absorption)

Decreasing albedo

Increasing reflectivity

Cooling the Planet with Crops (background)

albedo ~ 0.26
(74% absorption)

sugar beet

albedo ~ 0.23
(77% absorption)

barley

Decreasing albedo

Increasing reflectivity

Cooling the Planet with Crops (background)

albedo ~ 0.25
(75% absorption)

albedo ~ 0.23
(77% absorption)

albedo ~ 0.21
(79% absorption)

Decreasing albedo

Increasing reflectivity

Cooling the Planet with Crops (background)

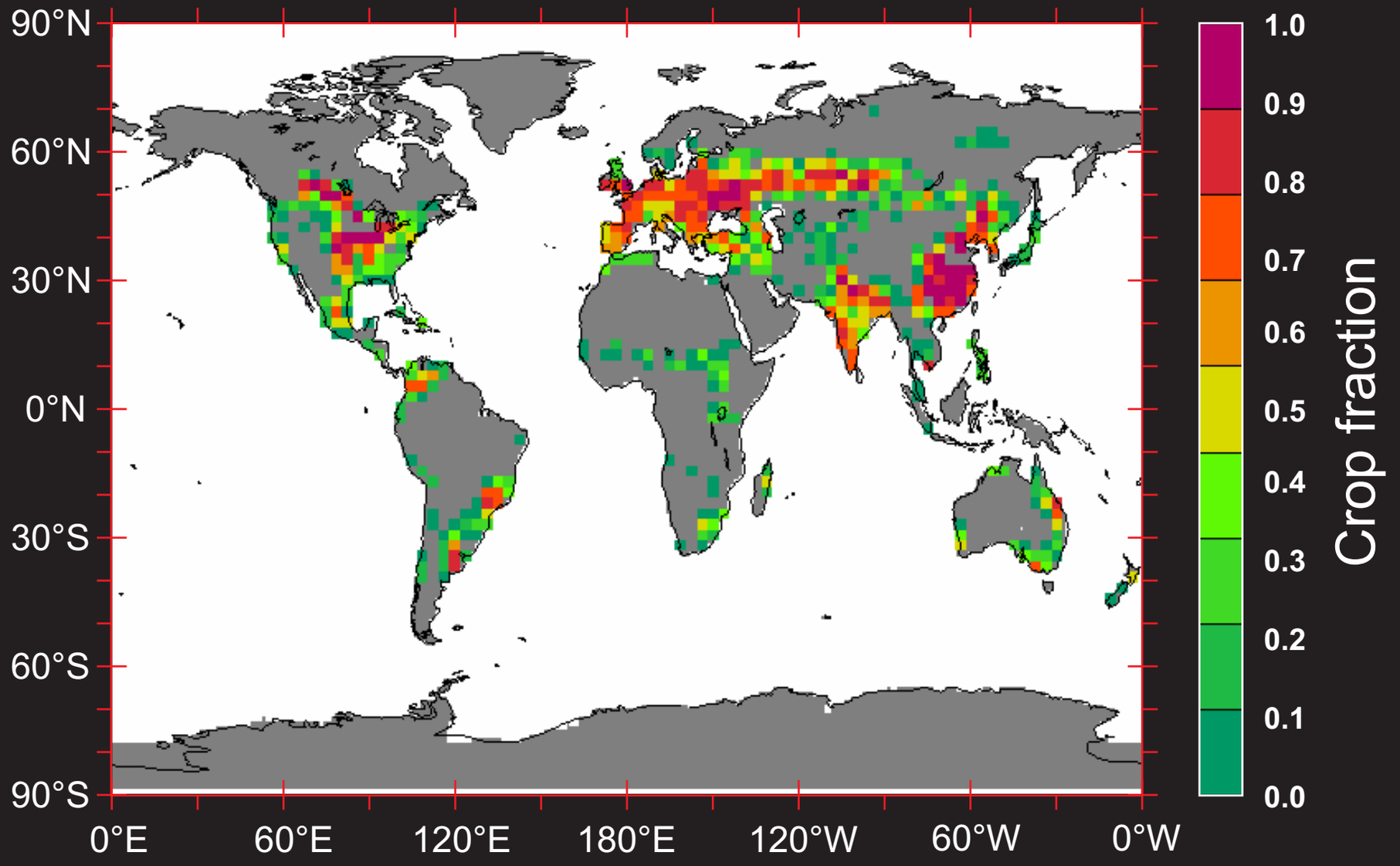
Controls on (intra) variety crop albedo:

