UNFCCC [United Nations Framework Convention on Climate Change] *aims "to stabilize greenhouse gas concentrations at a level that would prevent dangerous anthropogenic (human induced) interference with the climate system"*

The Paris Agreement

- Mitigation (lowering greenhouse gas emissions through nationally determined contributions [NDCs] for all countries)
- Finance (from developed countries to developing countries, including information on finance to be provided in advance and accounting of finance provided)
- Enhanced Transparency Framework (to provide accountability on progress)
- Global Stocktake (to measure progress every five years)

COP24 Katowice

Changing together

Dec 2–15, 2018

Annual meeting of the **Conference of the Parties (COP)** to the **United Nations Framework Convention on Climate Change (UNFCCC)** where countries find consensus on documents outlining **global climate action**

196 member countries

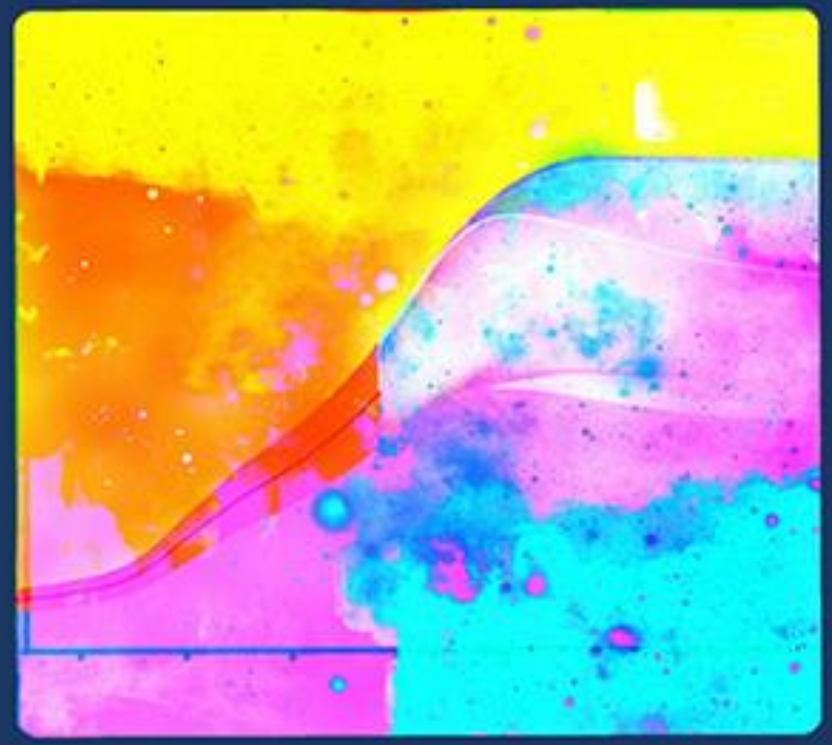
IPCC 1.5°C Report:

1) There is a BIG difference between 1.5 and 2 degrees.
2) Global warming is likely to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate.

ipcc
INTERGOVERNMENTAL PANEL ON climate change

Global Warming of 1.5°C

An IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty.



Subsidiary Body on Science and Technology Advancement (SBSTA)

Maldives (for AOSIS) supported by Colombia (for AILAC), Republic of Korea (for EIG), Ethiopia (for the LDCs), Norway, the EU, Canada, New Zealand, Ghana, South Africa, Tanzania, Zambia, and Argentina urged "welcoming," rather than "noting," the IPCC Special Report on Global Warming of 1.5°C in the draft conclusions.

Saudi Arabia, Kuwait, and Russian Federation opposed. The **US** said that the IPCC's acceptance of the Report does not imply that the US endorsed it.

What’s in a word? A lot, apparently…

Amjad Abdulla, Maldives

Maldives: *We, the group of Alliance of Small Island States believes that there is one paragraph where we have not been able to reach a consensus, and that is a paragraph that is critically important to our group and to many of the parties that are present here. That is the issue on how we as parties respond to the special report on 1.5 degrees by the IPCC.*

What's in a word? A lot, apparently…

Amjad Abdulla, Maldives

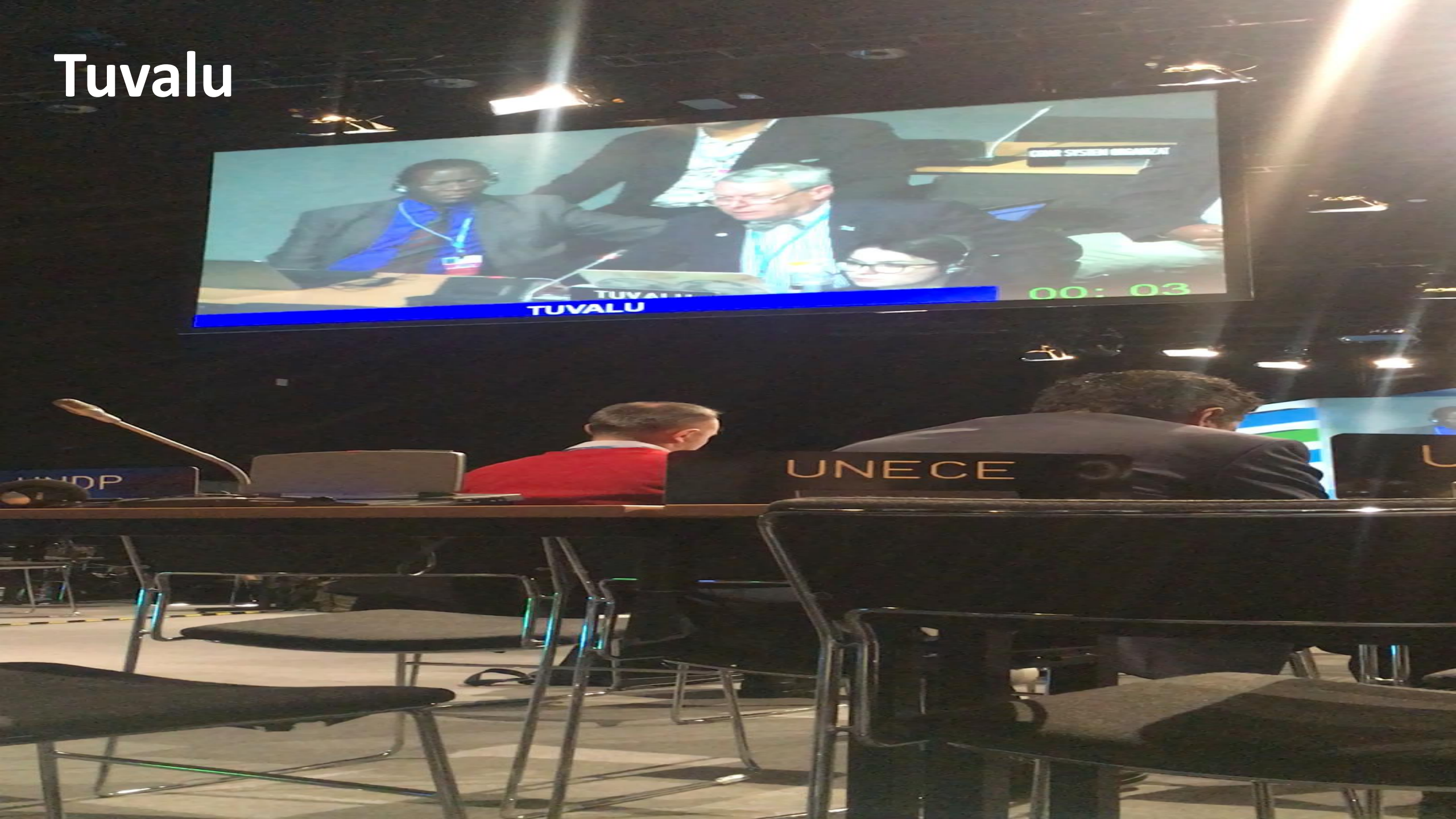
What signal does it send to the world and to the IPCC if we cannot welcome the best available science?

We need to welcome it, and we need to listen, and we need to show that the world is serious about tackling climate change, that we have understood. And the message that the science is sending to us, that is one of the greatest urgency.

Therefore we insist on ***welcoming*** *the report of the IPCC. Thank you*


This is ludicrous!

