Short-lived climate forcers (SLCF) in the IPCC WGI contribution to the 6th Assessment Report

Jan Fuglestvedt, Vice chair Working Group I

Thanks to: Vaishali Naik (CLA Ch6), Sophie Szopa (CLA Ch6), Terje Berntsen (LA Ch6), Sarah Connors (Head of Science Team, TSU), Bill Collins (LA Ch7)

Joint 1st and 2nd IPCC Expert Meeting on Short-Lived Climate Forcers 11 – 22 October 2021

IPCC Working Group I report outline

Chapter 1: Framing, context, methods

Large-scale climate change

Chapter 2: Changing state of the climate system

Chapter 3: Human influence on the climate system

Chapter 4: Future global climate: scenario-based projections and near-terminformation

Climate processes

Chapter 5: Global carbon and other biogeochemical cycles and feedbacks

Chapter 6: Short-lived climate forcers

Chapter 7: The Earth's energy budget, climate feedbacks, and climate sensitivity

Chapter 8: Water cycle changes

Chapter 9: Ocean, cryosphere, and sea level change

Regional climate information

Chapter 10: Linking global to regional climate change

Chapter 11: Weather and climate extreme events in a changing climate

Chapter 12: Climate change information for regional impact and for risk assessment

Atlas of Regional Climate Information

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What is SLCF?

A set of chemically and physically reactive compounds with atmospheric **lifetimes typically shorter than two decades** but differing in terms of physiochemical properties and environmental effects.

SLCFs can be classified as **direct** or **indirect**, with direct SLCFs exerting climate effects through their radiative forcing and indirect SLCFs being precursors of direct climate forcers.

Direct SLCFs include **methane (CH_4)**, **ozone (O_3)**, short lived halogenated compounds, such as hydrofluorocarbons (**HFCs**), hydrochlorofluorocarbons (**HCFCs**), and **aerosols**.

Indirect SLCFs include **nitrogen oxides (NOx**), **carbon monoxide (CO**), **non-methane volatile organic compounds (NMVOCs**), **sulphur dioxide (SO_2**), and **ammonia (NH_3**).

Aerosols consist of **sulphate (SO_4^{2-}), nitrate (NO_3^-), ammonium (NH_4^+), carbonaceous aerosols** (e.g., black carbon (BC), organic aerosols (OA)), mineral dust, and sea spray.

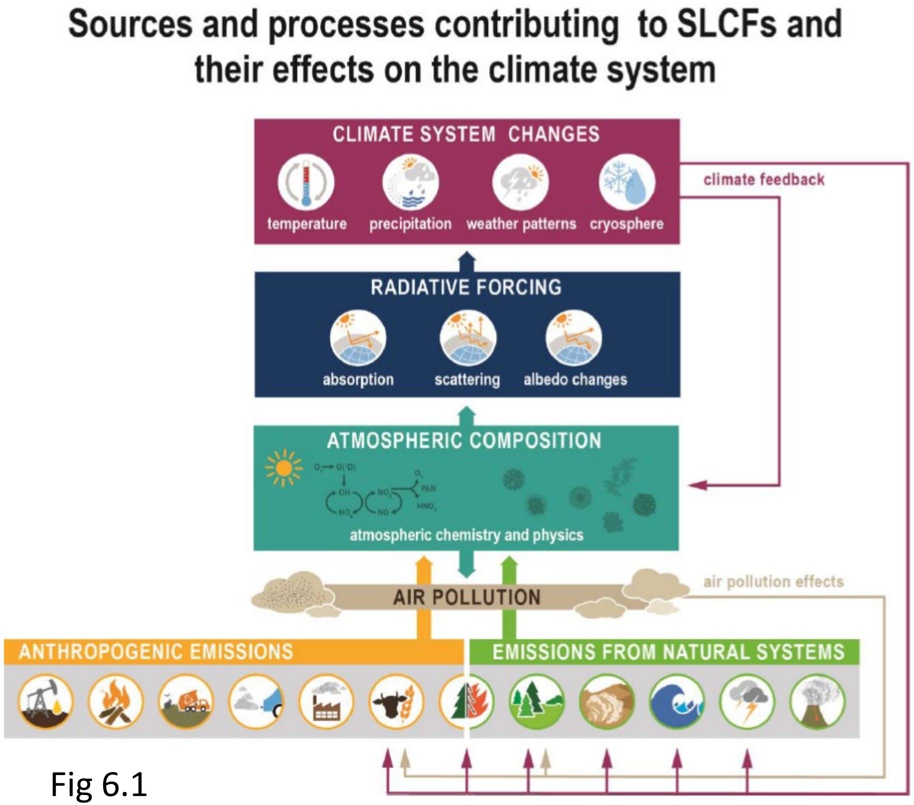


Fig 6.1

Table 6.1

Compounds	Source Type[a]	Lifetime	Direct	Indirect	Climate Forcing	Other effects on climate	WHO AQ guidelines[b]
CH_4	Primary	~9 years ~12 years (perturbation time)	CH_4	O_3, H_2O, CO_2	+		No[c]
O_3	Secondary	Hours - weeks	O_3	CH_4, secondary organic aerosols, sulphates	+	Ecosystem	100 $\mu g\ m^{-3}$ 8-hour mean
NO_x (= NO + NO_2)	Primary	Hours - days		O_3, nitrates, CH_4	+/-	Ecosystem	40 $\mu g\ m^{-3}$ annual mean 200 $\mu g\ m^{-3}$ 1-hour mean
CO	Primary + Secondary	1-4 months		O_3, CH_4	+		No
NMVOCs	Primary + Secondary	Hours - months		O_3, CH_4, organic aerosols	+/-		No
SO_2	Primary	Days (trop.) to weeks (strat.)		sulphates, nitrates, O_3	-		20 $\mu g\ m^{-3}$ 24-hour mean 500 $\mu g\ m^{-3}$ 10-minute mean
NH_3	Primary	Hours		Ammonium Sulphate, Ammonium Nitrate	-	Ecosystem	No
HCFCs	Primary	Months – years	HCFCs	Stratospheric O_3	+/-		No[c]
HFCs	Primary	Days – years	HFCs		+		No[c]
Halons and Methylbromide	Primary	Years	Halons and Methylbromide	Stratospheric O_3	+/-		No[c]
Very Short-Lived halogenated Species (VSLSs)	Primary	less than 0.5 year		Stratospheric O_3	-		No[c]
Sulphates	Secondary	Minutes – weeks	Sulphates		-	Cloud	as part of PM[d]
Nitrates	Secondary	Minutes – weeks	Nitrates		-	Cloud	as part of PM[d]
Carbonaceous aerosols	Primary + Secondary	Minutes to Weeks	BC, OA		+/ -	Cryo, Cloud	as part of PM[d]
Sea spray	Primary	day to week	Sea spray		-	Cloud	as part of PM[d]
Mineral dust	Primary	Minutes to Weeks	Mineral dust		-	Cryo, Cloud	as part of PM[d]

Recent Evolution in SLCF Emissions and Abundances

Over the last decade, **strong shifts in the geographical distribution of emissions**

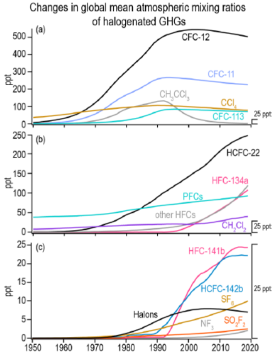
Observations show **strong regional variations in trends of ozone (O_3), aerosols and their precursors.**

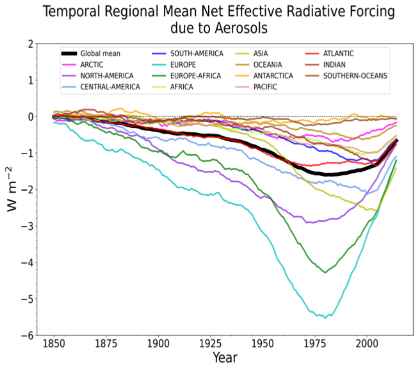
Tropospheric columns of nitrogen dioxide (NO_2) and sulphur dioxide (SO_2) continued to decline over North America and Europe and to increase over South Asia, but have declined over East Asia.