leaf waxiness

leaf/stem hairs

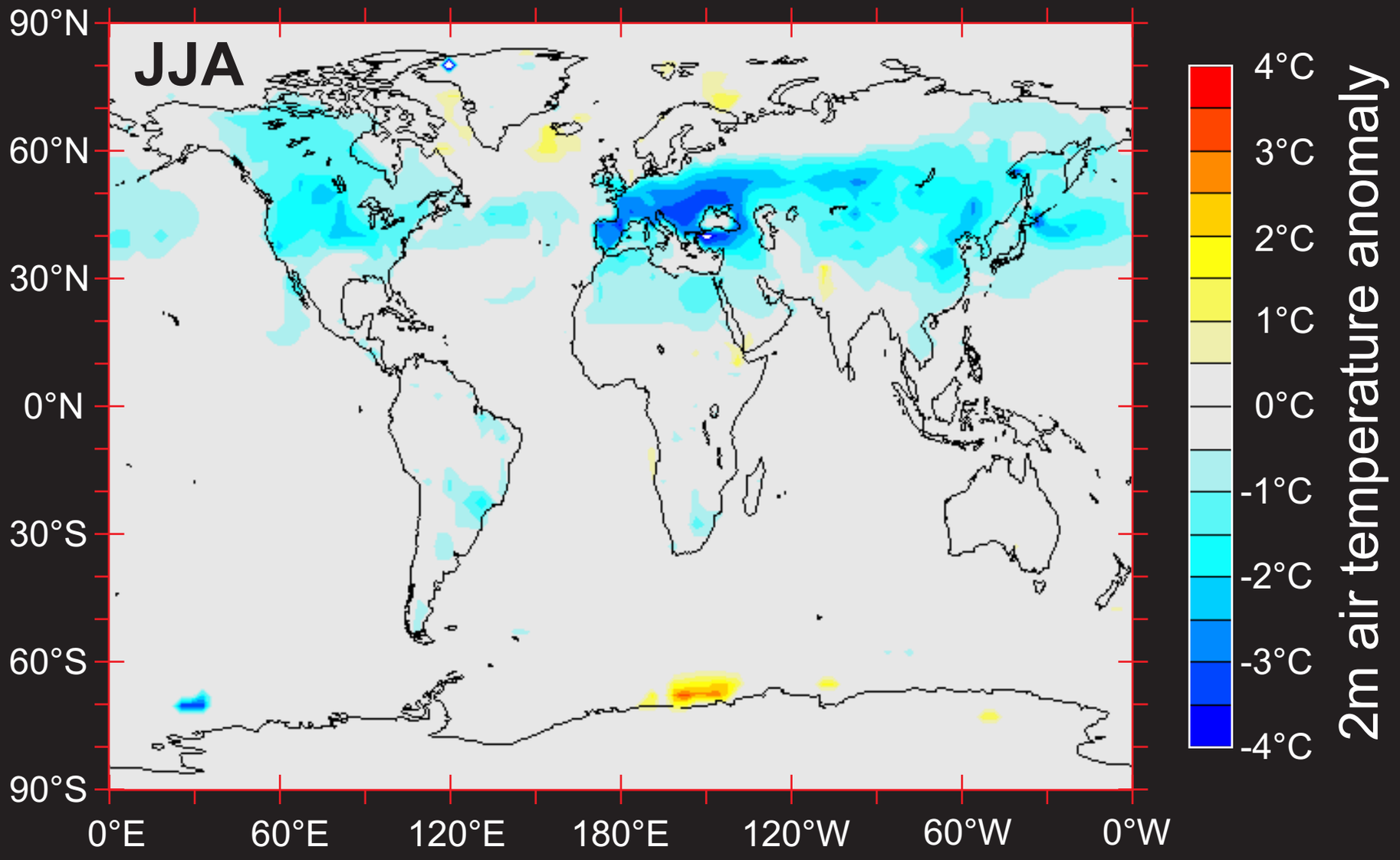
canopy structure

Cooling the Planet with Crops (proof-of-concept)



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

Cooling the Planet with Crops (proof-of-concept)



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

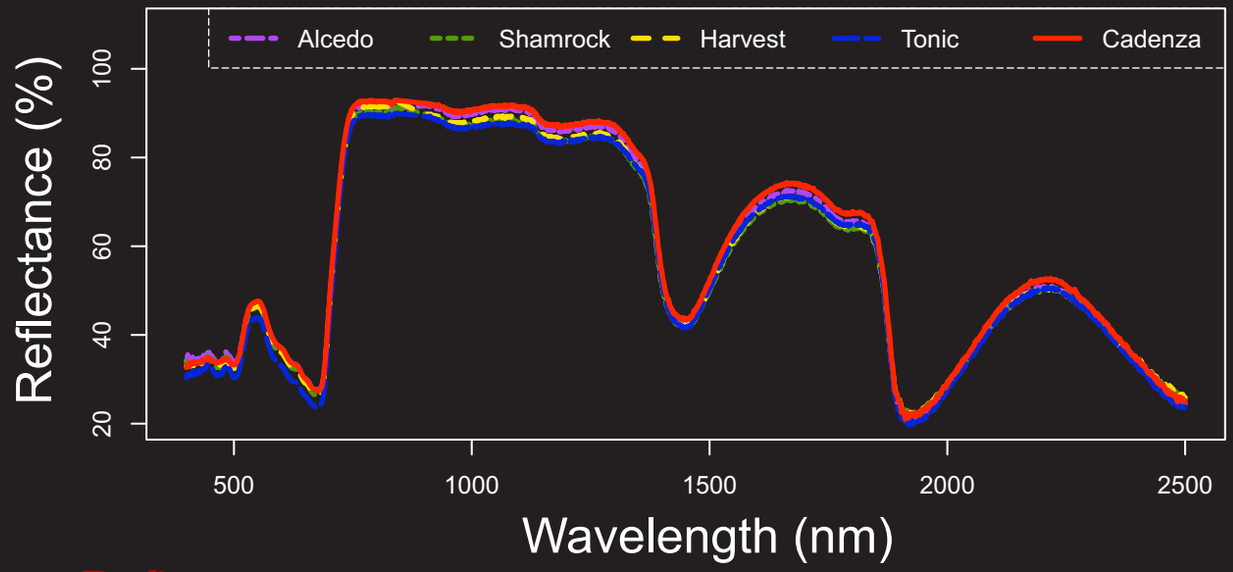
Cooling the Planet with Crops (feasibility)

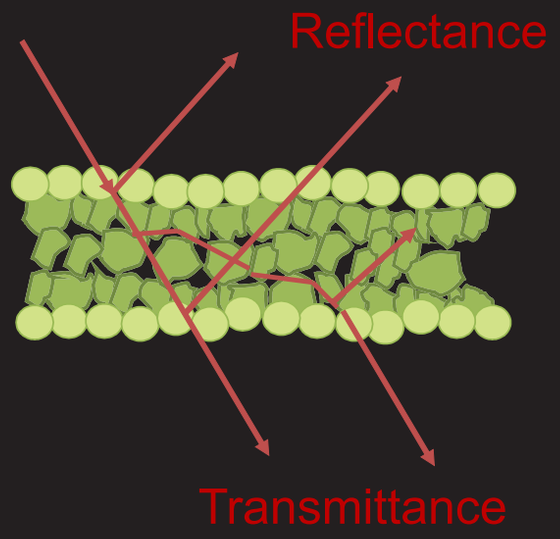
#1 Growing range of commercially available strains of wheat.

Cooling the Planet with Crops (feasibility)

#1 Growing range of commercially available strains of wheat.

#2 Measuring reflectance and transmissivity of the leaves.





