SIXTH ASSESSMENT REPORT
Working Group I – The Physical Science Basis

ipcc
INTERGOVERNMENTAL PANEL ON climate change

WMO UNEP

Short-lived climate forcers (SLCF) in the IPCC WGI AR6: Input to the TFI 3rd Expert Meeting

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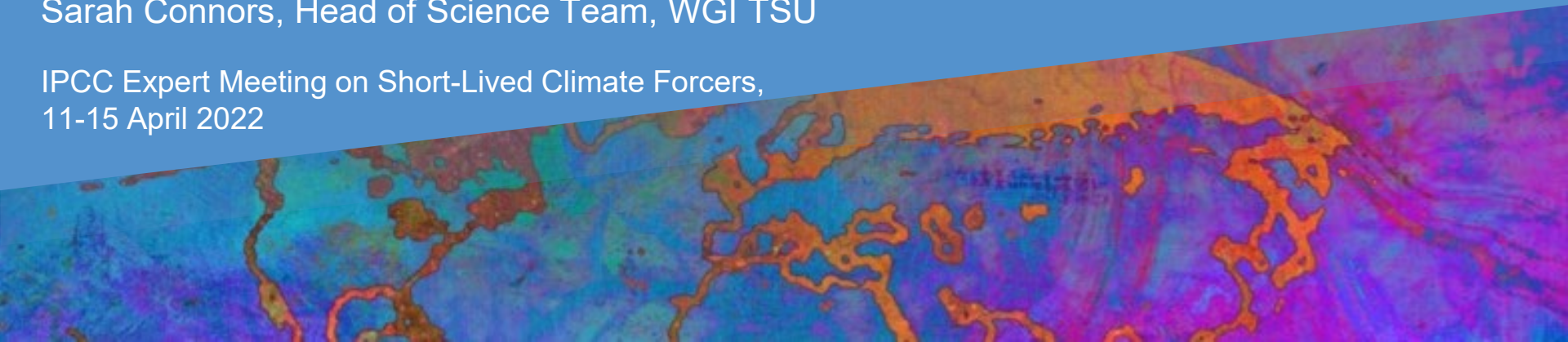
IPCC Expert Meeting on Short-Lived Climate Forcers,
11-15 April 2022



What are Short-lived climate forcers (SLCF)?

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

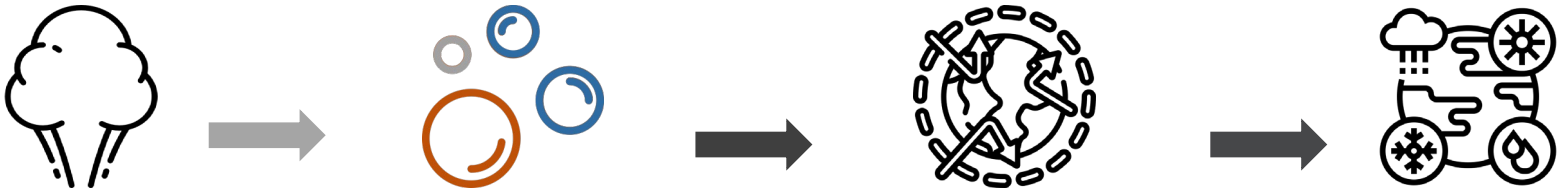
SLCFs can be classified as **direct** or **indirect**, with **direct** SLCFs exerting climate effects through their radiative forcing and **indirect** SLCFs being precursors of direct climate forcers.

- **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.

Particulate matter (PM): A combination of all aerosol species

From emissions to climate effects



Aerosols: climate impact of aerosols depend on shape, size, composition and optical properties

- Therefore, for PM2.5 only characterizing the size thus does not inform on climate effect. It is not possible to characterize the optical properties of PM2.5 in a model to estimate the climate effect
- Therefore, PM2.5 has less of a priority within a climate framing (but is still important within a health framing)