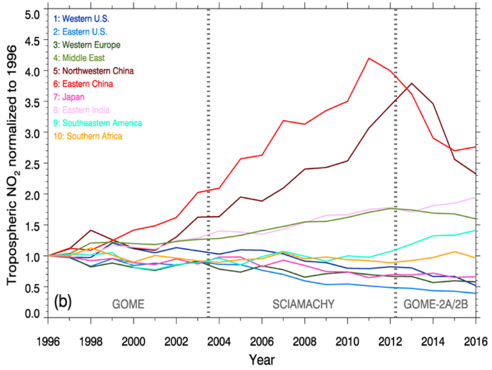
Global carbon monoxide (CO) abundance has continued to **decline**.

The concentrations of **hydrofluorocarbons (HFCs) are increasing**.

Global carbonaceous aerosol budgets and trends remain **poorly characterized** due to limited observations, but sites representative of background conditions have reported multi-year **declines in black carbon (BC) over several regions of the Northern Hemisphere**.







[Credit: Yoda Adaman | Unsplash]

"It is indisputable that human activities are causing climate change, making extreme climate events, including heat waves, heavy rainfall, and droughts, more frequent and severe.

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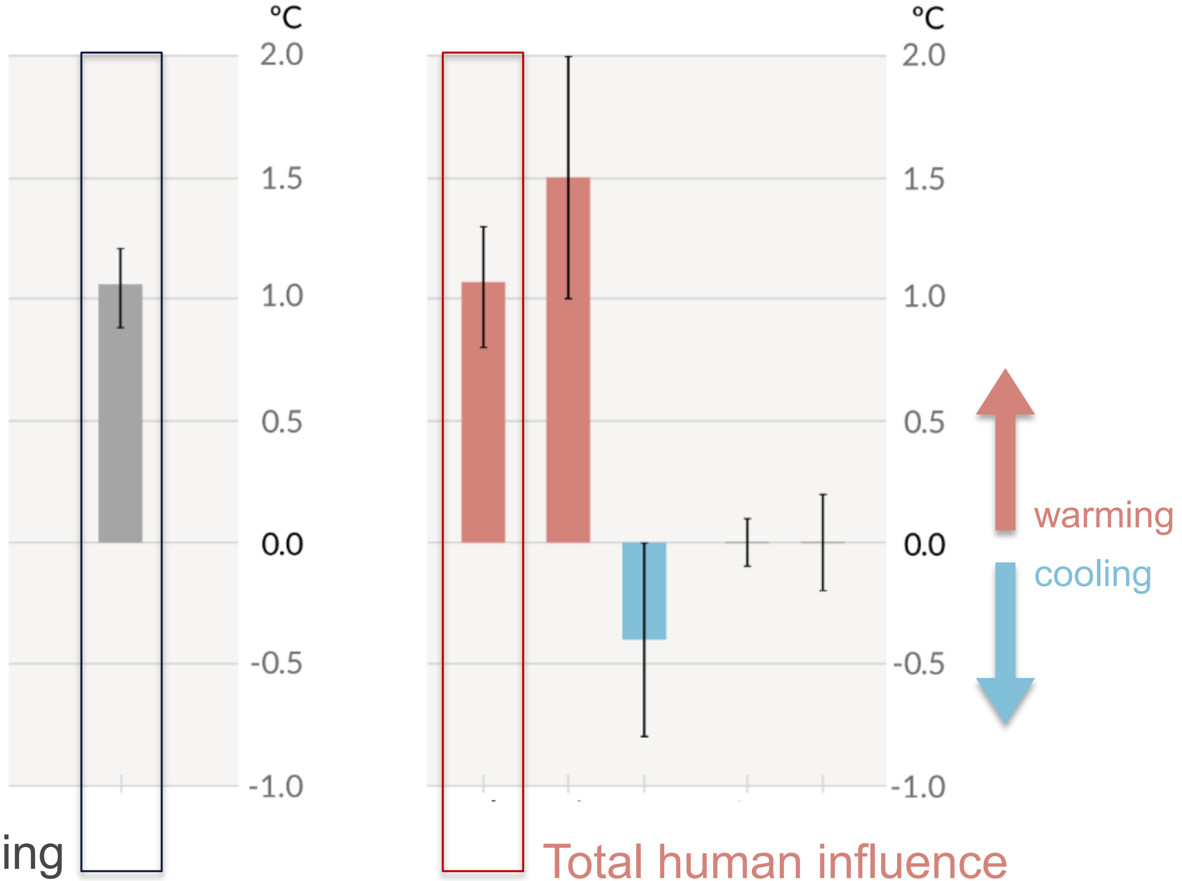
INTERGOVERNMENTAL PANEL ON climate change
WMO UNEP

Observed warming is driven by emissions from **human activities**, with **greenhouse gas** warming partly masked by **aerosol cooling**



Observed warming

Total human influence

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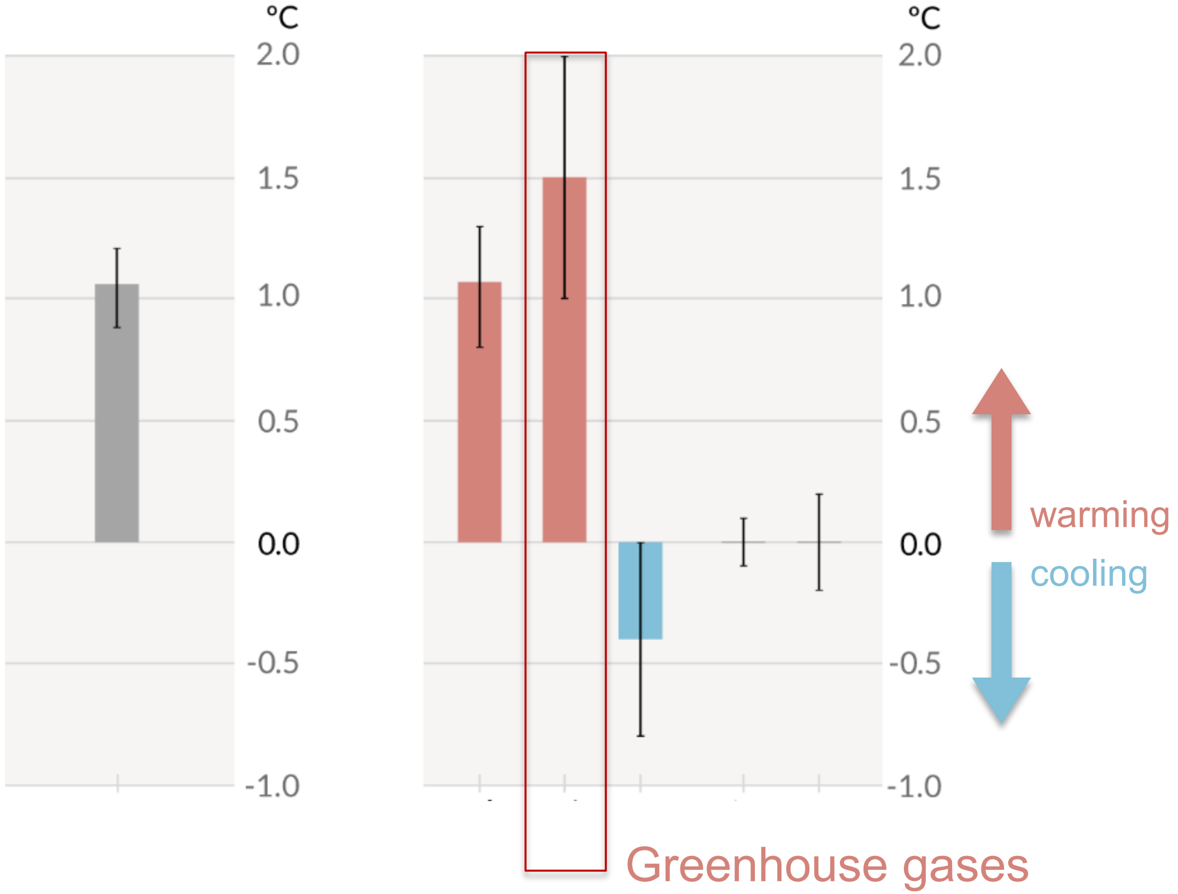