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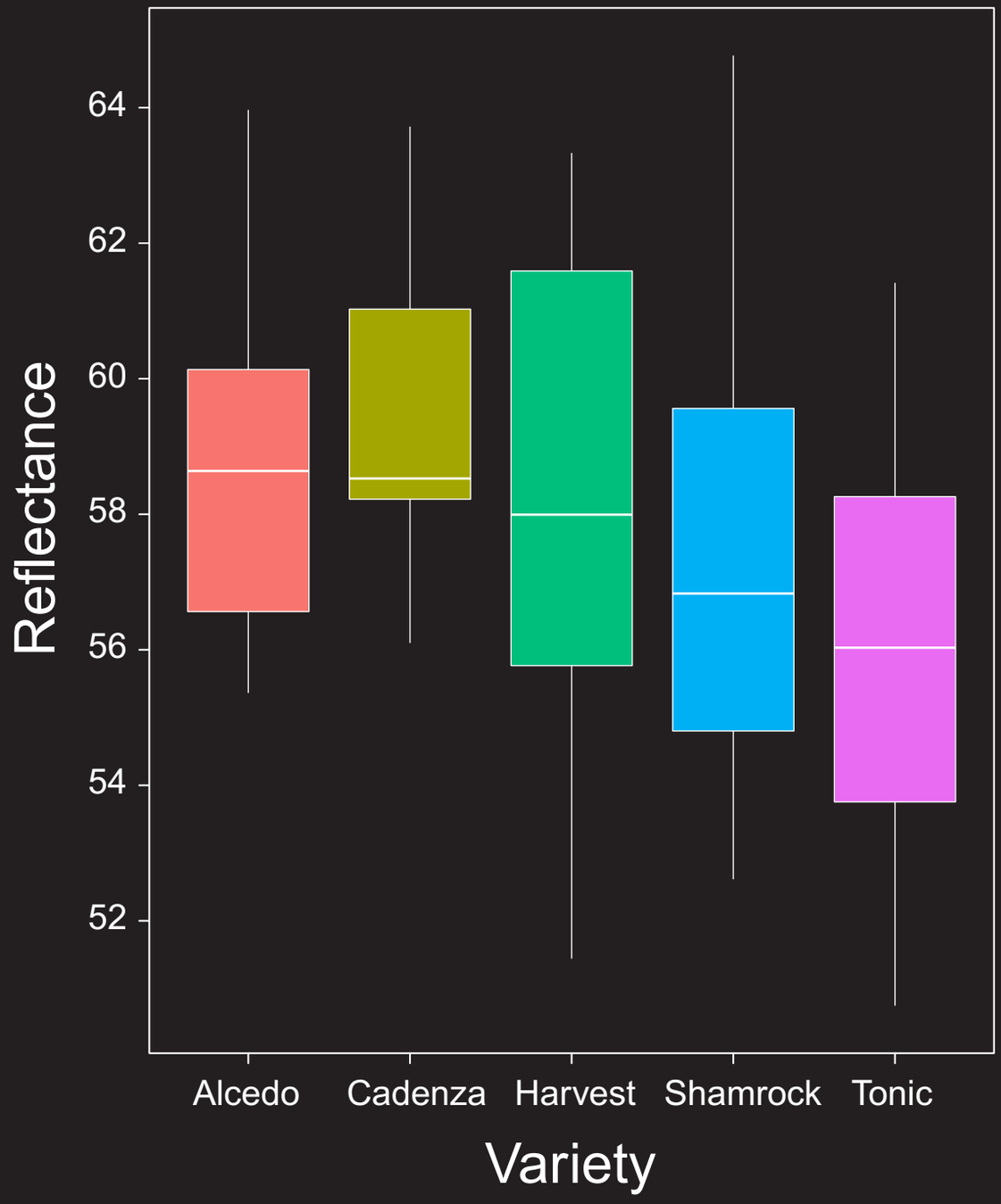


Cooling the Planet with Crops (feasibility)

#1 Growing range of commercially available strains of wheat.

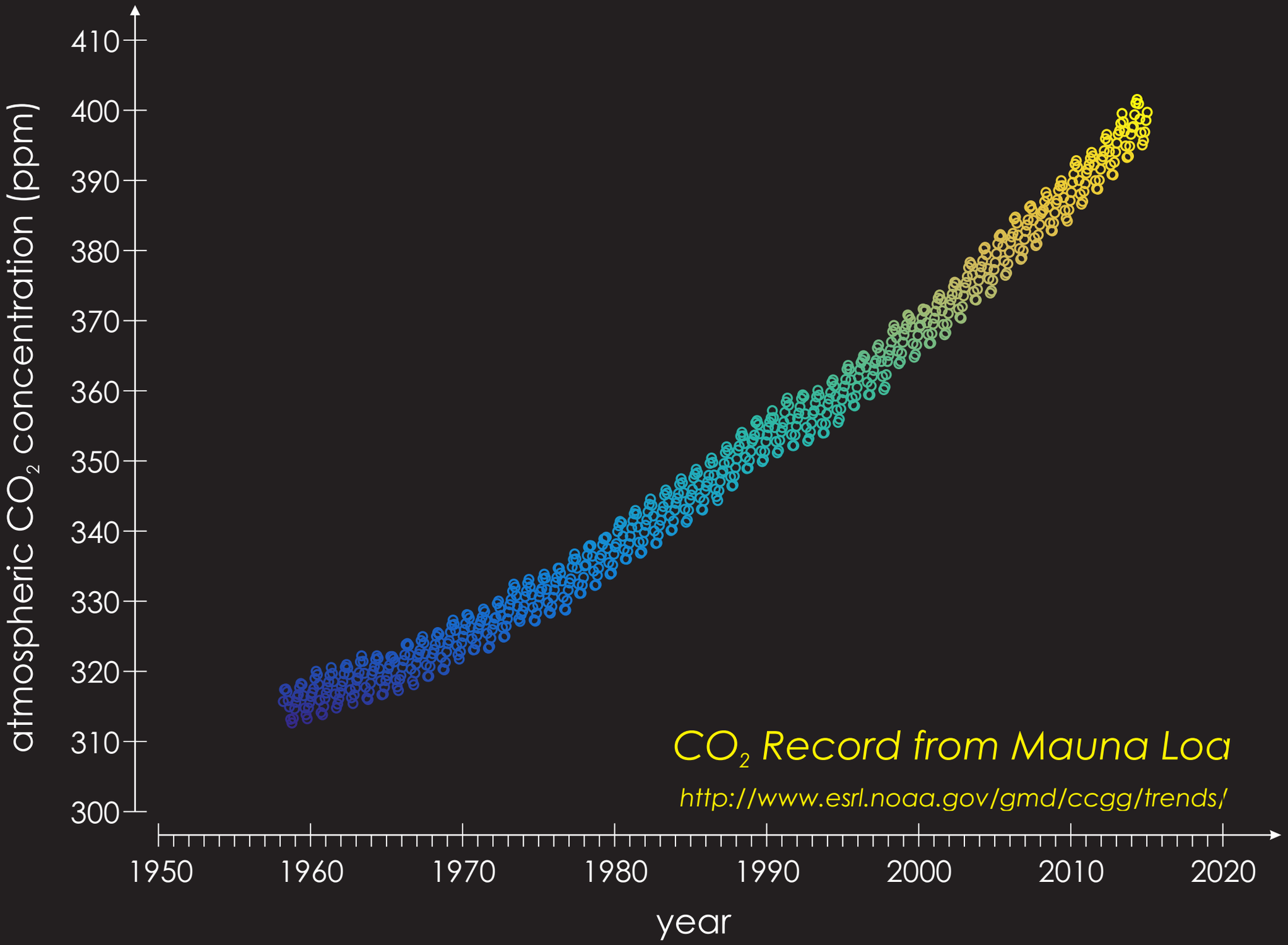
#2 Measuring reflectance and transmissivity of the leaves.