Tuvalu



New Zealand

Switzerland

USA

Marshall Islands

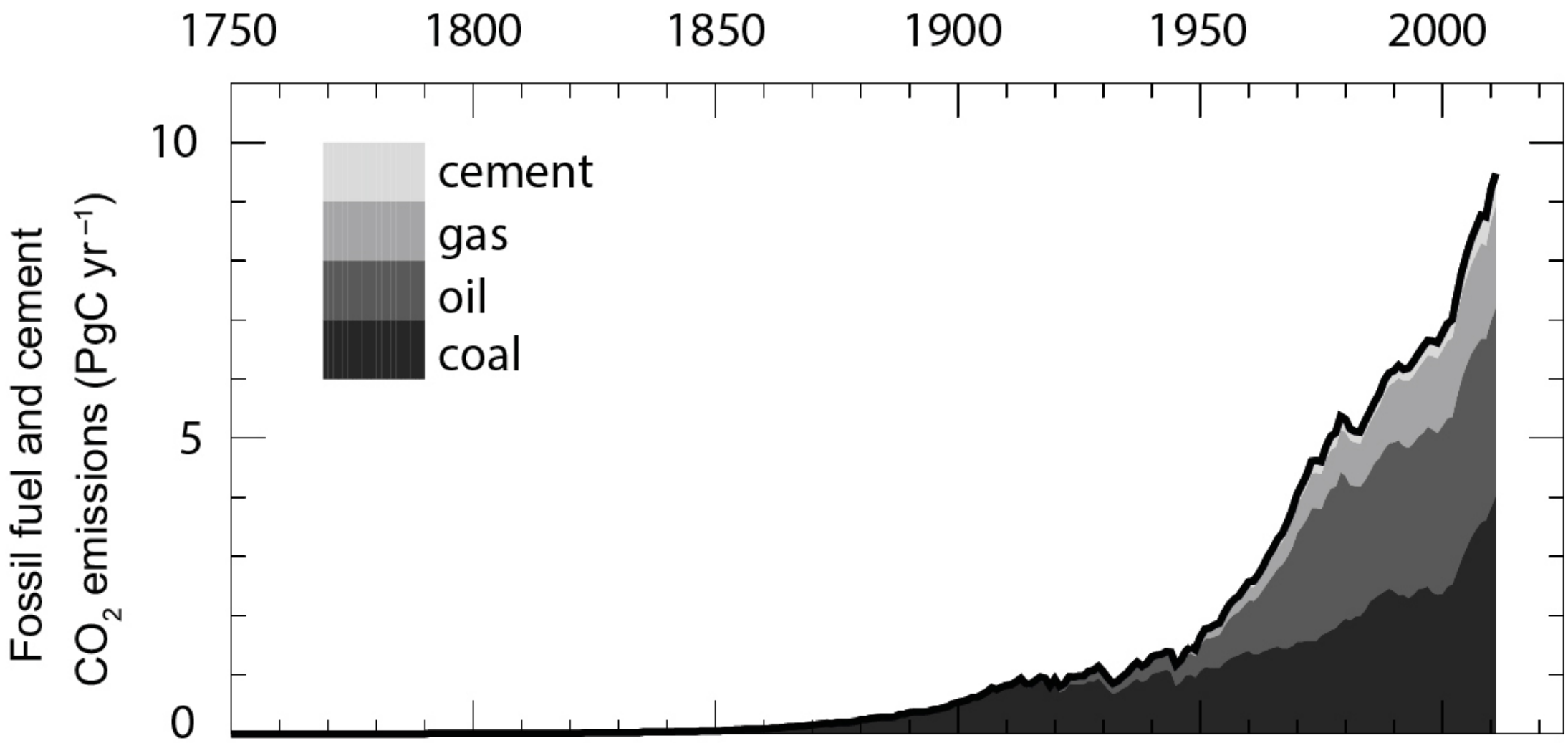
St. Kitts and Nevis

- The SBSTA welcomed the work of the IPCC, including on the Special Reports on “Global Warming of 1.5 °C”, “Oceans and Cryosphere in a Changing Climate”, and “Climate Change and Land”; and the “2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories”.
- The SBSTA noted the importance of the work of the scientific community and the IPCC in support of strengthening the global response to climate change.

This Week: Anthropogenic Forcings

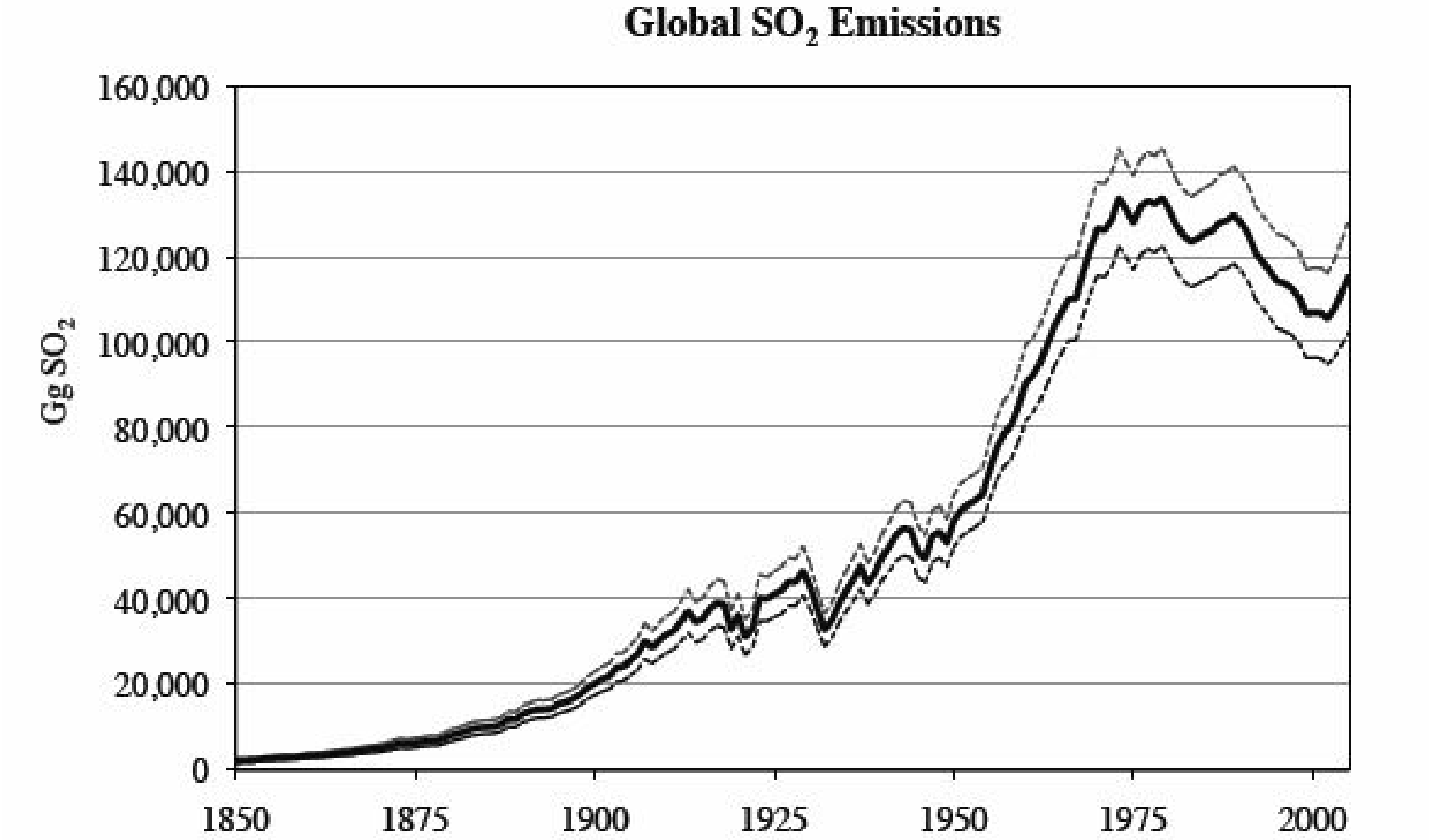
- Aerosol forcings
- An example of a global anthropogenic forcing that was mitigated
- Expected impacts of GHG forcing (Part 1)