Climate effect of Aerosols

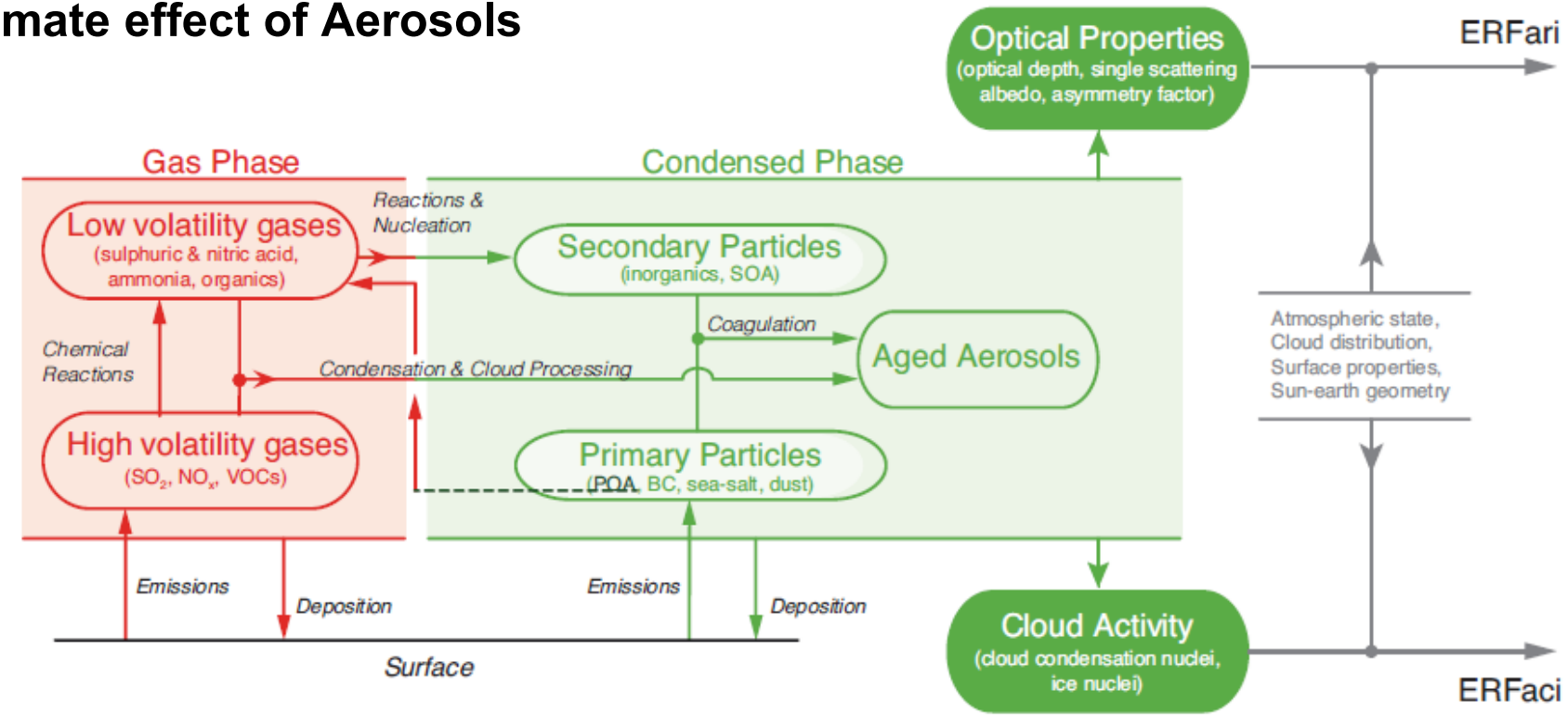
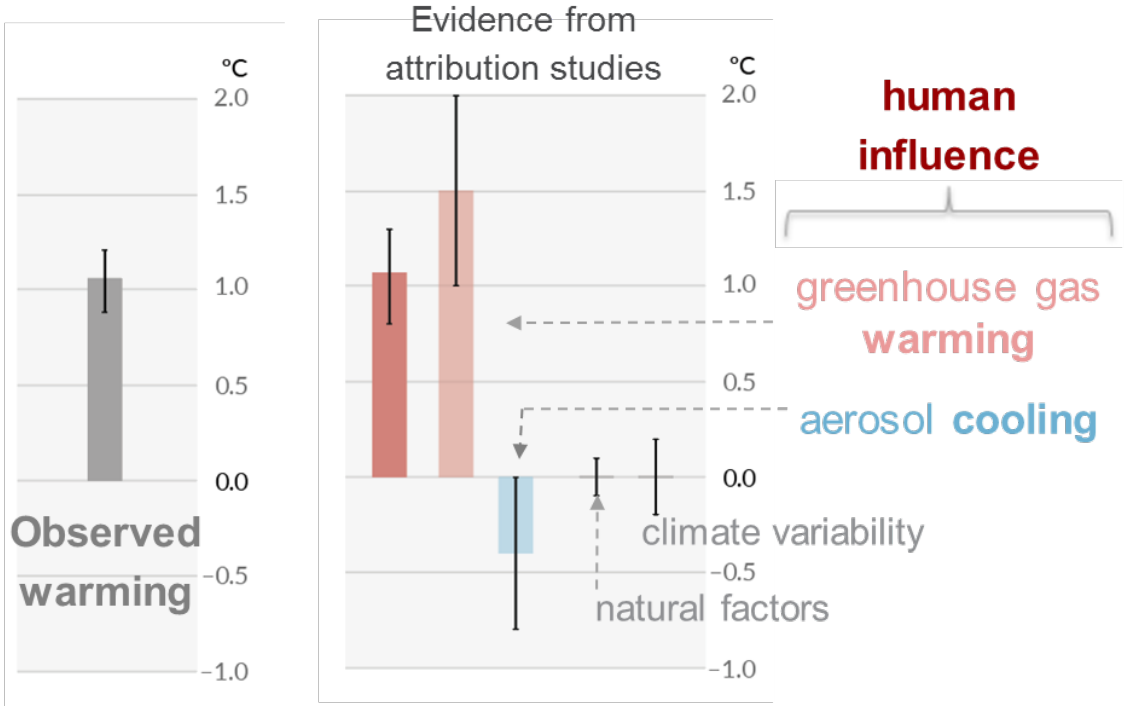