#3 Calculation of yield in crop models.

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

#5 Field measurements.

#6 ...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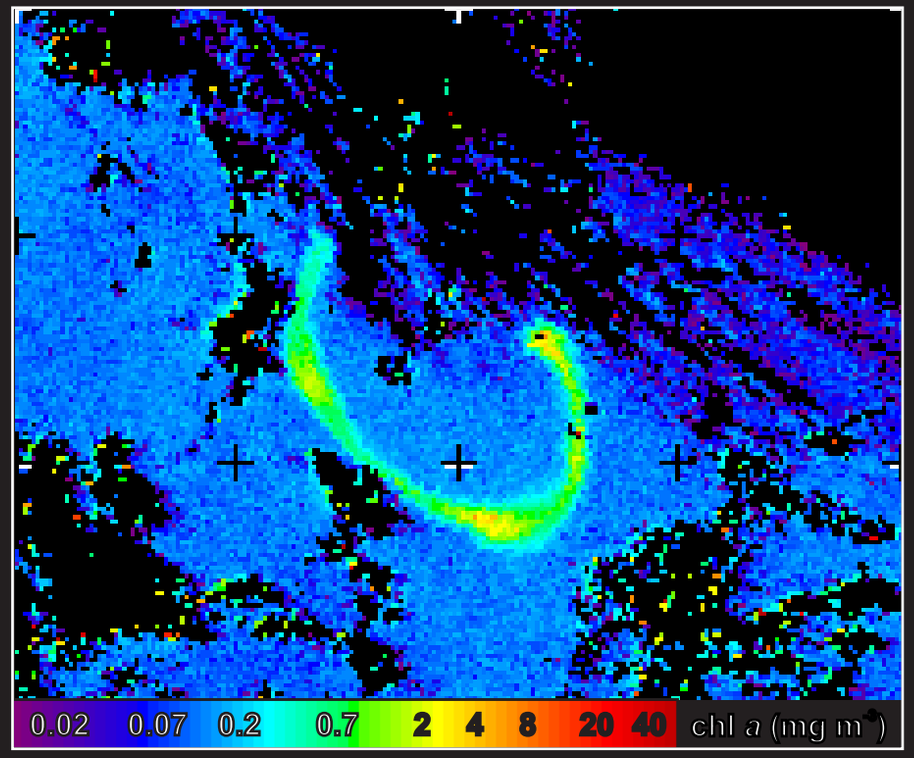
CO_2 Record from Mauna Loa
http://www.esrl.noaa.gov/gmd/ccgg/trends/

Sequestering CO_2 directly in the ocean?

Brewer et al. [1999]