Anthropogenic CO_2 emissions since pre-industrial

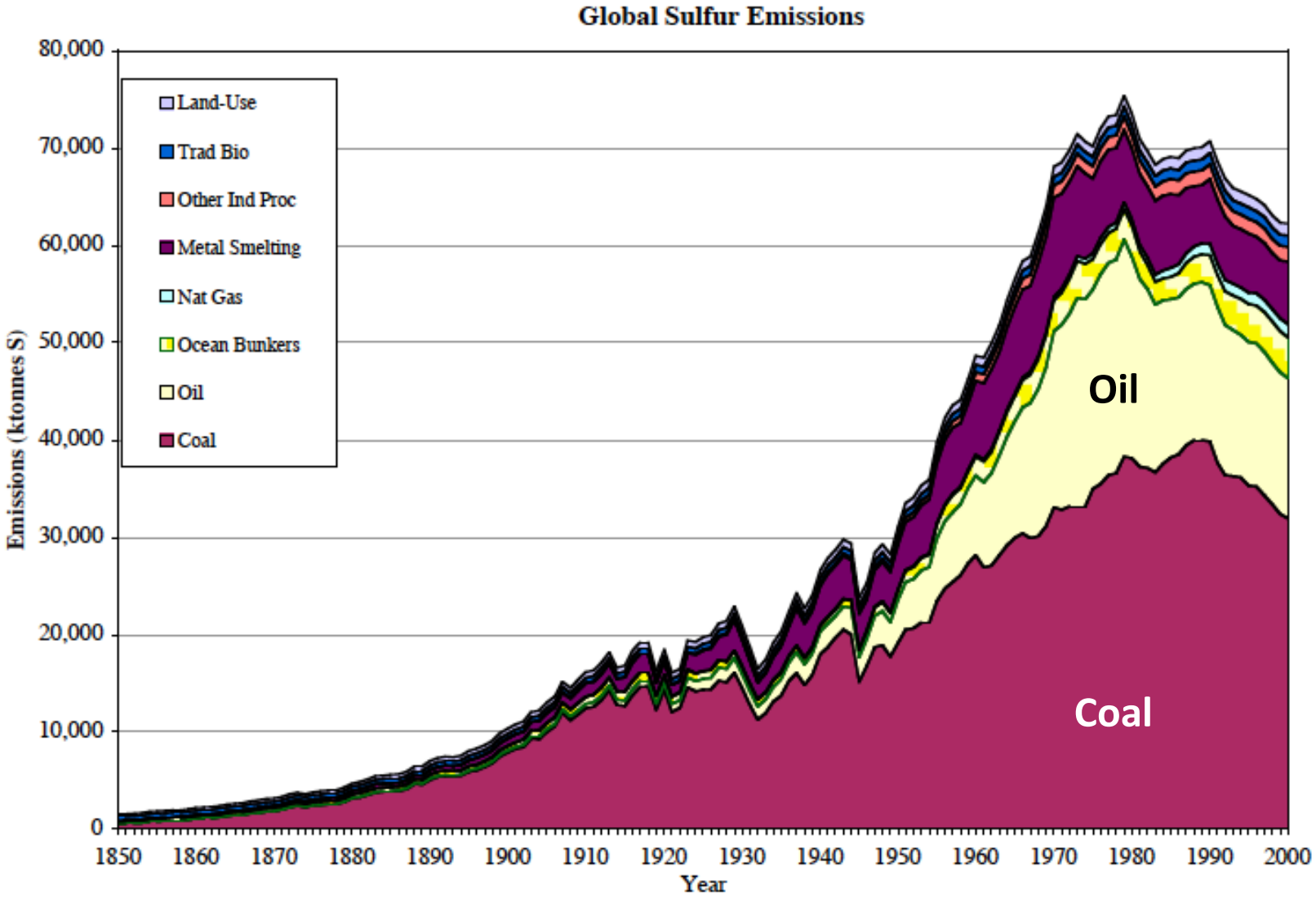


IPCC 2014

Anthropogenic Sulfur Dioxide (SO_2) Emissions

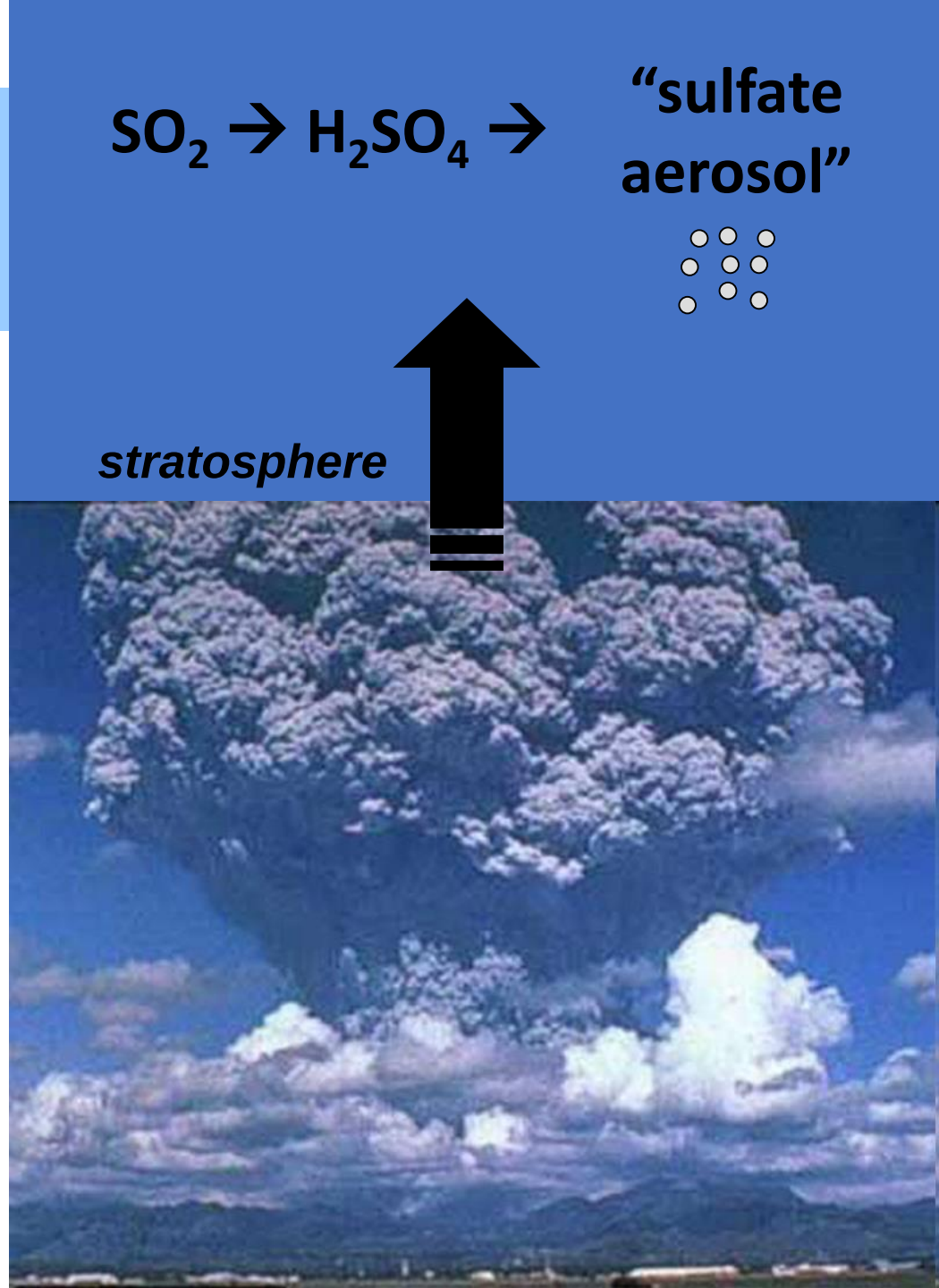


Sulfur Dioxide (SO_2) Emissions



Recall: Volcanic Aerosol Forcing (in stratosphere)

- **5 – 30% by volume of volcanic emissions are SO_2 or H_2S**
- **A single large eruption can inject 20 Mtons of S as SO_2 *into stratosphere***
- **Anthropogenic** emissions of SO_2 (60 Mtons/year) enhance aerosol particles



Recall: Aerosol particles

Small droplets or solid particles, 0.003 μm – 10 μm in diameter, suspended in air ("haze", volcanic plumes, sea spray, dust storms)

Recall: Aerosol particles

Small droplets or solid particles, 0.003 μm – 10 μm in diameter, suspended in air ("haze", volcanic plumes, sea spray, dust storms)

Aerosol Direct Effects

- Particles mostly scatter incoming solar radiation to space – though some absorb (soot / "black carbon")
- [If] albedo forcing is increased → F_{in} reduced → $\Delta F_{aerosols} < 0$
- Anthropogenic-induced changes in aerosol amount have resulted in ΔF = -0.3 to -0.9 W/m^2

Aerosol pollution in N. India and Pakistan

includes
sulfate aerosol
+
carbonaceous aerosol
(soot from burning of crop residues and biofuels)

Combustion of diesel, wood, and other organic carbon based fuels can lead to the emission of soot (aka "black carbon") aerosol particles. Increased emissions of soot particles could represent a

When poll is active, respond at **PollEv.com/joelathornto254**

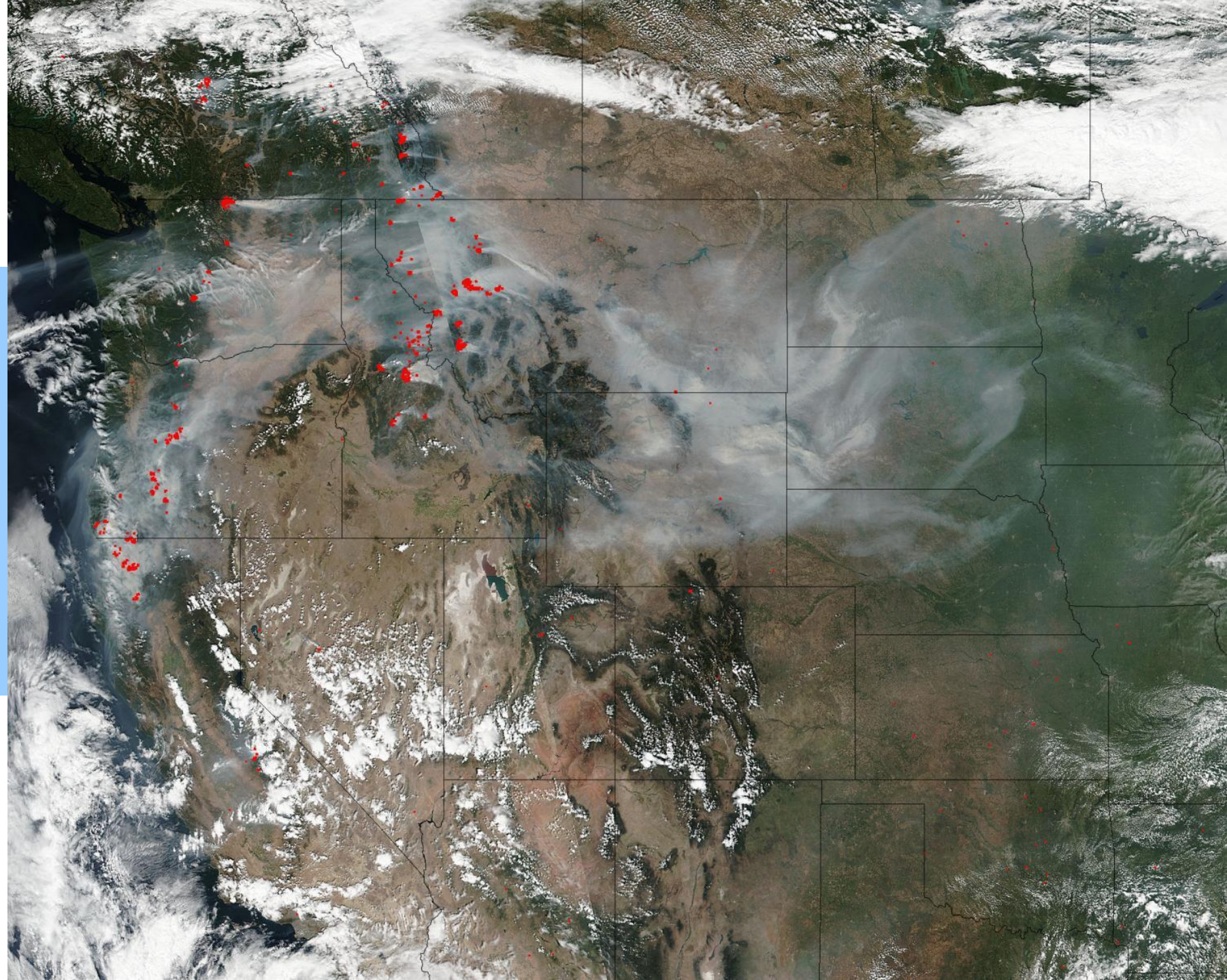
Text **JOELATHORNTO254** to **22333** once to join

positive radiative forcing due to absorption of solar radiation

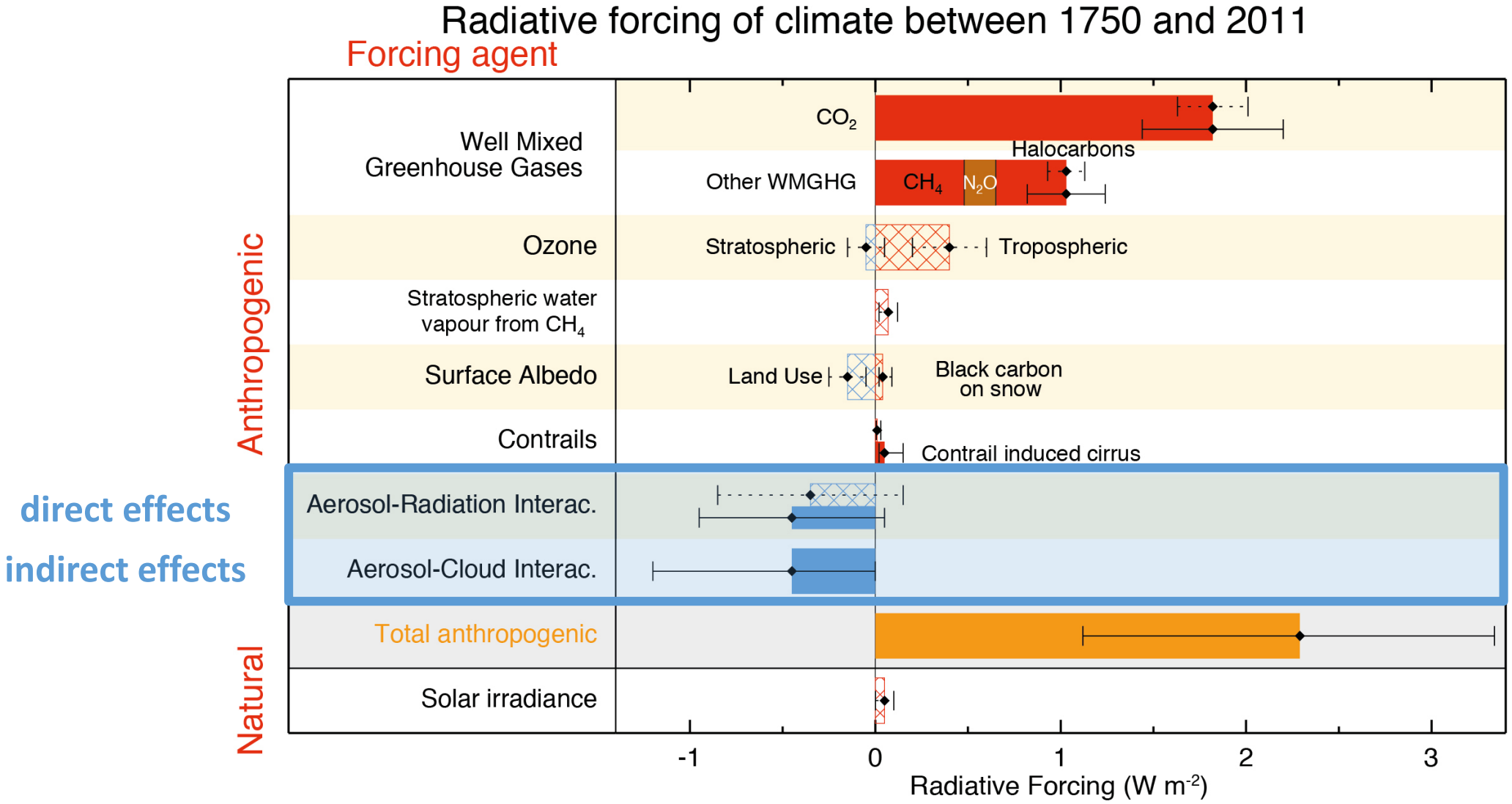
negative radiative forcing due to absorption of solar radiation