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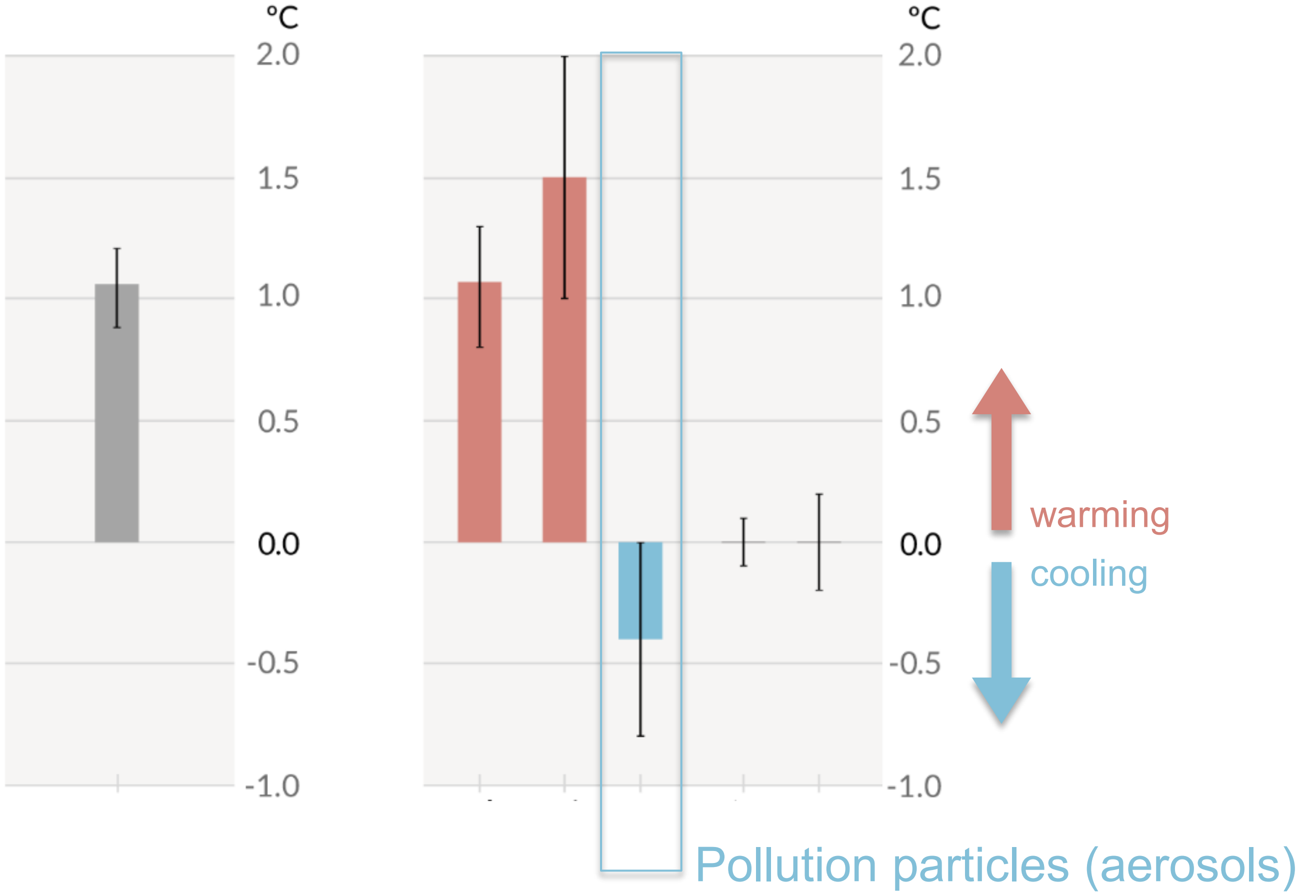

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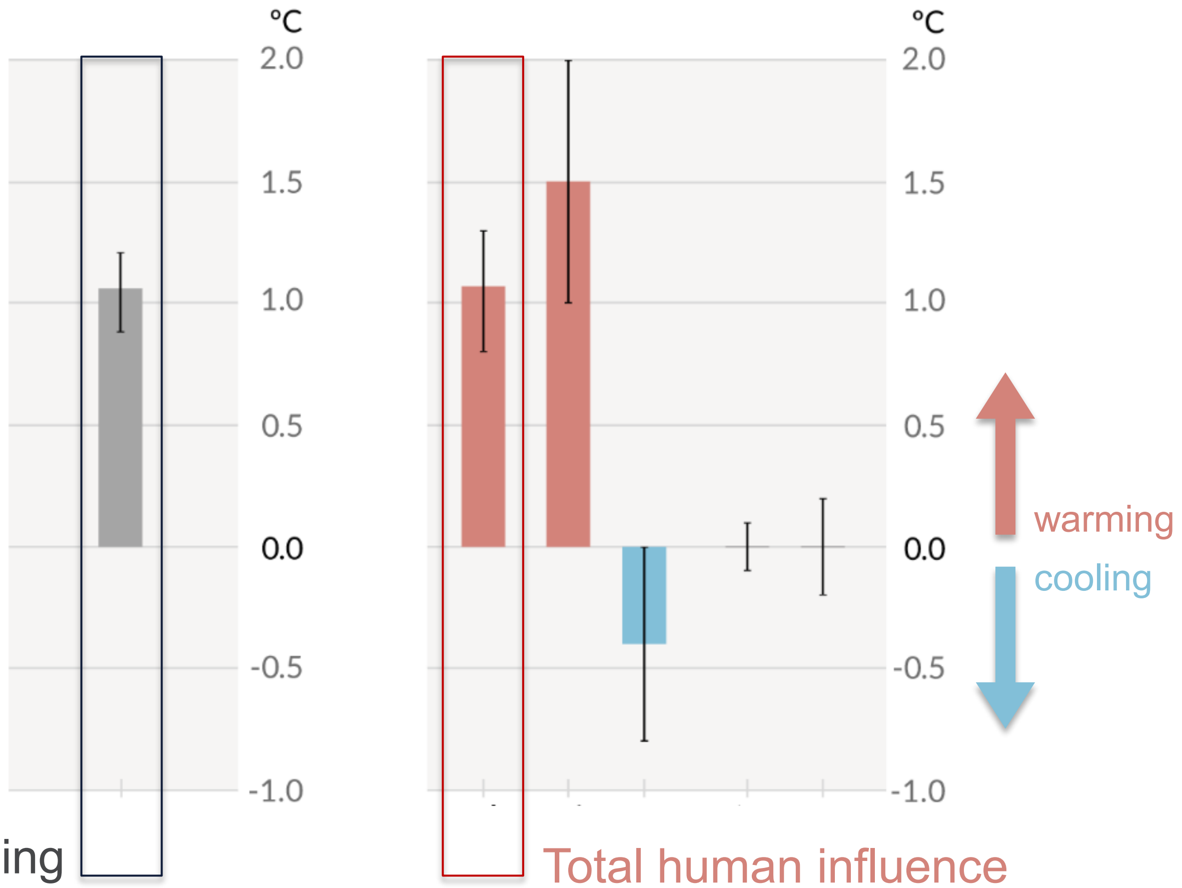
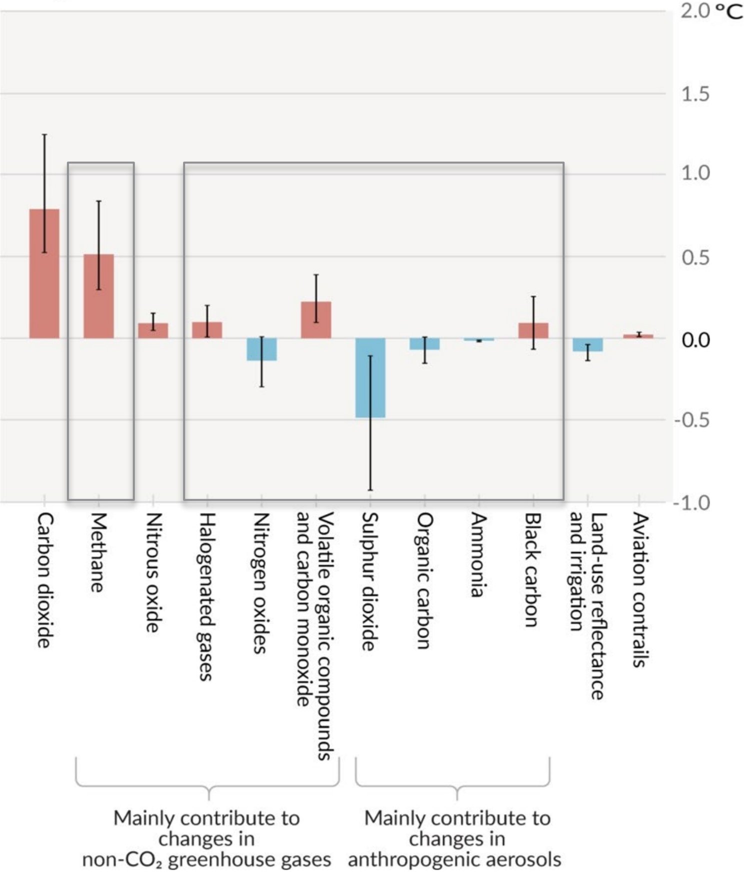