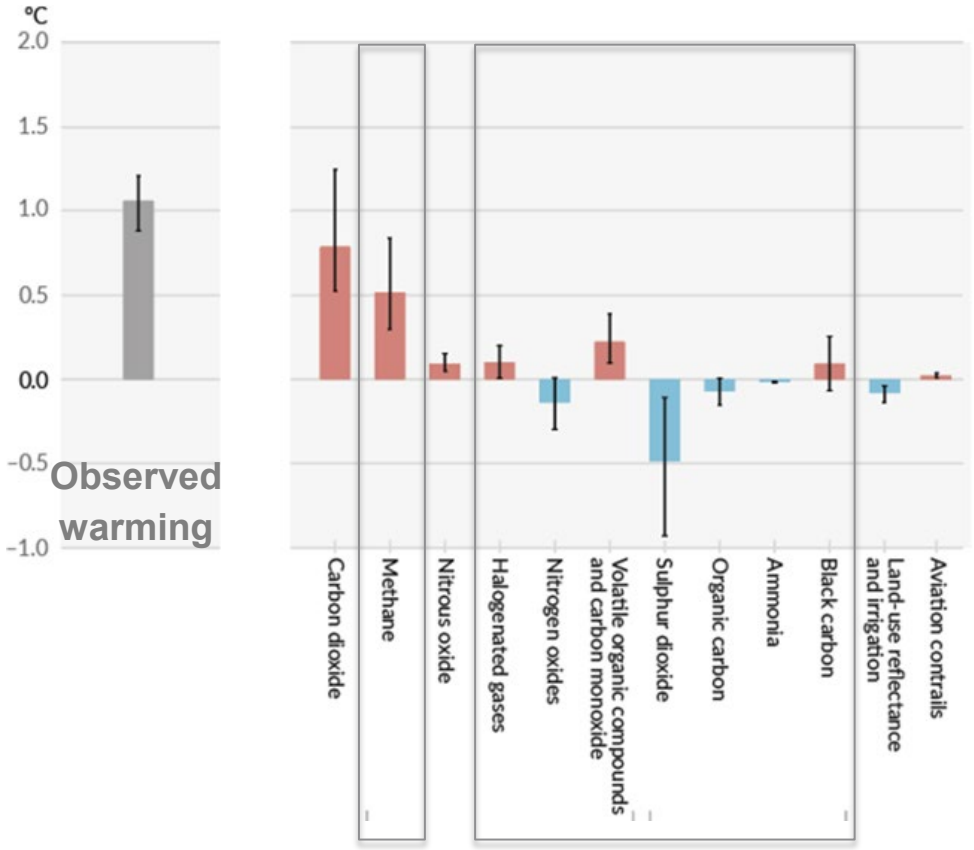
Figure 7.12 | Overview of atmospheric aerosol and environmental variables and processes influencing aerosol–radiation and aerosol–cloud interactions. Gas-phase variables and processes are highlighted in red while particulate-phase variables and processes appear in green. Although this figure shows a linear chain of processes from aerosols to forcings (ERFari and ERFaci), it is increasingly recognized that aerosols and clouds form a coupled system with two-way interactions (see Figure 7.16).