Total Results: 0

Western US wildfires emit soot particles



Anthropogenic Global Radiative Forcing



direct effects

indirect effects

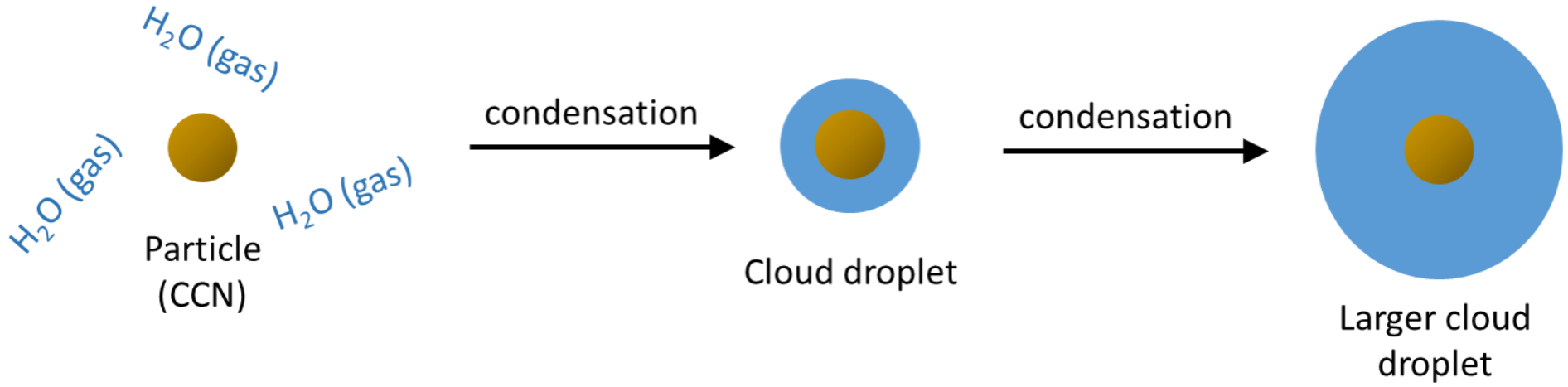
IPCC 2013

Aerosol Indirect Effects

- **Aerosol particles are the nuclei on which clouds form.** Without aerosol particles, it’s unlikely we’d have clouds

Clouds do not form without a “seed” particle

Water vapor cannot self-organize into a droplet (or ice crystal) in Earth’s atmosphere.

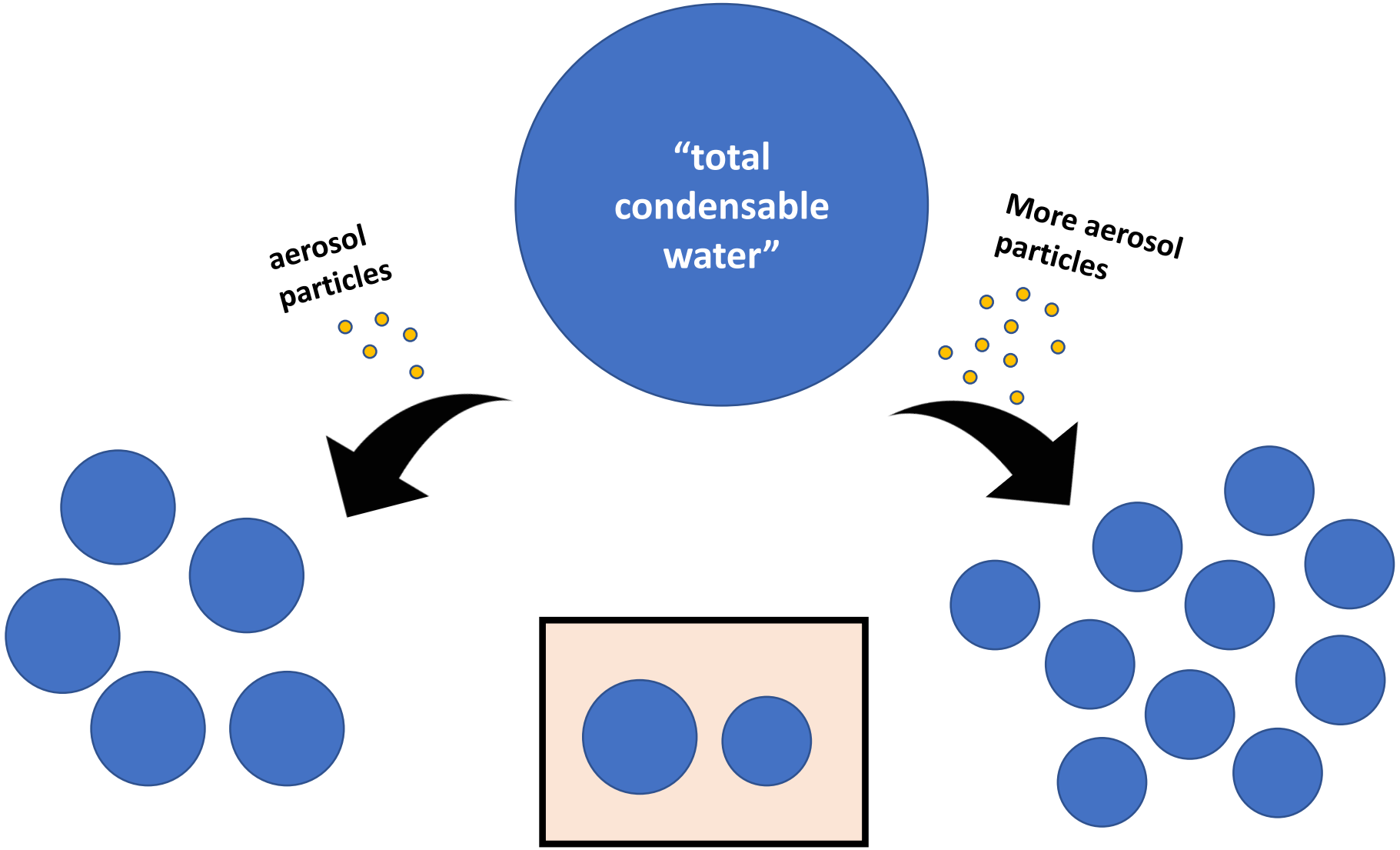


Instead water vapor requires a condensation site: “seed” or “cloud condensation nucleus” (CCN).

Aerosol Indirect Effects

- **Aerosol particles are the nuclei on which clouds form.** Without aerosol particles, it's unlikely we'd have clouds
- Increasing aerosol particles cause more cloud drops that are smaller in size

More particles = more, smaller cloud drops



Aerosol Indirect Effects

- **Aerosol particles are the nuclei on which clouds form.** Without aerosol particles, it's unlikely we'd have clouds
- Increasing aerosol particles cause more cloud drops that are smaller in size
- Twomey effect: Clouds with more, smaller cloud droplets are more reflective (scatter more radiation)
  - **About -0.5 W/m^2 forcing (but uncertain)**

Enhanced light scattering for smaller grains

Coarse Grains

Fine Grains

Cloud interactions with ship emissions

Ships emit particles and SO_2 that become CCN

Cloud interactions with ship emissions

"Ship Tracks"