Ocean (iron) fertilization



Effectiveness

Affordability

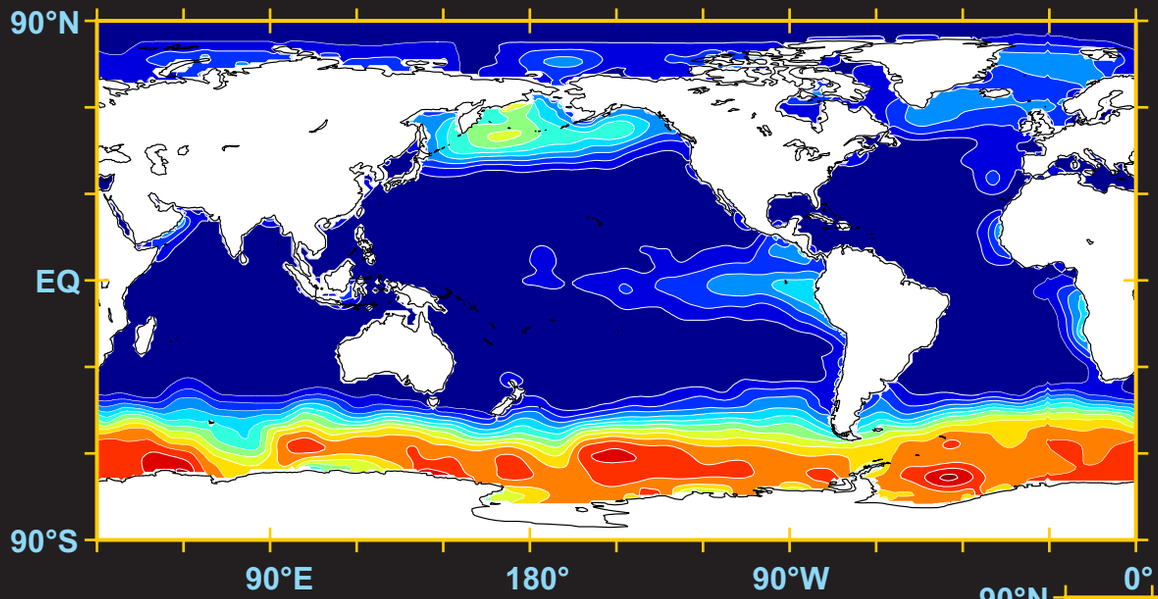
Ocean fertilisation

Safety: red=low; green=high

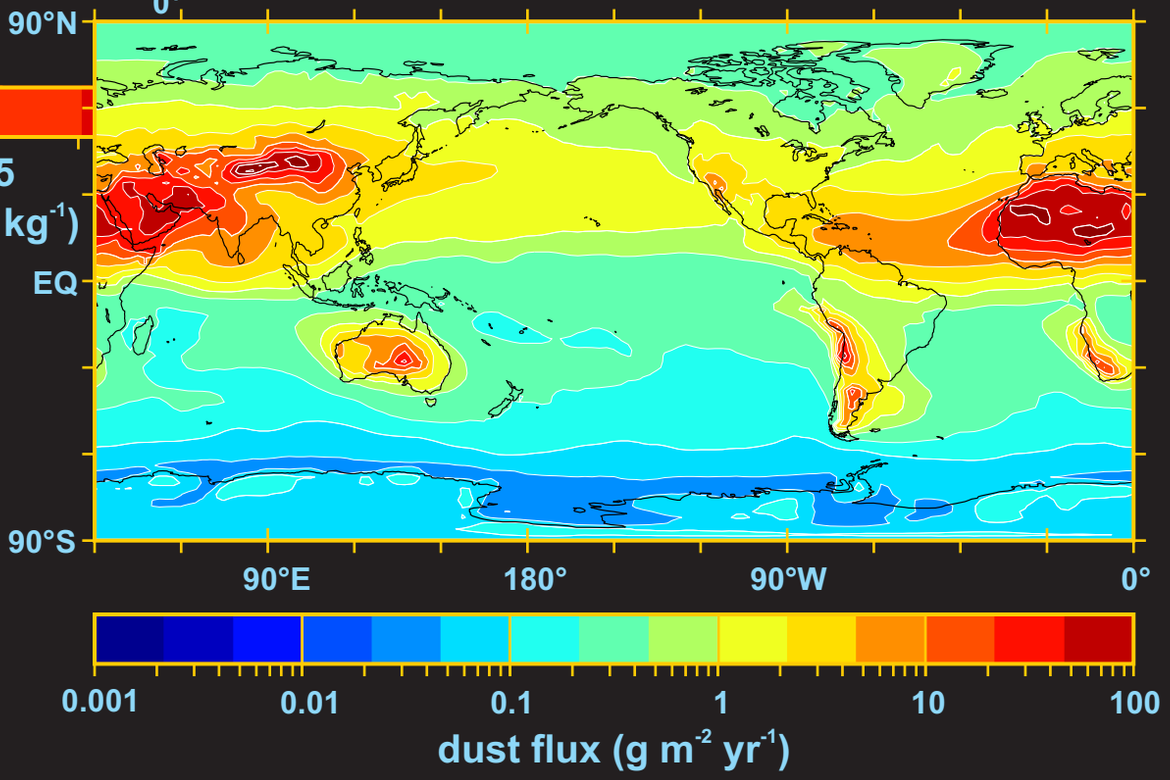
Timeliness: large=quick; small=slow

Royal Society [2009]

Global distribution of near-surface (30 m depth) ocean nitrate concentrations [*Conkright et al.*, 1994]

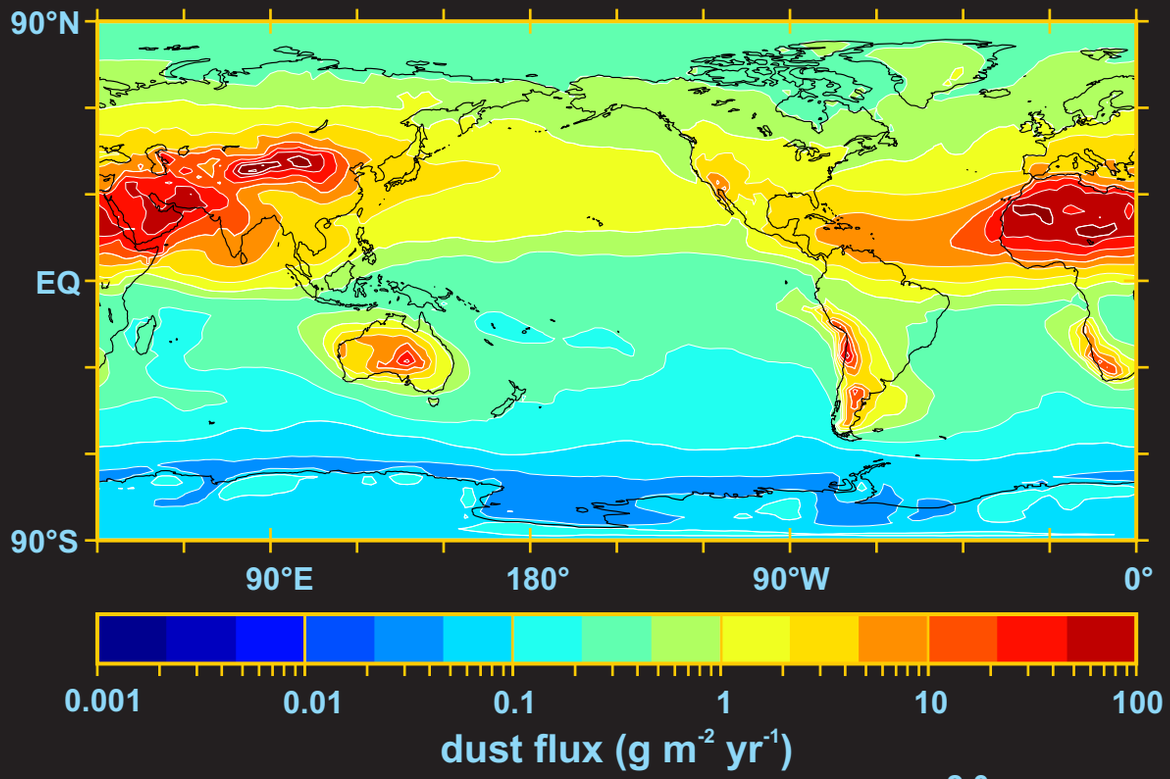


Model-simulated annual mean dust flux to the Earth's surface [*Ginoux et al.*, 2001]



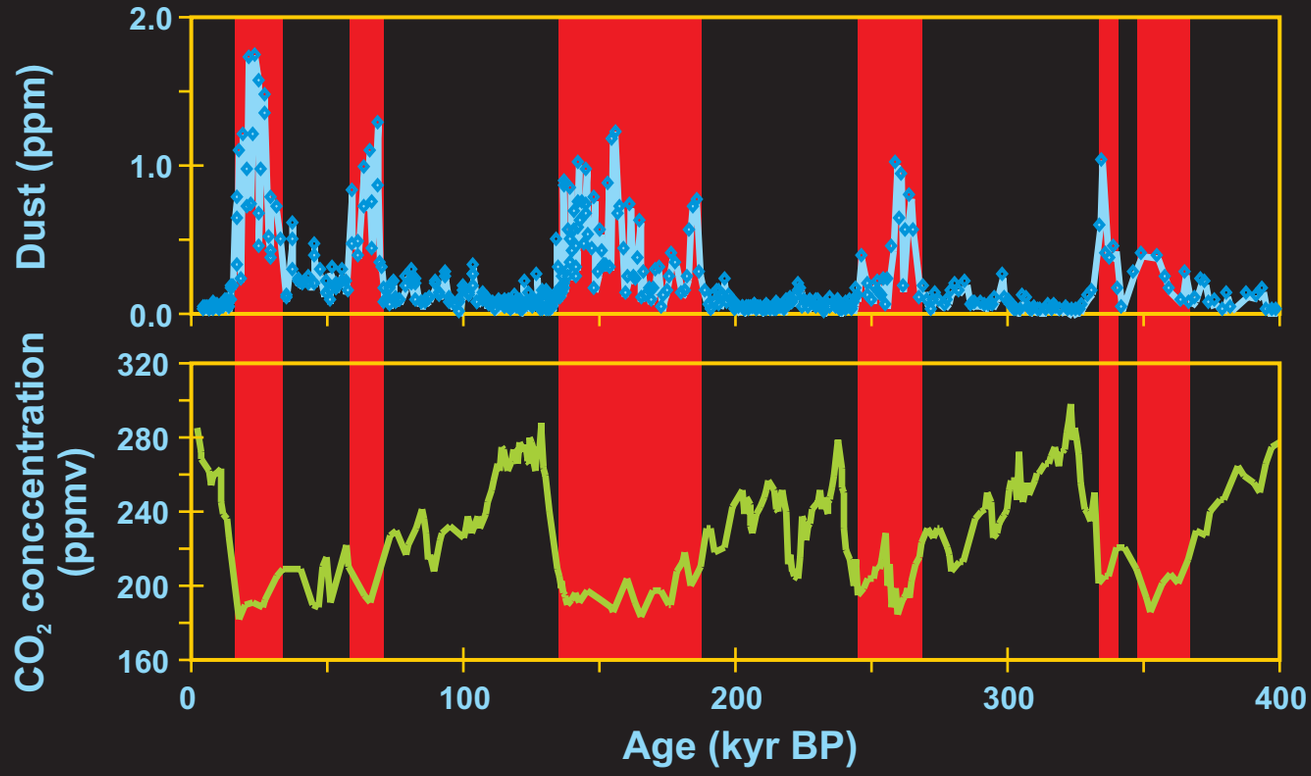
Modifying the 'biological pump' in the ocean