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



Adapted from Figure SPM.2

Short-lived climate forcers (SLCFs) have modify global temperatures



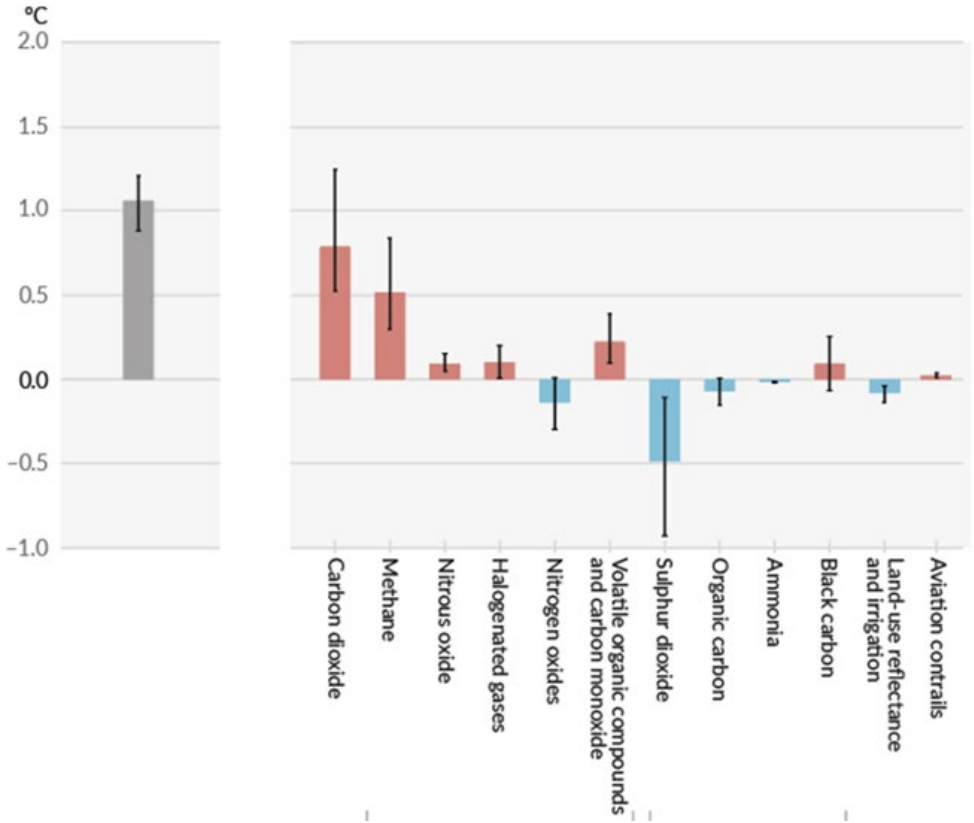
SLCFs play an important role in changing the climate

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

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

Adapted from Figure SPM.2

Short-lived climate forcers (SLCFs) modify global temperatures



Key SLCFs of importance, based on **current forcing** on climate, are:

- Methane
- Sulphur dioxide
- Volatile organic carbon (VOCs)
- Carbon monoxide
- Nitrogen oxides
- Black carbon
- Halogenated gases
- Organic carbon
- Ammonia