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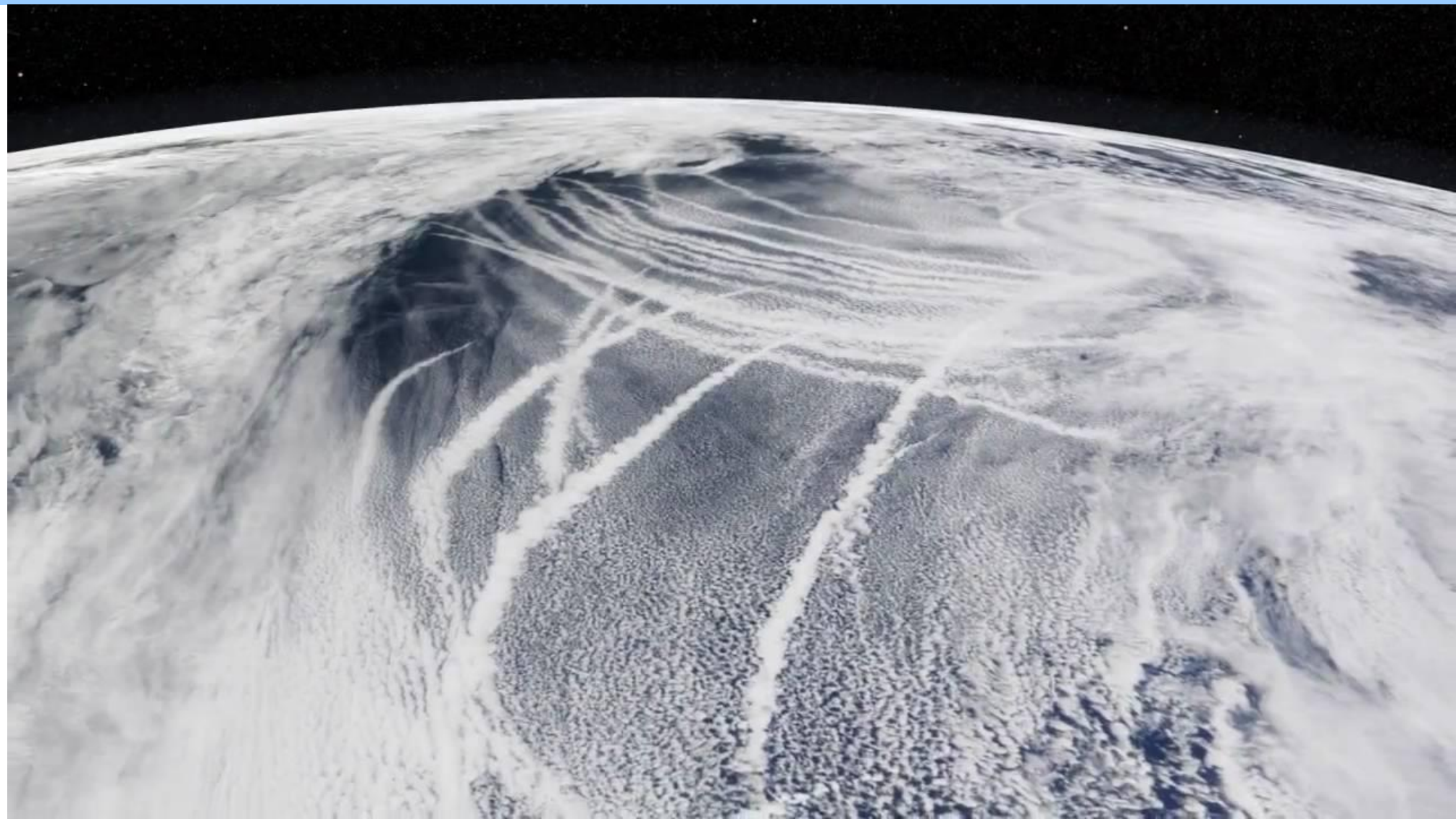
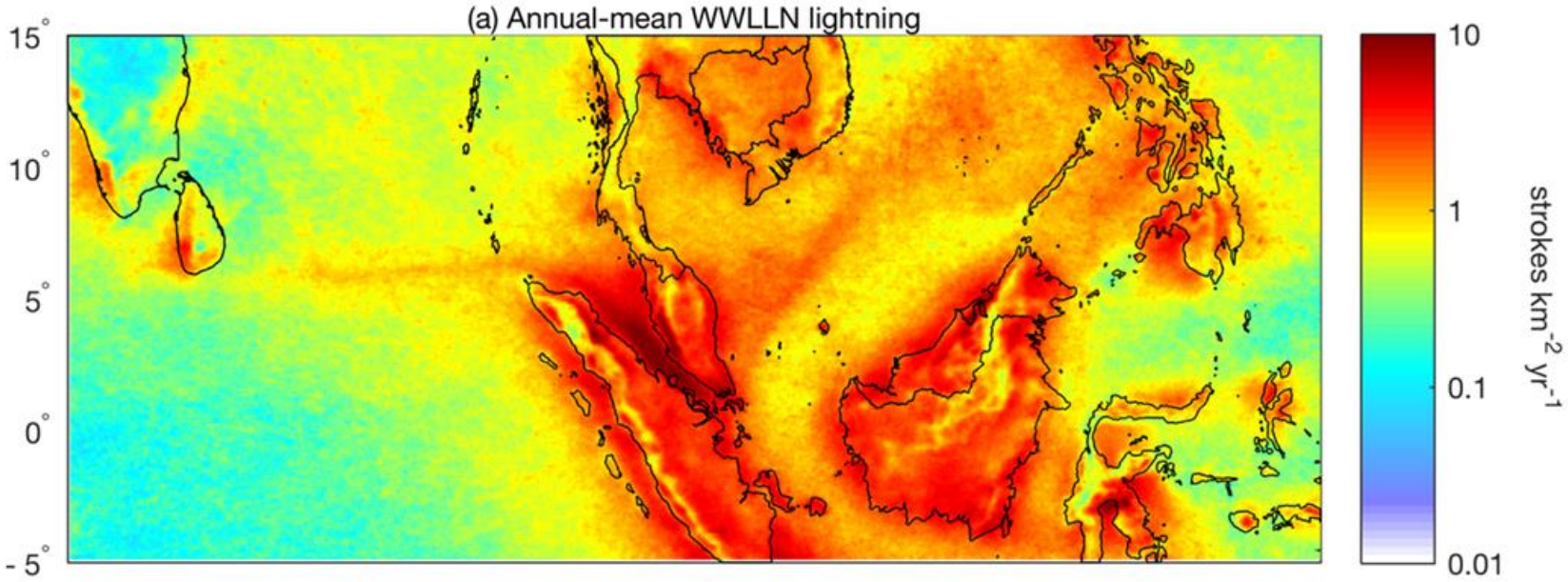
example of aerosol "indirect" effect



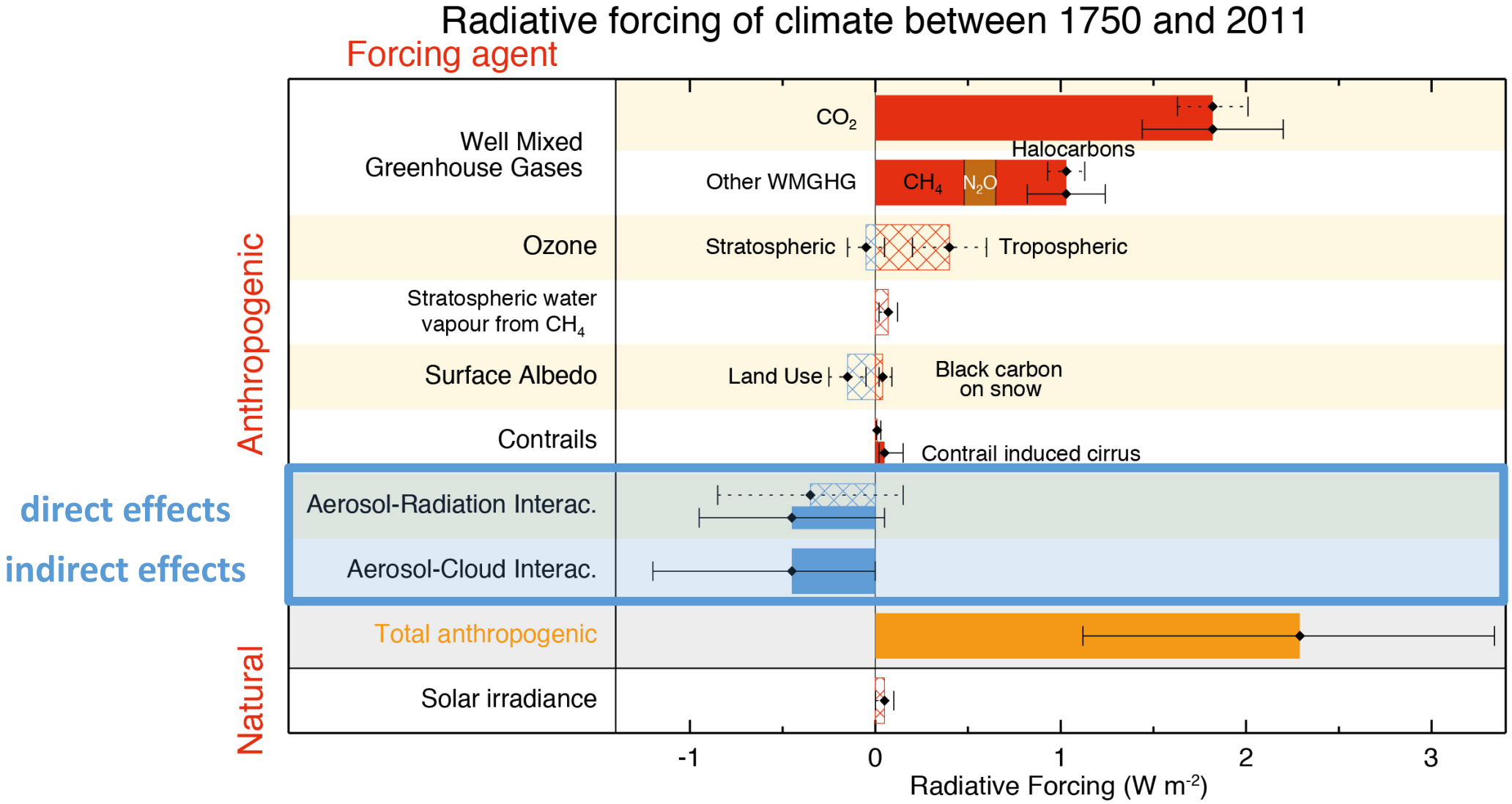
UW Research: Ship aerosols affect lightning

Ships emit particles. Along ship tracks, tropical storms make more lightning.