Contributions by component to 2010-2019 warming relative to 1850-1900.

CO_2 emissions dominate historical warming

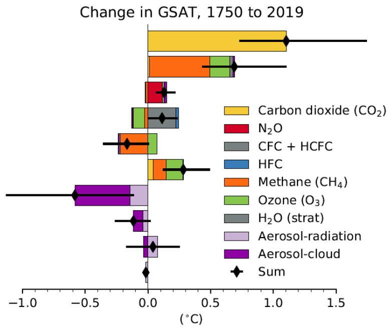
Among non-CO_2 emissions, methane contributes the most to historical warming

SO_2 emissions (via sulfate aerosols) have contributed the most to cooling



SPM.2c

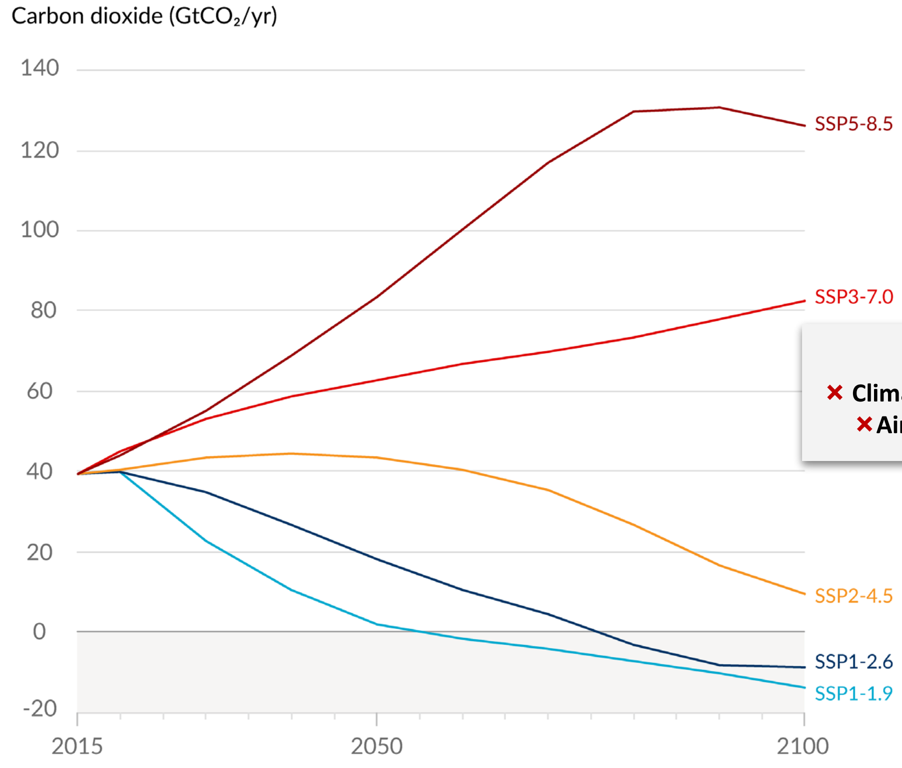
More details in chapter 6



[Credit: Peter John Maridable]

"Unless there are immediate, rapid, and large-scale reductions in greenhouse gas emissions, limiting warming to 1.5°C will be beyond reach.

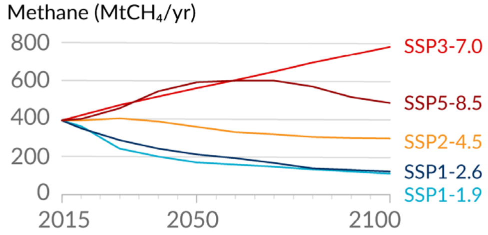
Scenarios used in IPCC AR6 WGI



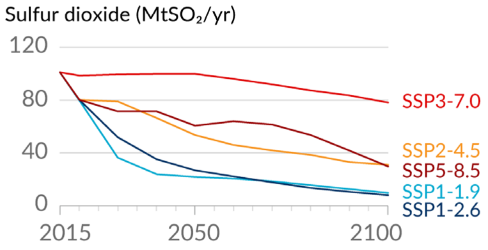
SSP5-8.5
✗ **Climate change mitigation**
✔✔ **Air pollution controls**