Adapted from Figure SPM.2

For SLCFs, there are several connections between climate and AQ / health

IPCC's main focus in on climate

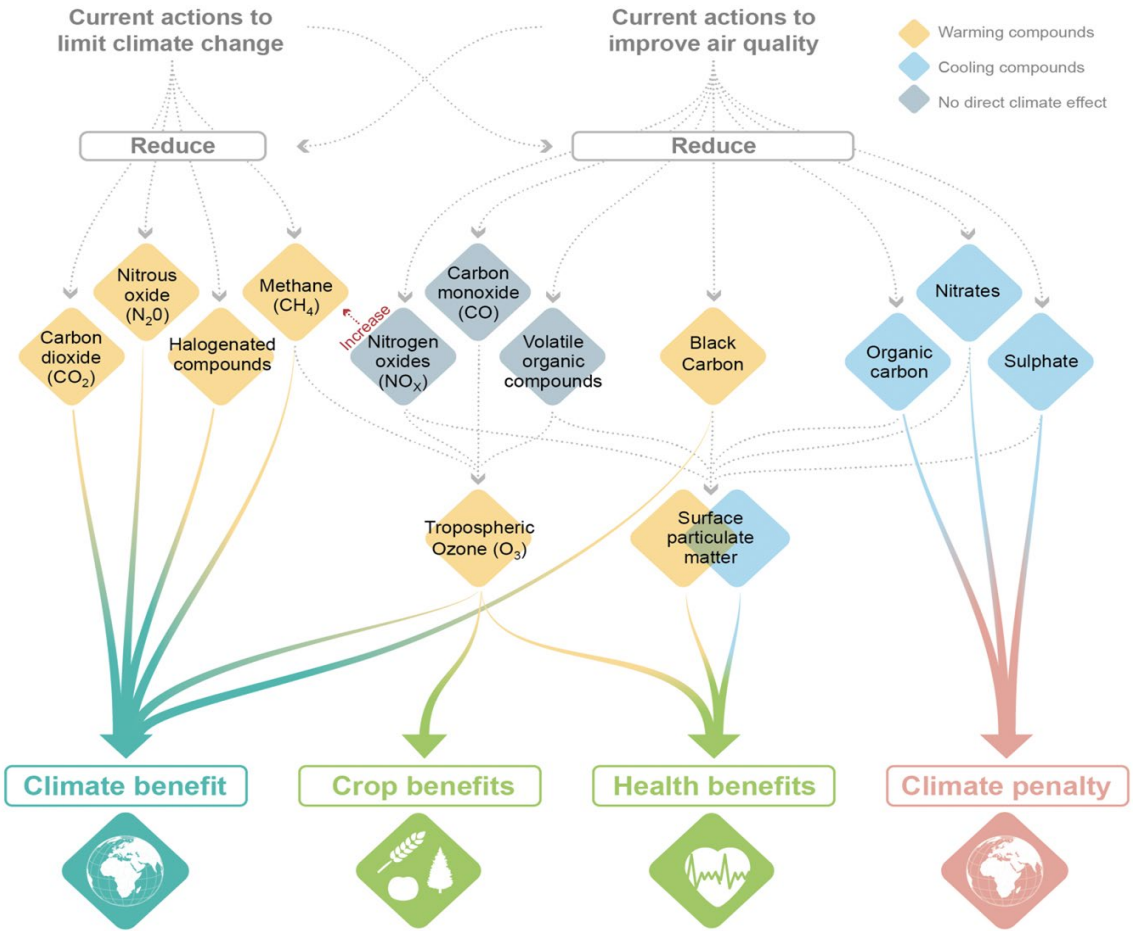
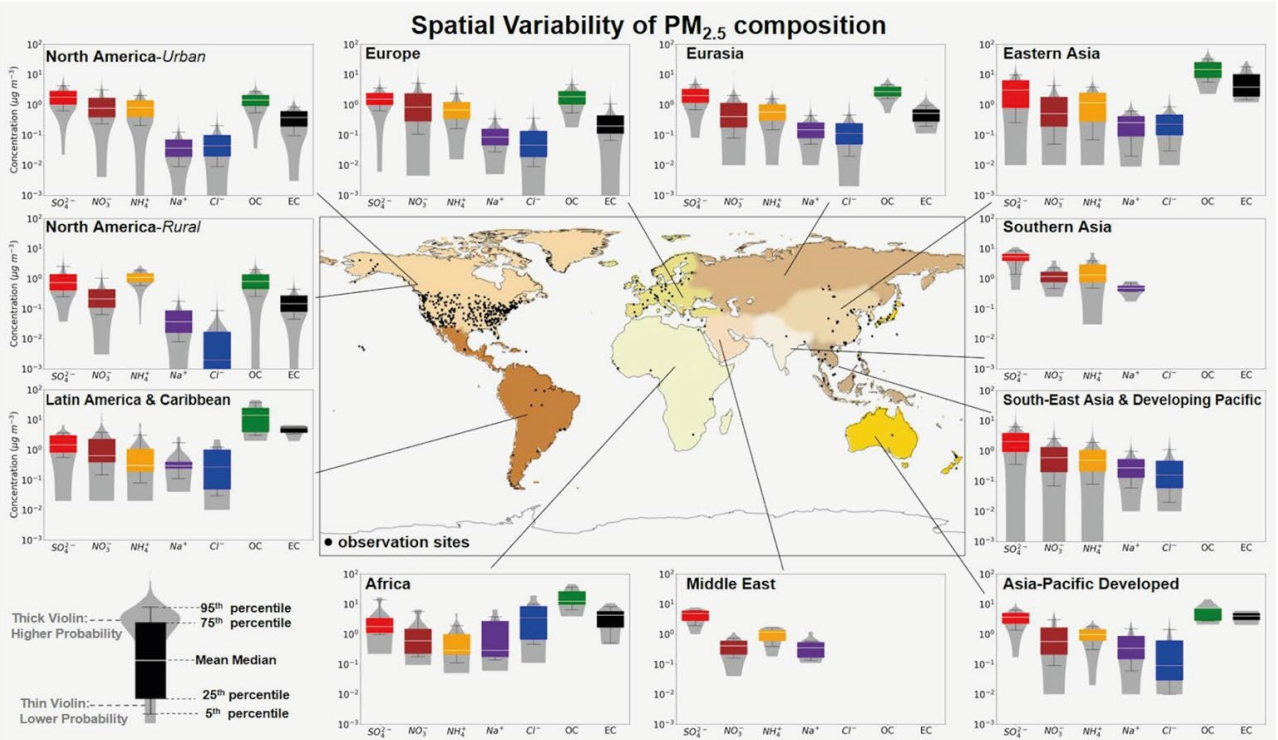