Thornton et al GRL 2017

Anthropogenic Global Radiative Forcing

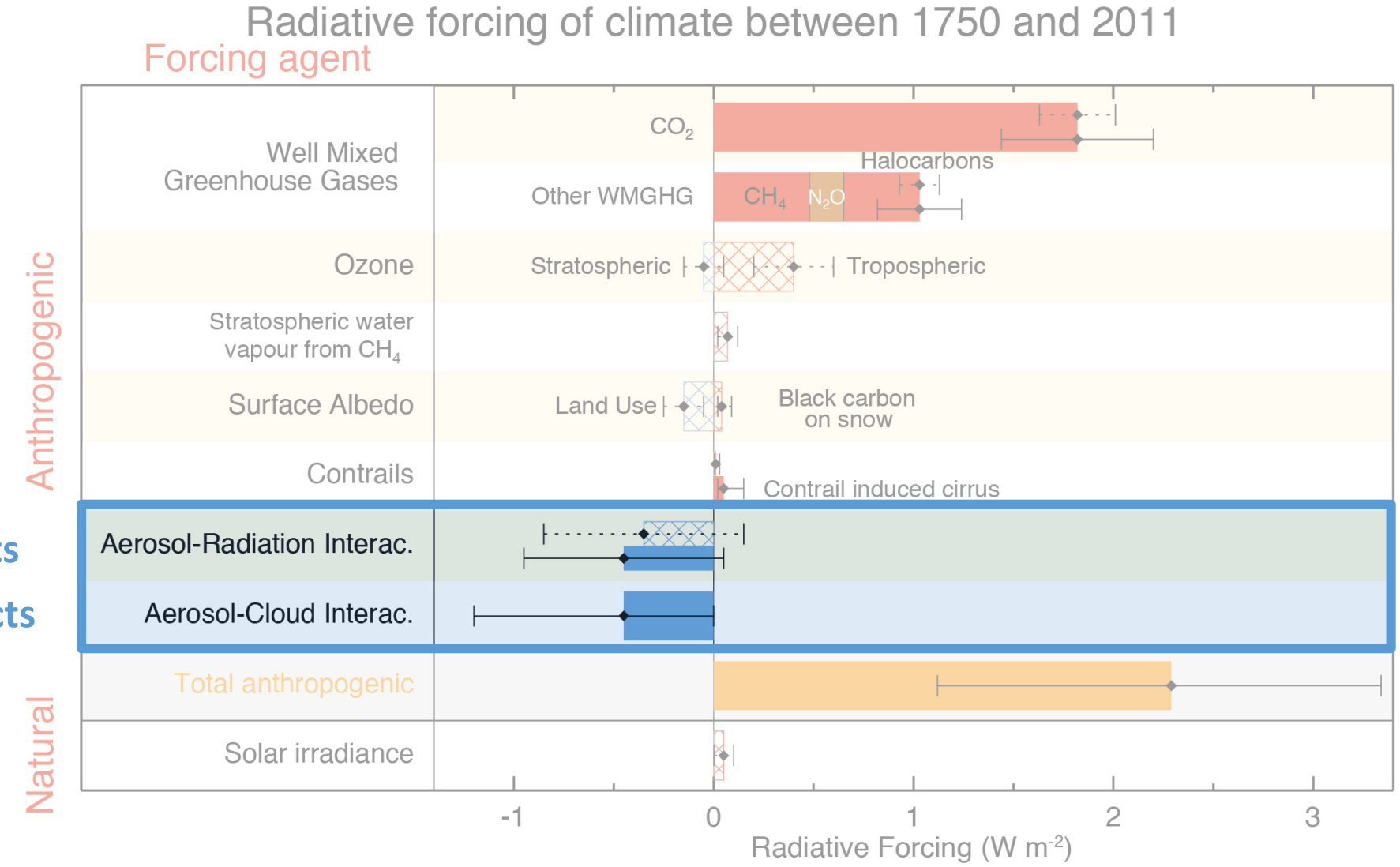


direct effects

indirect effects

IPCC 2013

Why are aerosol forcings so uncertain?



direct effects

indirect effects

IPCC 2013

Why are aerosol forcings so uncertain?

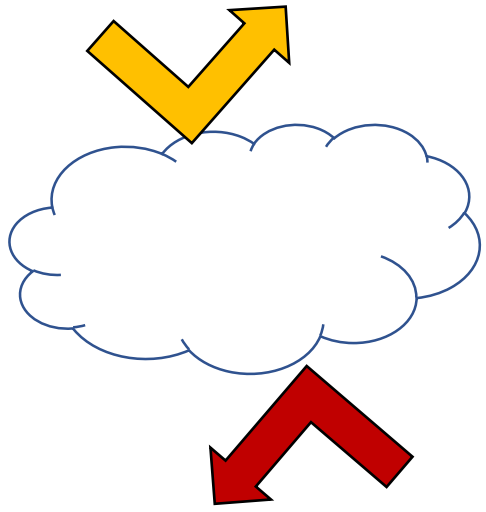
(1) Difficult to know how much anthropogenic activities have changed aerosol amounts since pre-industrial, because **we have no good record of this**

- Need to know change in **amount** of aerosols + **type** of aerosols (absorbing vs. scattering) + **global distribution** (magnitude of forcing, lifetime / rainout)

Why are aerosol forcings so uncertain?

(2) Aerosol effects on clouds are complex and have feedbacks.

- More aerosol brightens clouds, but the strength of this effect depends on the amount of condensable water + circulation patterns
- Clouds reflect solar radiation but also absorb outgoing longwave radiation (like greenhouse gases).



Incoming shortwave solar radiation

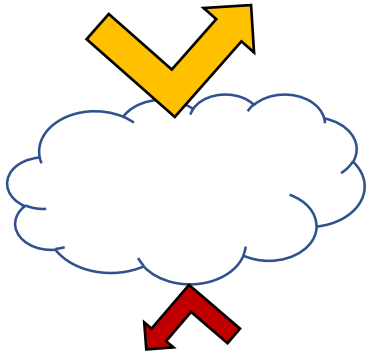
Outgoing longwave radiation (OLR)

Why are aerosol forcings so uncertain?

OLR from clouds depends on temperature (and therefore height)

- **High clouds** (e.g., cirrus) have a strong greenhouse effect but a low albedo

- **Low clouds** (e.g., marine stratus) have similar OLR to the surface = weak greenhouse effect, but have a high albedo.



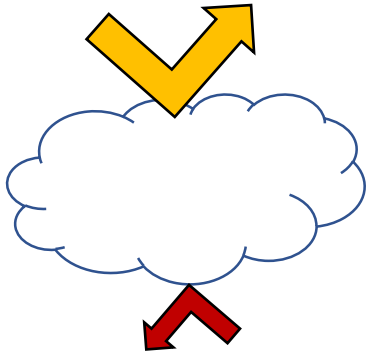
Why are aerosol forcings so uncertain?

If climate changes increase the prevalence of:

- **High clouds** (e.g., cirrus) have a strong greenhouse effect but a low albedo

Positive climate feedback

- **Low clouds** (e.g., marine stratus) have similar OLR to the surface = weak greenhouse effect, but have a high albedo.