SSP3-7.0
✗ **Climate change mitigation**
✗ **Air pollution controls**

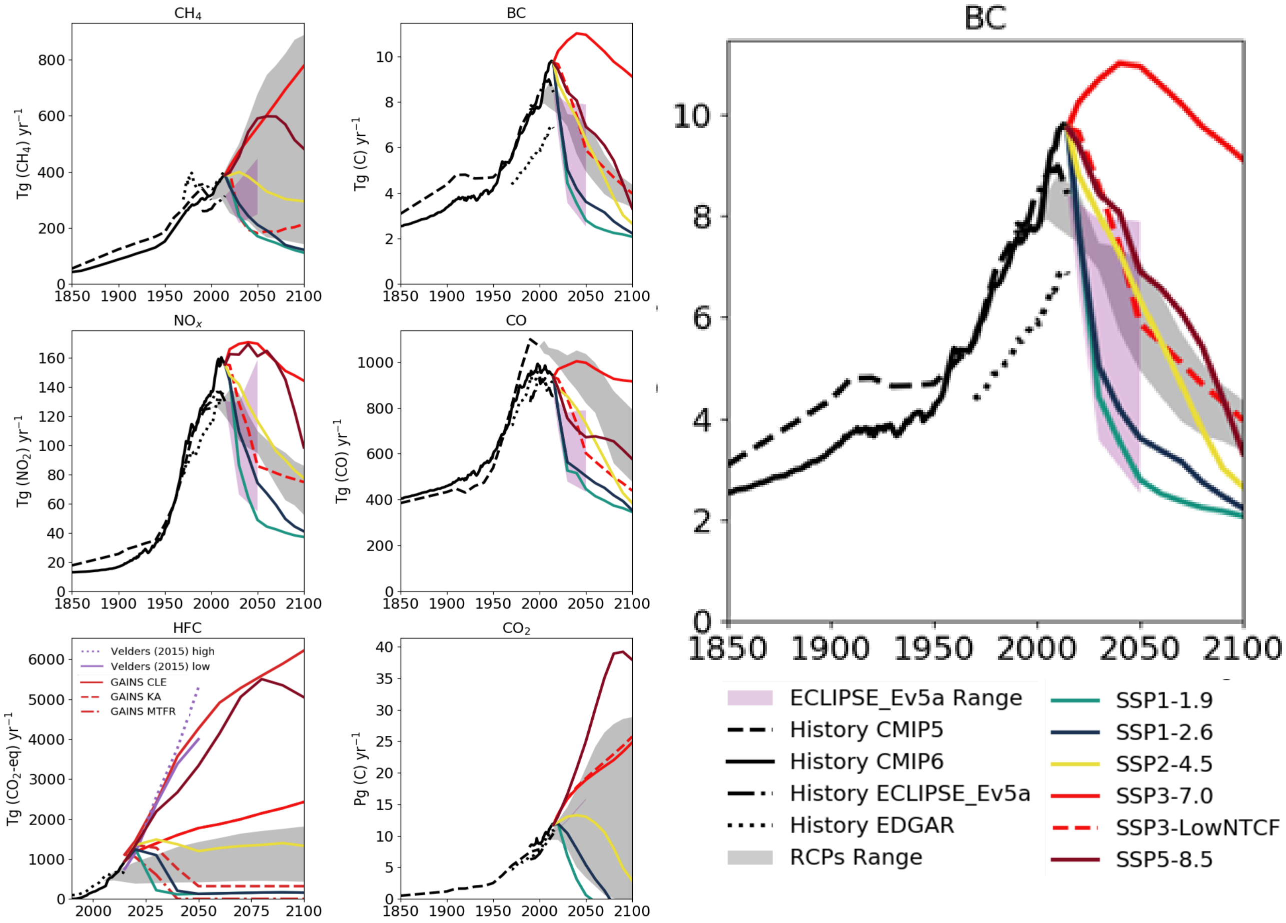
SSP1-1.9 & SSP1-2.6
✔✔ **Climate change mitigation**
✔✔ **Air pollution controls**



One air pollutant and contributor to aerosols



Feasibility or likelihood of individual scenarios is not part of the assessment

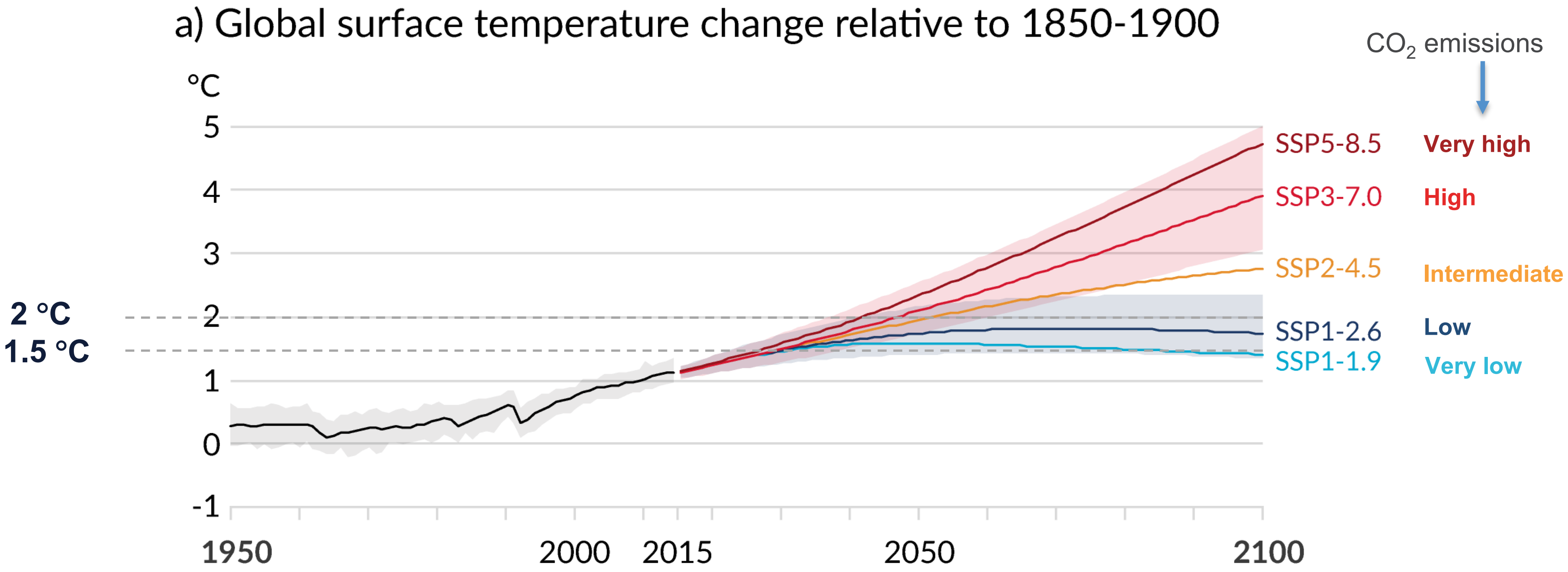


Wider range between SSP scenarios than RCPs

Rapid evolution of emissions, hard to catch in inventories

Figure 6.18. Global anthropogenic and biomass burning short-lived climate forcer (SLCF) and CO_2 emissions from 1850 to 2100 and HFC emissions from 1990 to 2100. Emissions for the Coupled Model Intercomparison Project Phase 6 (CMIP6) for the period 1850-2014 are based on Hoesly et al. (2018)

Global surface temperature will continue to increase until at least the mid-century under all emission scenarios considered



[Credit: evgeny-nelmin.]

"To limit global warming, strong, rapid, and sustained reductions in CO_2, methane, and other greenhouse gases are necessary.

This would not only reduce the consequences of climate change but also improve air quality.