In oxic (oxygenated) seawater, Fe is only sparingly soluble, and tends to be 'scavenged' by particles and removed from the water column.

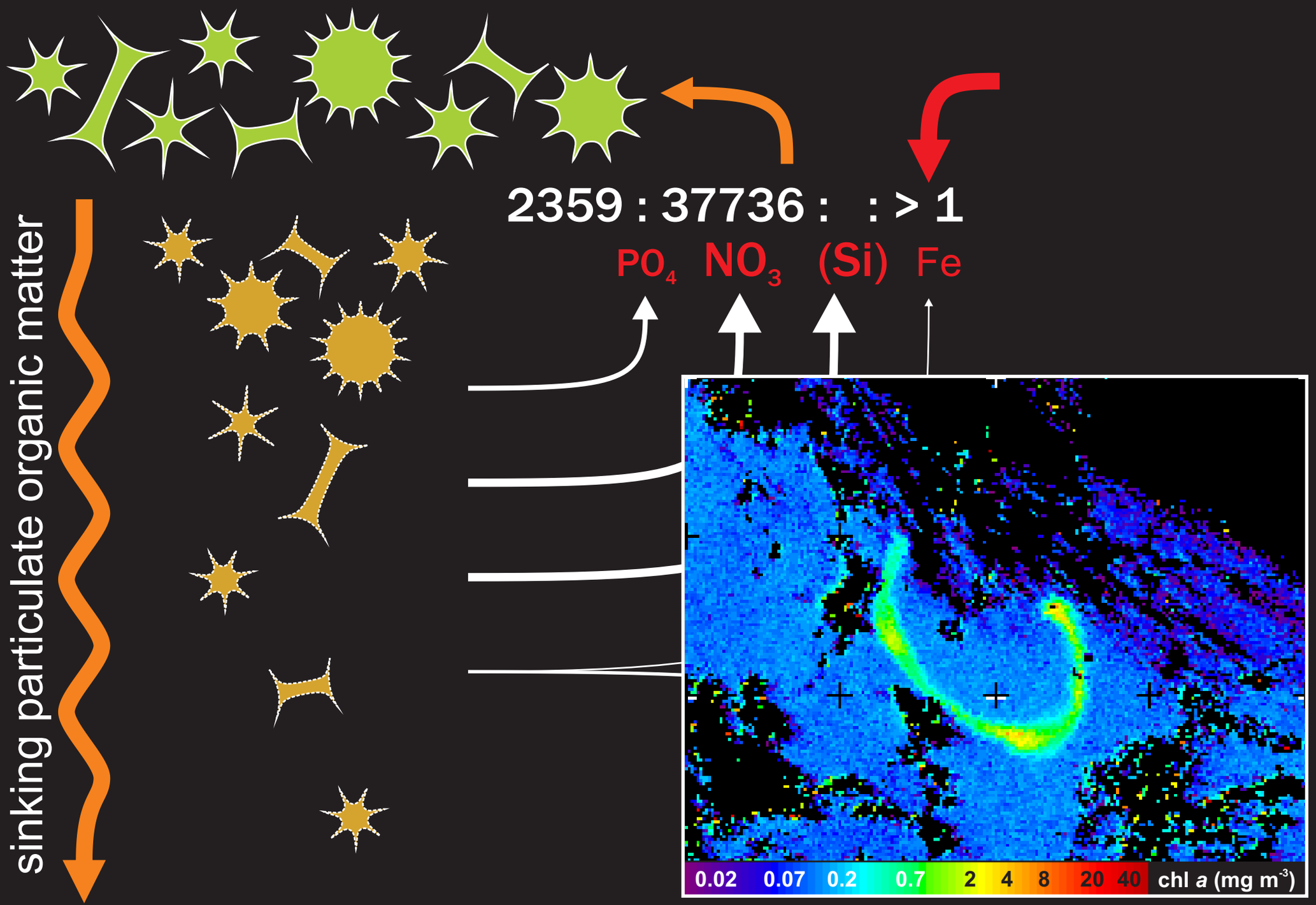


Model-simulated annual mean dust flux to the Earth's surface [*Ginoux et al.*, 2001]

Dust concentration (blue, top) and CO_2 content of air bubbles (green, bottom) trapped in the ice, both from the Vostok ice core, Antarctica. [*Petit et al.*, 1999]



'iron fertilization' of marine ecosystems



CO_2 capture from air

Safety: red=low; green=high
Timeliness: large=quick; small=slow

Royal Society [2009]