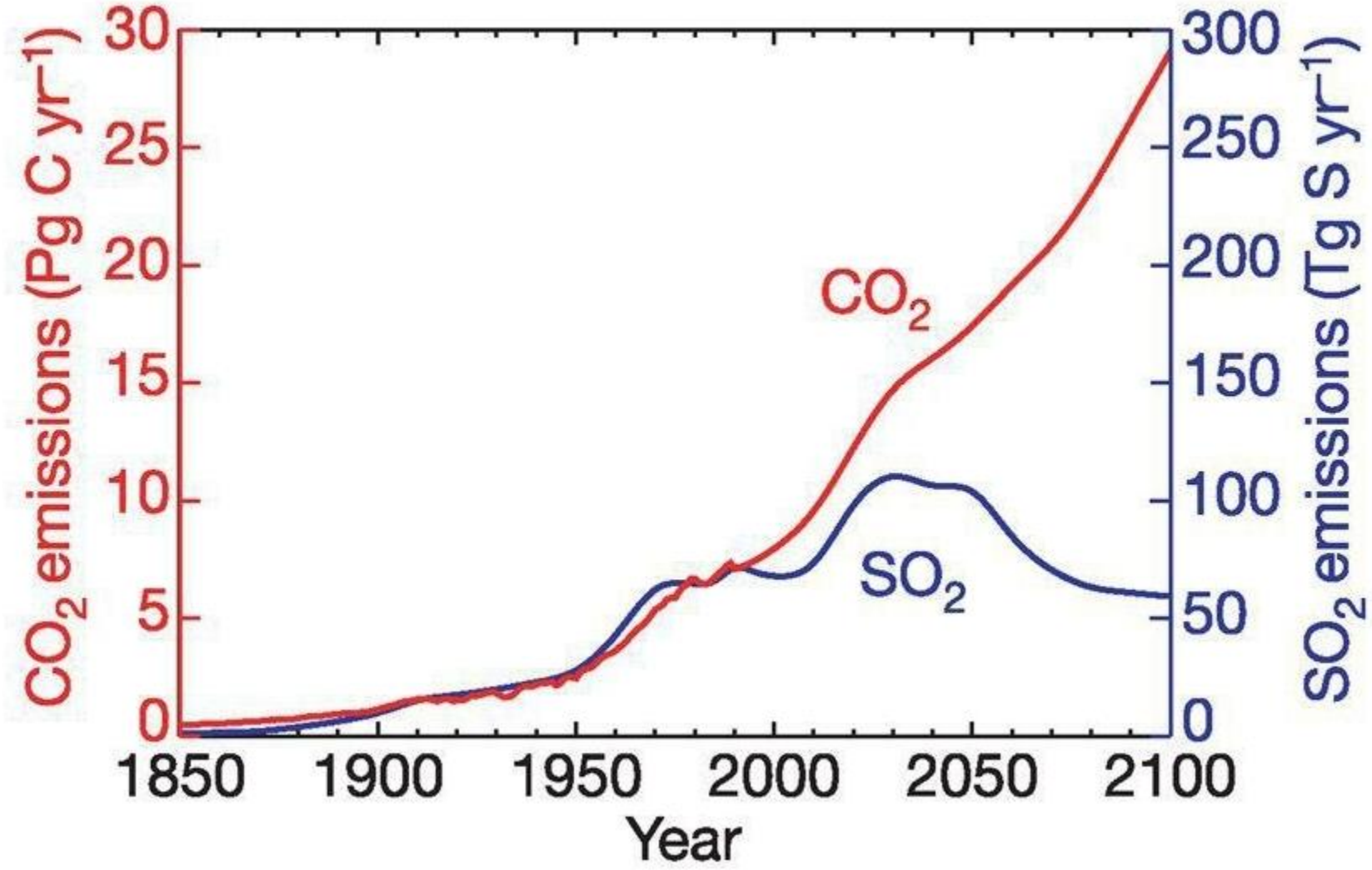


Negative climate feedback

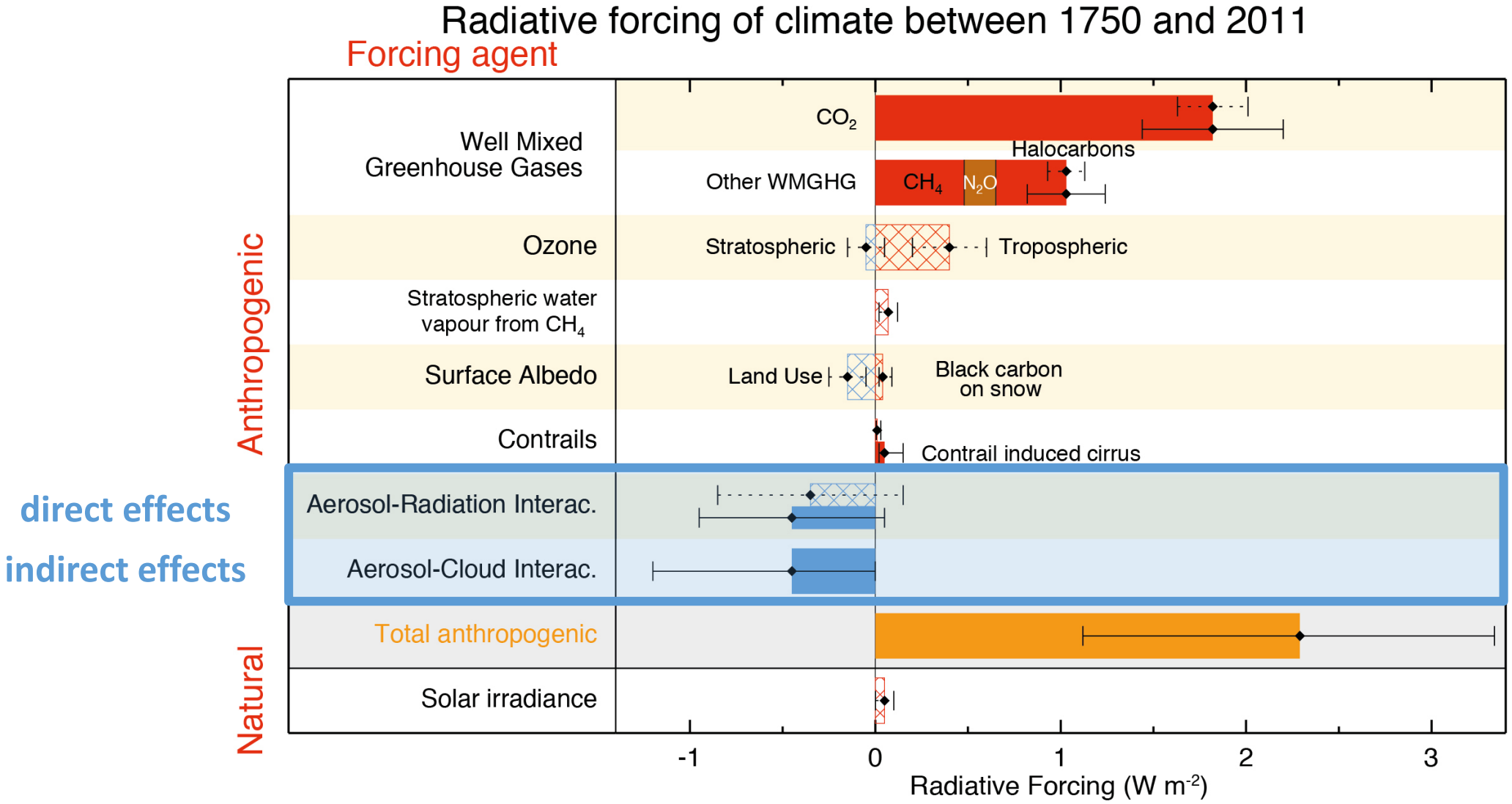
Why are aerosol forcings so uncertain?

It is challenging to quantify the net effect of more aerosol on <u>cloud distribution</u> (which clouds are affected by aerosol) **and <u>resulting radiation budget</u>** (OLR + albedo effects)**.**

Future of Aerosol Forcing



Anthropogenic Global Radiative Forcing

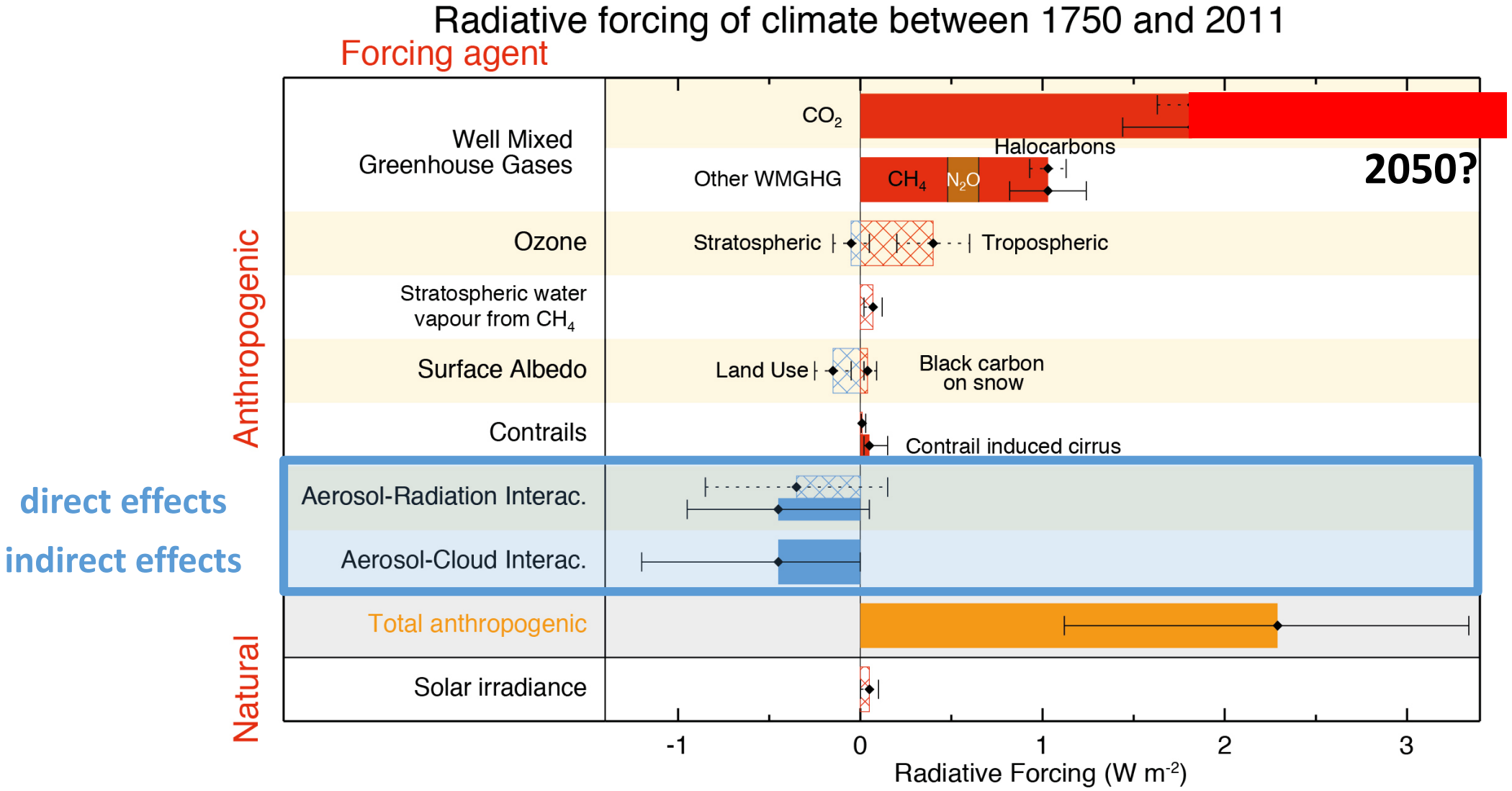


direct effects

indirect effects

IPCC 2013

Anthropogenic Global Radiative Forcing



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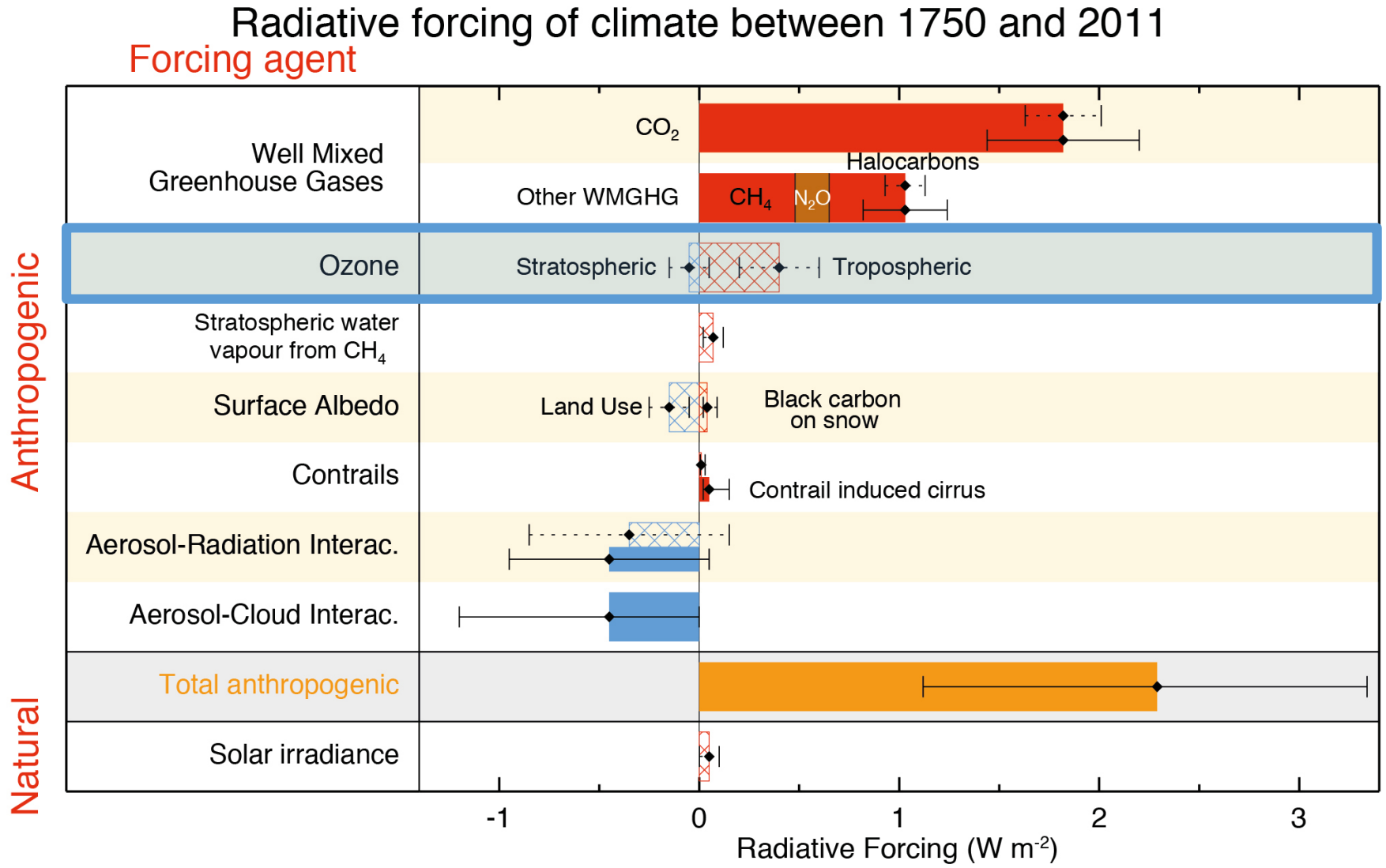
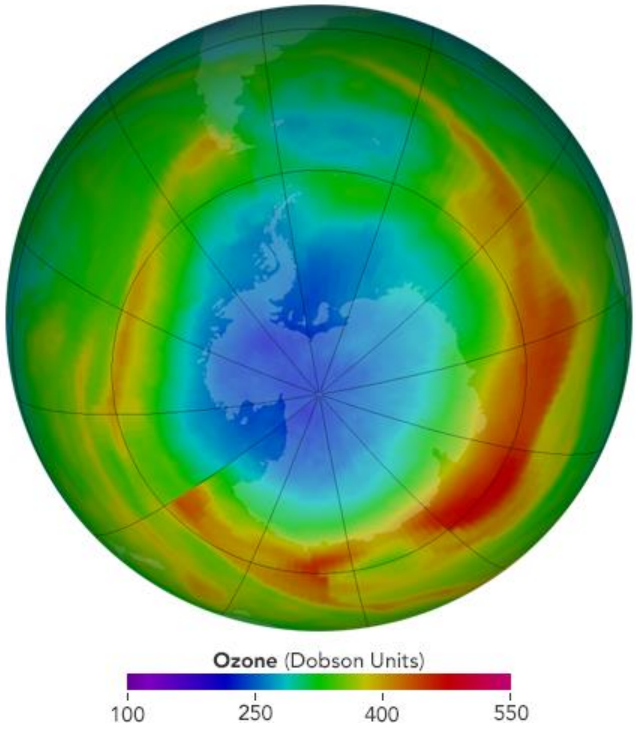