Links between actions aiming to limit climate change and actions to improve air quality

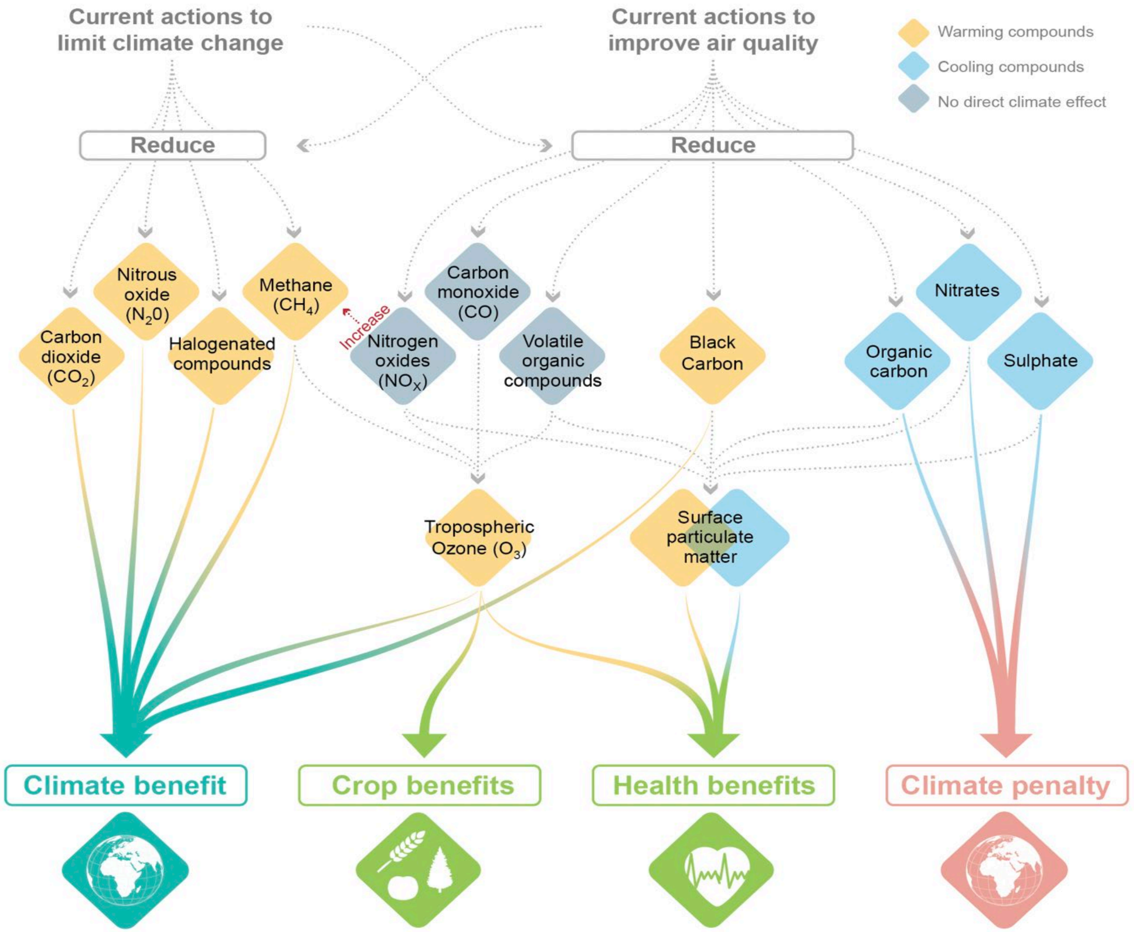


Figure FAQ 6.2

Impacts on air quality. PM2.5 and ozone

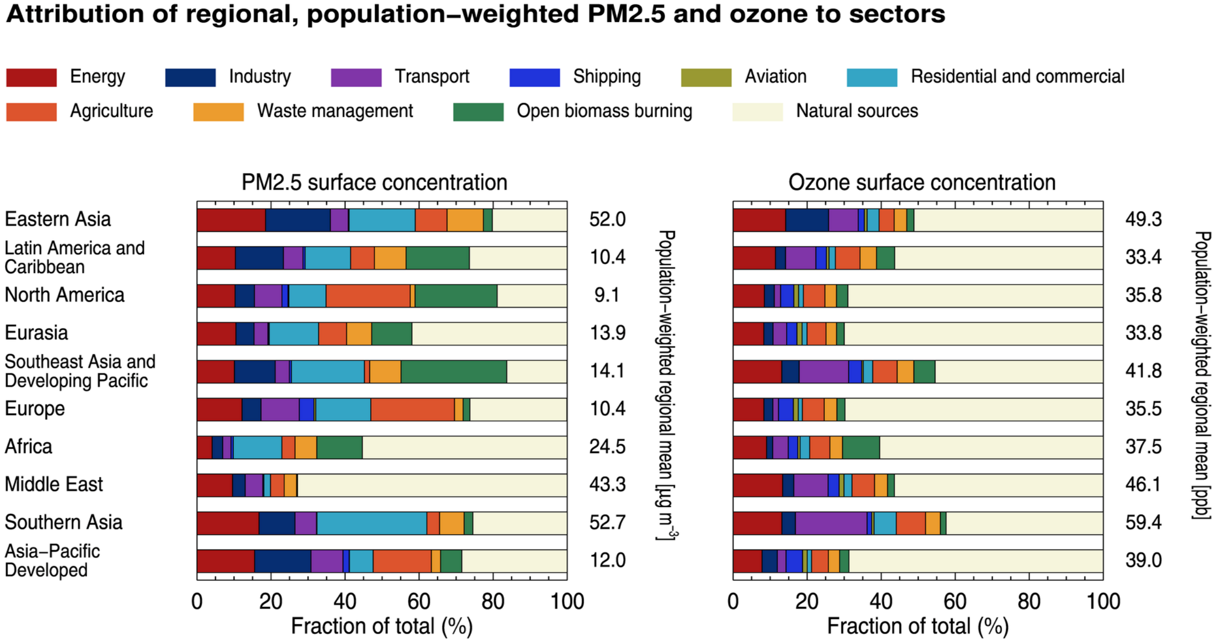
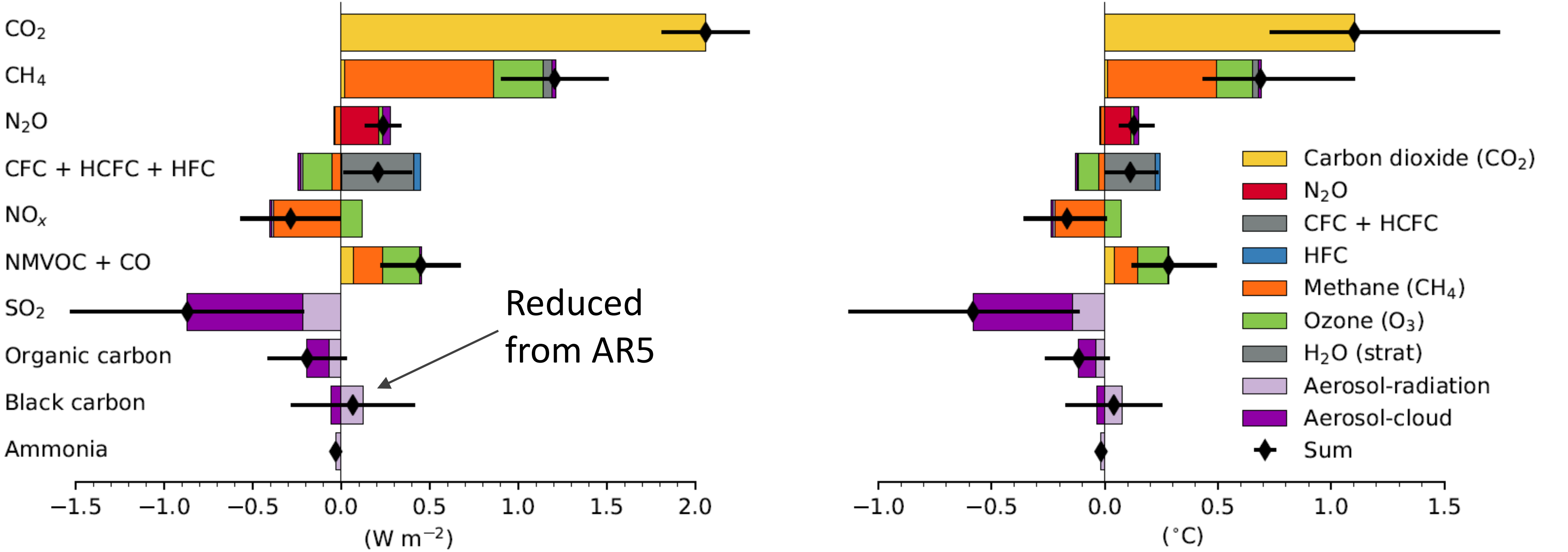


Figure 6.17 Emission source-sector attribution of regional population weighted mean concentrations of $PM_{2.5}$ and ozone for present day emissions (year 2014). Regional concentrations and source apportionment calculated with the TM5-FASST model (Van Dingenen et al., 2018) for the 2014 emission data from the Community Emissions Data System (CEDS) (Hoesly et al., 2018) and van Marle et al.(2017) for open biomass burning.