CO_2 capture from air: carbon disposal

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 $year^{-1}$

CO_2 capture from air: carbon disposal

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⇒ oil consumption
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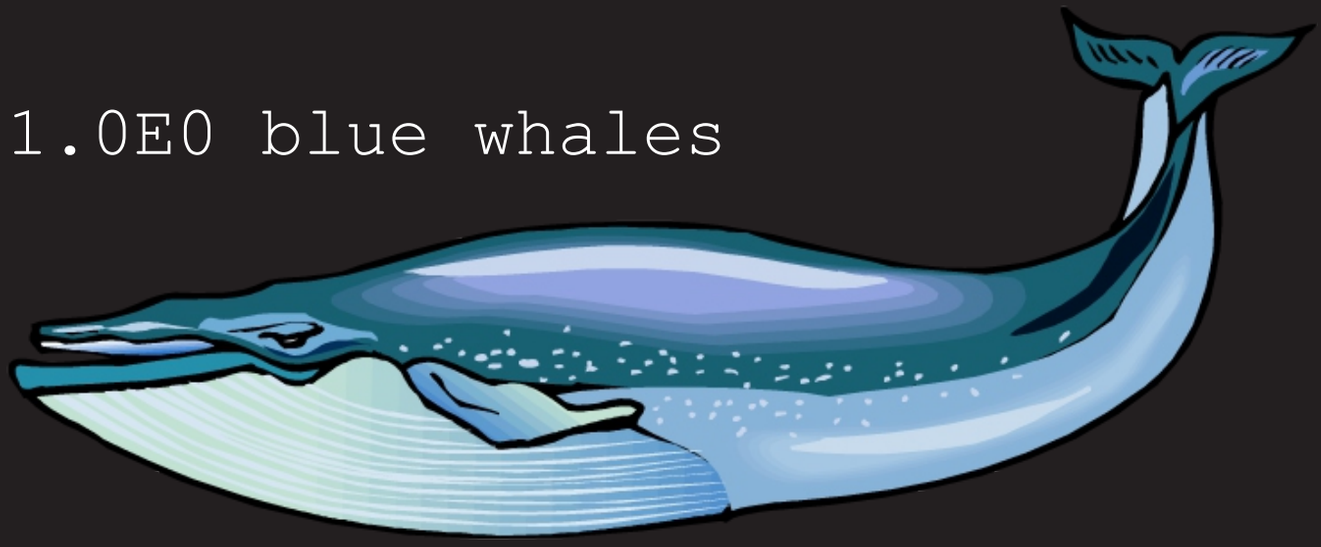
= 5.23 km^3 $year^{-1}$

1.0E0 blue whales



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1.0E0 Avon Gorges

CO_2 capture from air: carbon disposal

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

1.0 barrel = 159 l
= 159×10^3 cm^3

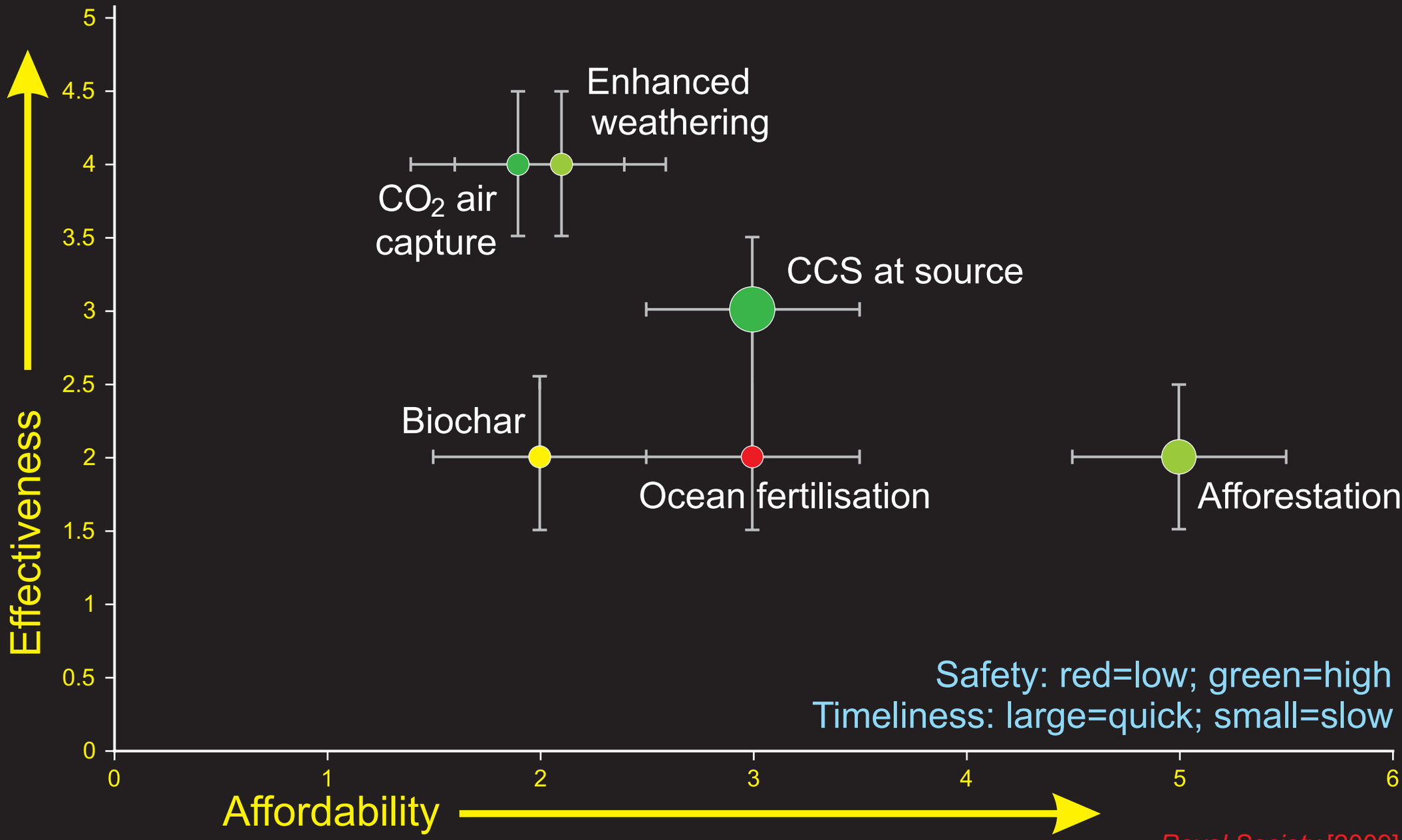
⇒ oil consumption
= 5.23×10^{15} cm^3 $year^{-1}$
= 5.23 km^3 $year^{-1}$

Assume:
101m deep × 214 across (at Bridge), 2.5 km long
⇒
volume = 2.5×0.101×0.214
= 0.054 km^3