IPCC 2013

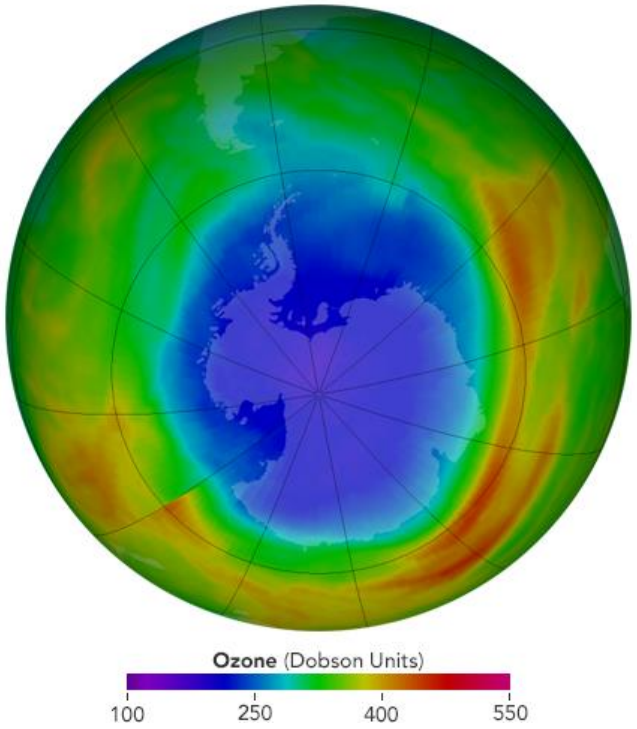
[Ozone Watch Web Page]

International Response to Another Global Problem: **The Antarctic Ozone Hole**

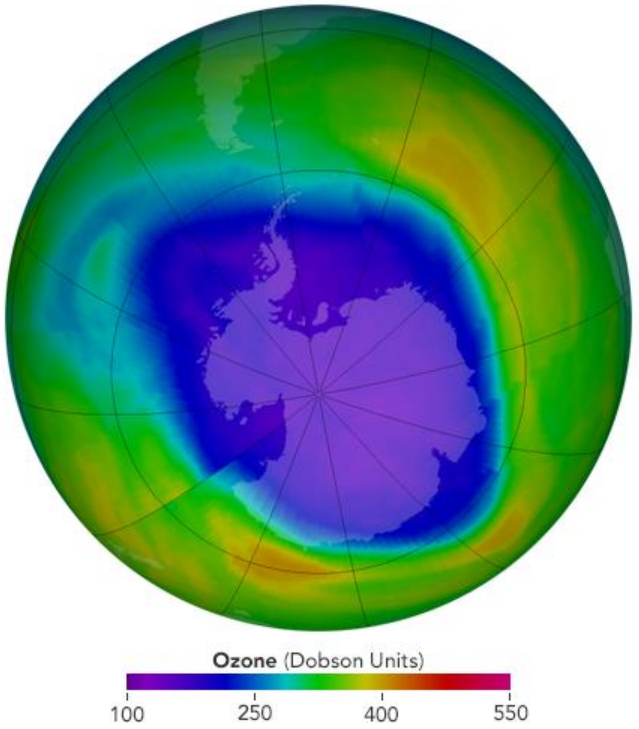
October 1980



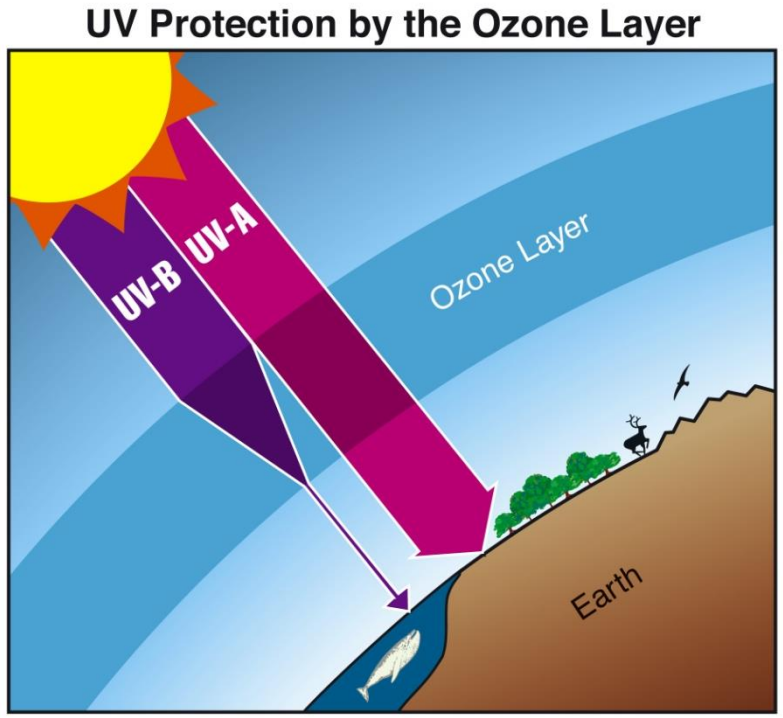
October 1984



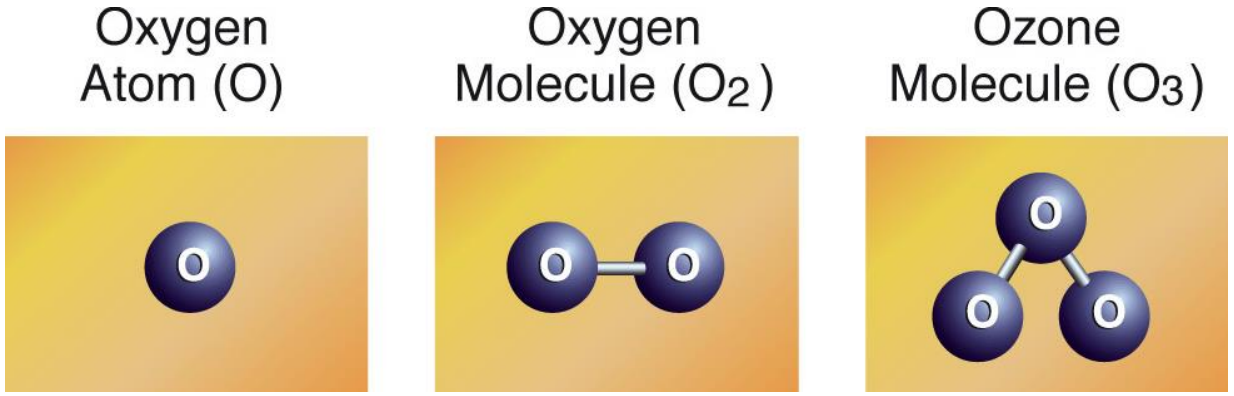
October 1993



Importance of Stratospheric Ozone (O_3)



- prevents exposure of terrestrial and surface water life to harmful UV radiation
- absorption of UV radiation important for energy balance (affecting circulation, precipitation)



Chlorofluorocarbons (CFCs)

- Non-toxic, non-flammable, easily compressible gases
- Used as refrigerants, propellants in spray cans
- Thought to be ideal due to safety and durability.

Note: “Aerosol” Spray Cans are NOT THE SAME as Atmospheric Aerosol Particles

Early Warning Signs (but never predicted ozone hole!)

Stratospheric sink for chlorofluoromethanes : chlorine atomc-atalysed destruction of ozone

Mario J. Molina & F. S. Rowland

Department of Chemistry, University of California, Irvine, California 92664

Chlorofluoromethanes are being added to the environment in steadily increasing amounts. These compounds are chemically inert and may remain in the atmosphere for 40–150 years, and concentrations can be expected to reach 10 to 30 times present levels. Photodissociation of the chlorofluoromethanes in the stratosphere produces significant amounts of chlorine atoms, and leads to the destruction of atmospheric ozone.

photolytic dissociation to $CFCl_2 + Cl$ and to $CF_2Cl + Cl$, respectively, at altitudes of 20–40 km. Each of the reactions creates two odd-electron species—one Cl atom and one free radical. The dissociated chlorofluoromethanes can be traced to their ultimate sinks. An extensive catalytic chain reaction leading to the net destruction of O_3 and O occurs in the stratosphere:

$$Cl + O_3 \rightarrow ClO + O_2 \quad (1)$$

$$ClO + O \rightarrow Cl + O_2 \quad (2)$$

This has important chemical consequences. Under most conditions in the Earth's atmospheric ozone layer, (2) is the slower of the reactions because there is a much lower concen-

***Nature* (June 28, 1974)**

Molina, Rowland, and Crutzen win Nobel Prize in 1994.

CFC-11 Atmospheric Abundance