Effective Radiative Forcing, 1750 to 2019

Global mean temperature change, 1750 to 2019



Implications of COVID-19 Restrictions for Emissions, Air Quality and Climate

Emissions reductions in 2020 associated with measures to reduce the spread of COVID-19 led to temporary but detectible effects on air pollution (*high confidence*), and an associated small, temporary increase in total radiative forcing, primarily due to reductions in cooling caused by aerosols arising from human activities (*medium confidence*).

Global and regional climate responses to this temporary forcing are, however, undetectable above natural variability (*high confidence*).

Atmospheric CO_2 concentrations continued to rise in 2020, with no detectable decrease in the observed CO_2 growth rate (*medium confidence*).

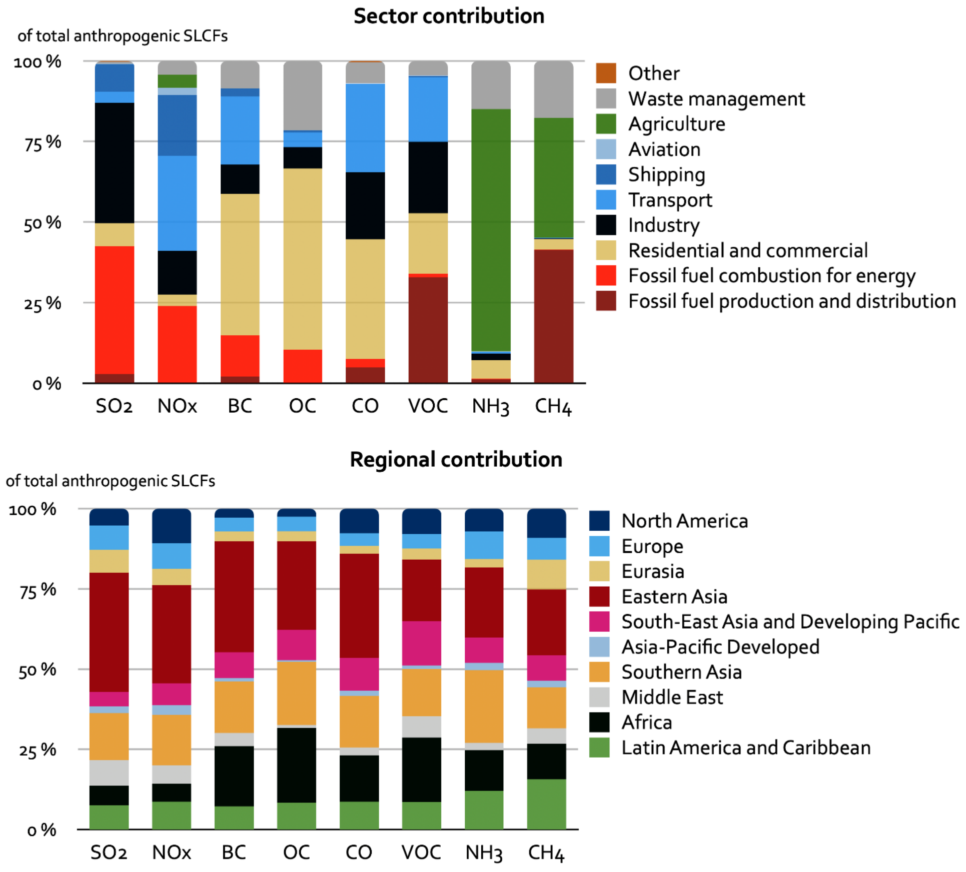
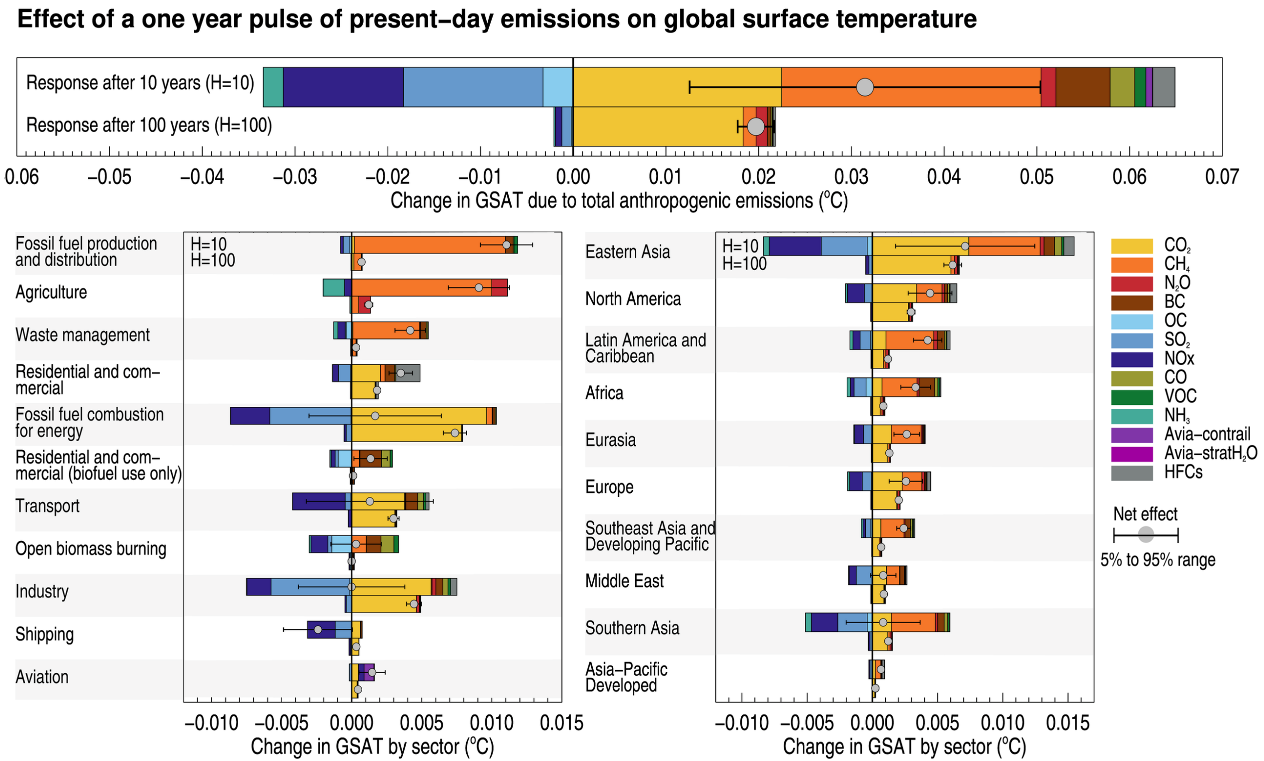