Figure FAQ 6.2

PM2.5 as an aggregate is less informative than individual species

PM2.5 mask the heterogeneity of composition - which is of importance for impact of aerosols **(both AQ/health and climate)**



Sulphate (SO_2^+)
Nitrate (NO_3^-)
Ammonia (NH_4^+)
Sodium (Na^+)
Chloride (Cl^-)
Organic Carbon (OC)
Elemental carbon (EC)

Figure 6.7

SLCFs are emitted from both anthropogenic and natural sources

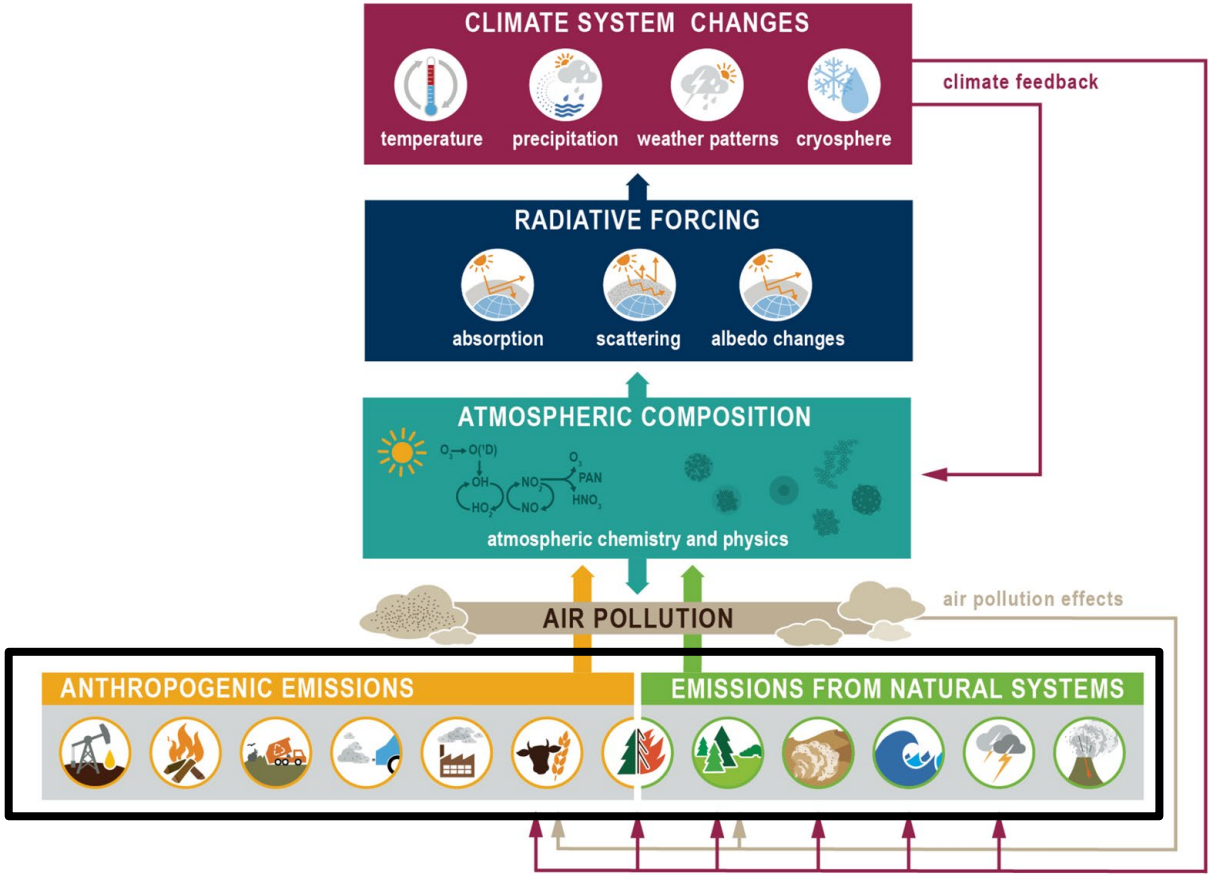
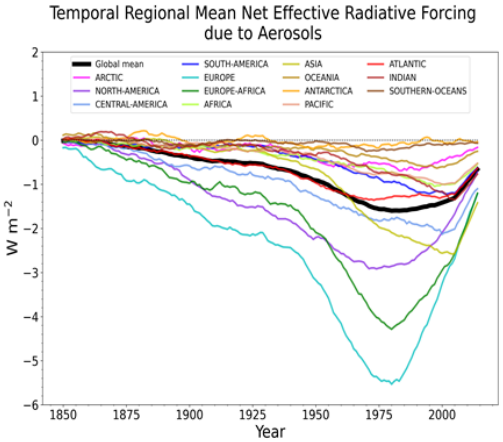


Figure 6.1

Anthropogenic emissions of SLCFs vary significantly by region and source sector

Chapter 6 provides assessments of how SLCFs vary by region and sector.