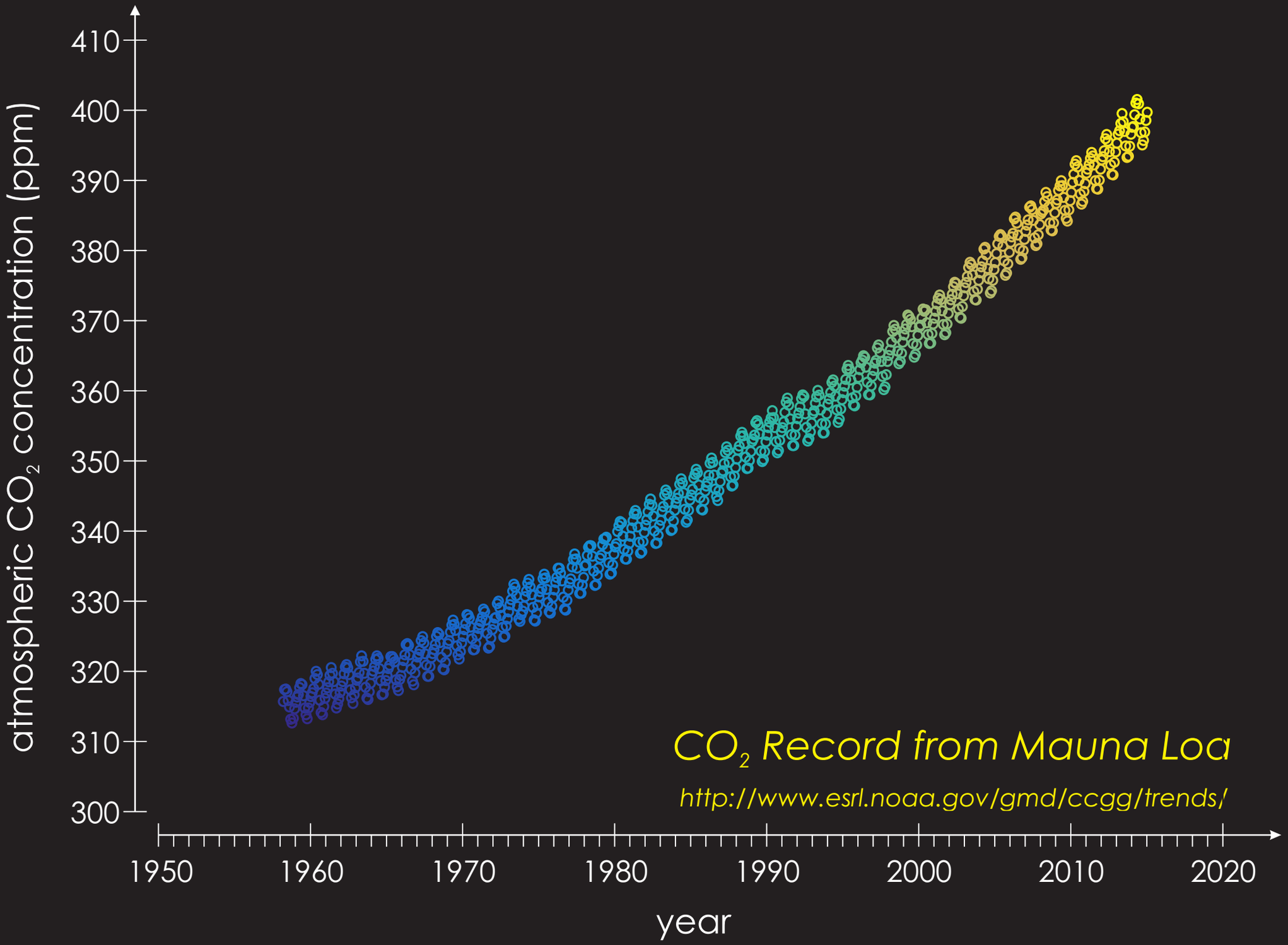
(3.8 days worth of global oil supply by volume)

1.0E0 Avon Gorges

Carbon dioxide removal geoengineering summary



Royal Society [2009]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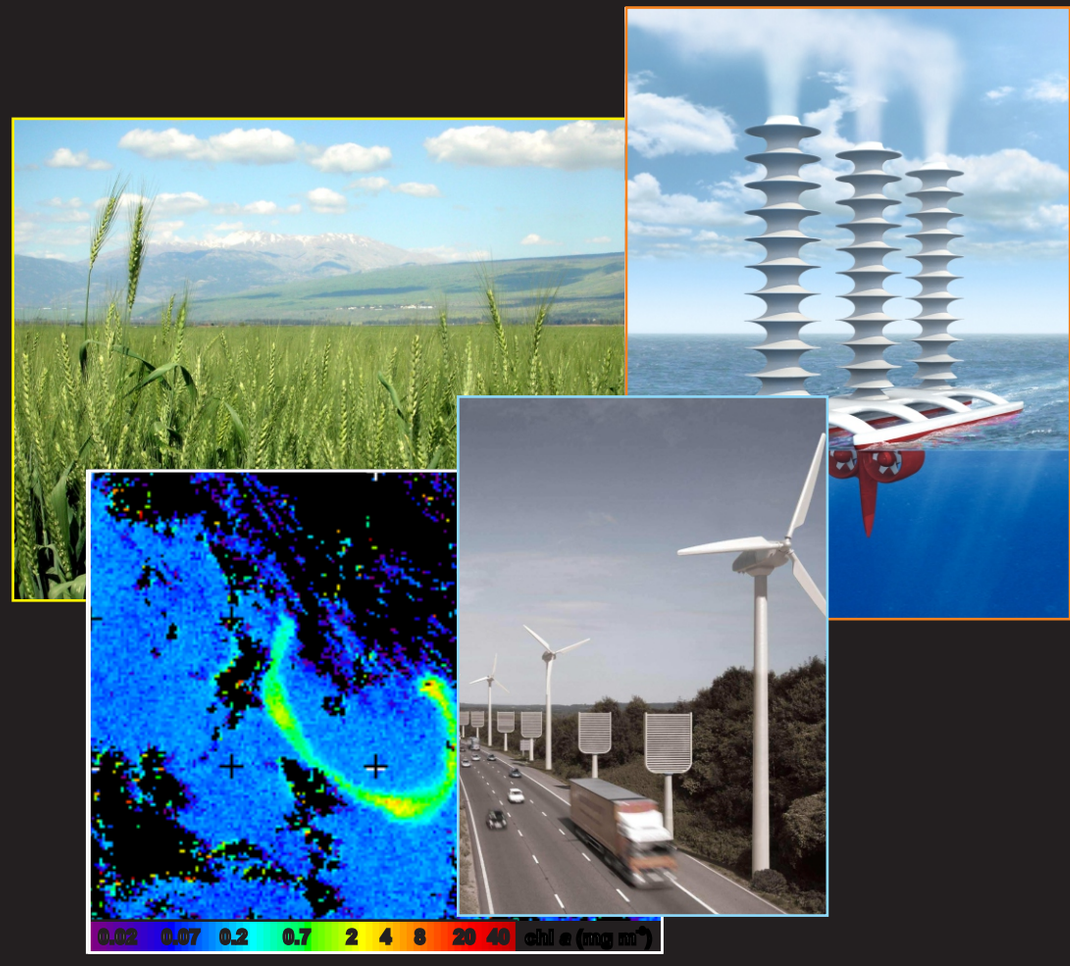
http://www.esrl.noaa.gov/gmd/ccgg/trends/



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].

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