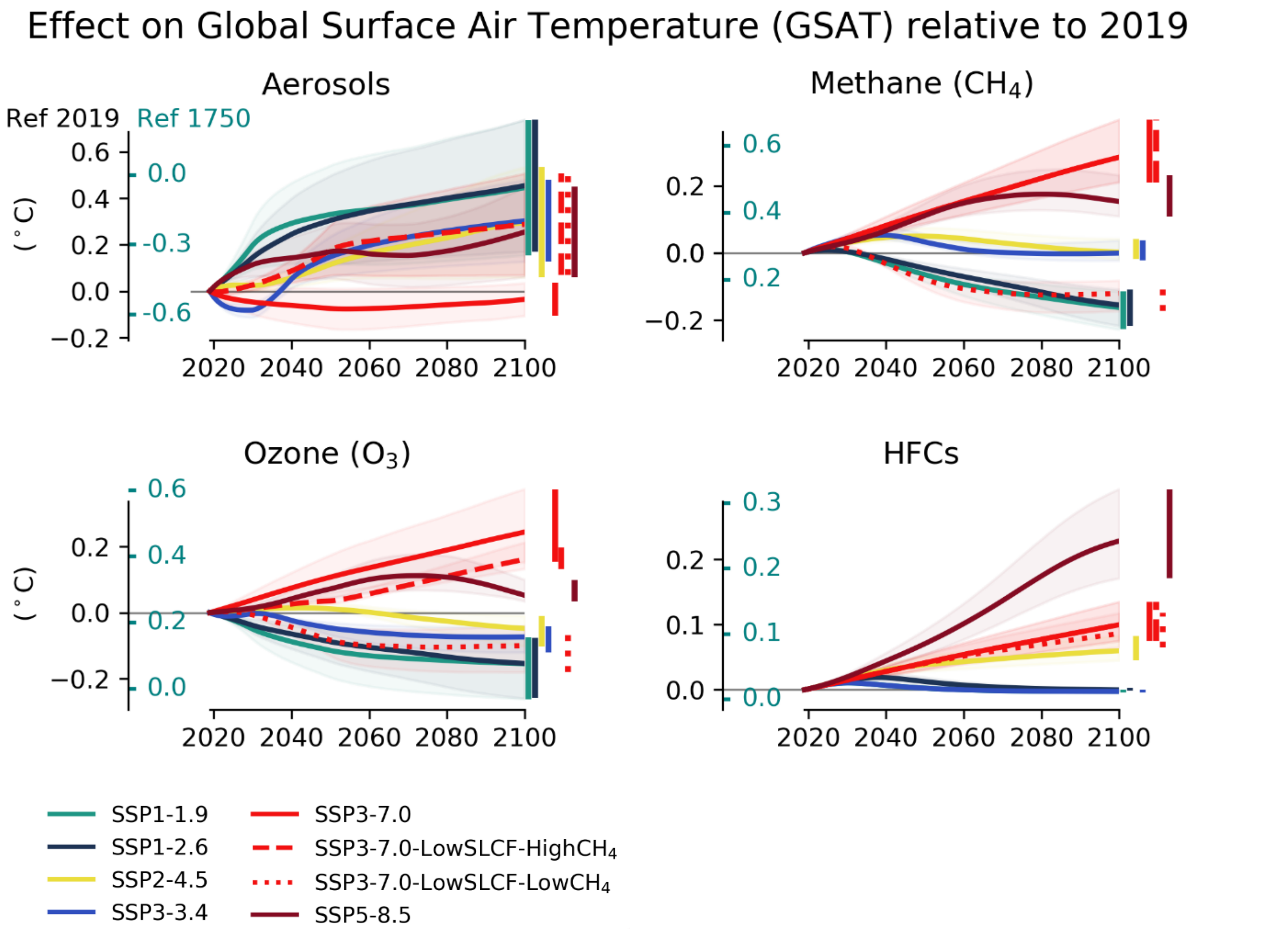
Figure 6.3. Relative regional and sectoral contributions to the present day (year 2014) anthropogenic emissions of Short Lived Climate Forcers (SLCFs).



Emission based temperature change for

- Regions
- Sectors

Figure 6.16. Global-mean temperature response 10 and 100 years following one year of present-day (year 2014) emissions. The temperature response is broken down by individual species and shown for total anthropogenic emissions (top), sectoral emissions (left) and regional emissions (right). Sectors and regions are sorted by (high-to-low) net temperature effect on the 10-year time scale. Error bars in the top panel show uncertainty (5-95% interval) in net temperature effect due to uncertainty in radiative forcing



Evolution of the effects of short-lived climate forcers (SLCFs) and HFCs on global temperature across the core Shared Socio-Economic Pathways (SSPs). Effects of net aerosols, methane, tropospheric ozone and hydrofluorocarbons (HFCs) (with lifetimes <50years), relative to year 2019 and to year 1750.

Remaining carbon budgets

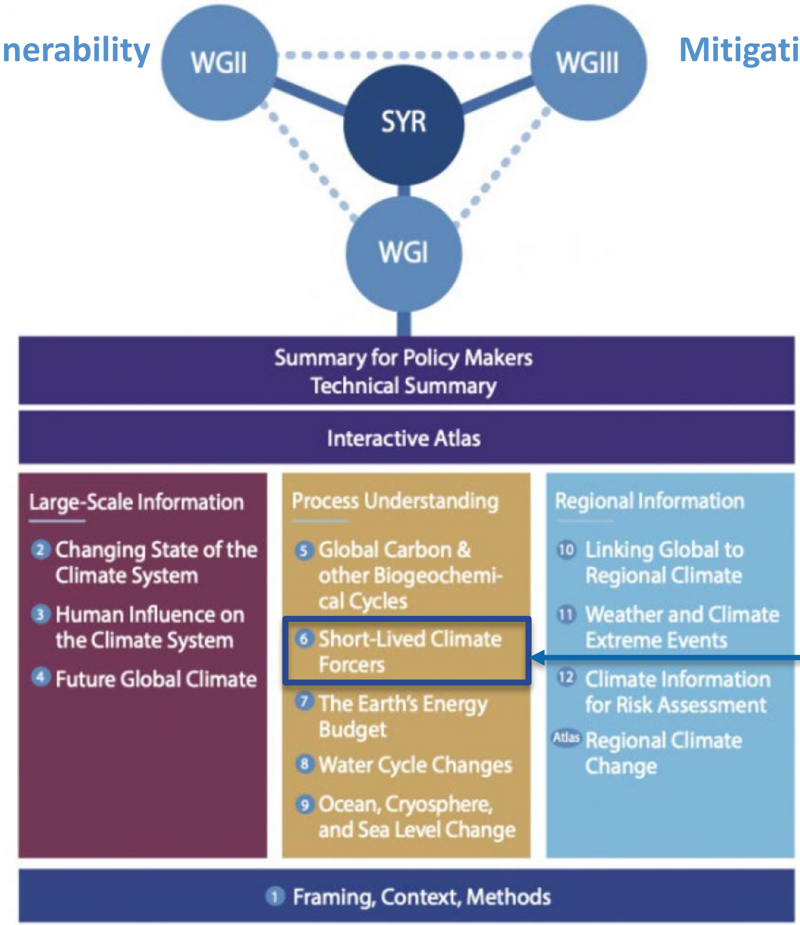
Approximate global warming relative to 1850–1900 until temperature limit *(°C)**(1)	Estimated remaining carbon budgets from the beginning of 2020 *($GtCO_2$)* *Likelihood of limiting global warming to temperature limit*(2)*				
	17%	*33%*	*50%*	*67%*	*83%*
1.5	900	650	500	400	300
1.7	1450	1050	850	700	550
2.0	2300	1700	1350	1150	900

Estimates may vary by ±220 $GtCO_2$ depending on the level of non-CO_2 emissions at the time global anthropogenic CO_2 emissions reach net zero levels. This variation is referred to as **non-CO_2 scenario uncertainty** and will be further assessed in the AR6 Working Group III Contribution.

Geophysical uncertainties surrounding the climate response to these non-CO_2 emissions (such as CH_4, N_2O, and aerosols) result in an additional uncertainty of at least ±220 $GtCO_2$

Impacts, Adaptation and Vulnerability

Mitigation of Climate Change



The structure of the AR6 WGI Report

Thank you.

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