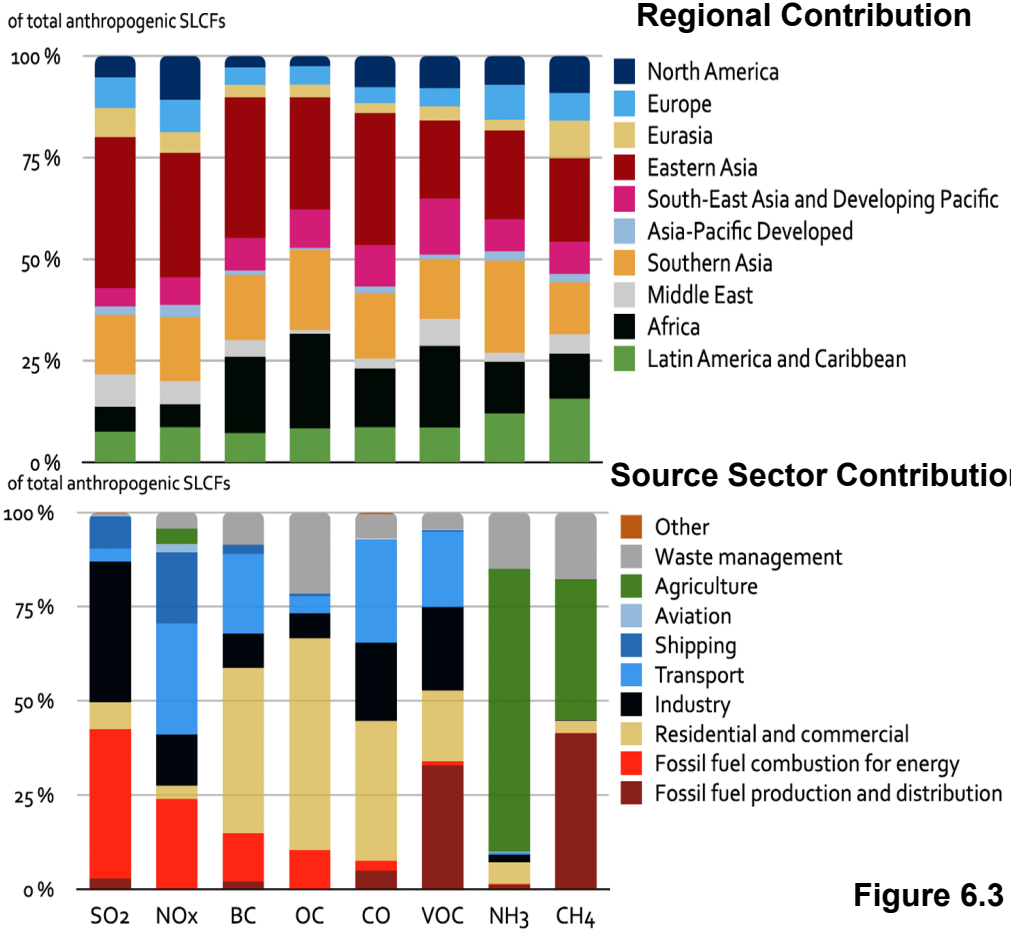


Figure 6.3

More information in Chapter 6 of the WGI report

Chapter 6: Short-lived climate forcers

Chapter 6 discusses the evolution of reactive compounds and their effects on climate and global air quality.

Section 6.1
Importance of short-lived climate forcers (SLCFs) for climate and air quality

Section 6.2
SLCF emissions

Section 6.3
SLCF atmospheric abundance

Section 6.4
SLCF radiative forcing and climate effects

Section 6.5
Implications of changing climate on air quality

Section 6.6
Air quality and climate response to SLCF mitigation

Section 6.7
Future projections of SLCFs, air quality and climate response in SSP scenarios

Section 6.8
Perspectives

FAQs

Chapter 6: Quick guide

Key topics and corresponding sub-sections

- Connections to air quality
  6.5 | 6.6.2 | 6.6.3 | 6.7.2 | CC Box 6.1 | Box 6.2
- Historical and future evolution of SLCF concentrations
  6.3 | 6.7.1 | (and Chapter 5 for methane)
- Implications of socio-economic and emissions pathways
  6.6.3 | 6.7
- Interactions between SLCFs and clouds and precipitation
  6.4.3 | (and Chapters 7 and 8)
- Oxidizing capacity
  6.3.6
- Sectoral attribution
  6.6.2
- SLCF radiative forcing
  6.4.1 | 6.4.2 | (and Chapter 7)
- Solar radiation modification
  6.4.6 | (and Chapters 4 and 5)

Boxes

Box 6.1
SLCFs: From process-level studies to global models

Box 6.2
SLCFs mitigation and sustainable development goals

Cross-chapter boxes

CC Box 6.1
COVID-19 and air quality

More information in Chapter 6 of the WGI report

Section 6.2 discussing emissions (and their uncertainties)

Figure 6.3 for SLCF emissions

Figure 6.12 for effect on climate

Figures 6.18 and 6.19 for evolution of emissions

Compounds	Source Type	Lifetime	Direct	Indirect	Climate Forcing	Other Effects on Climate[a]	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 to weeks	O_3	CH_4, secondary organic and sulphate aerosols	+	Ecosystems	100 µg m^{-3} 8-hour mean
NO_x (= NO + NO_2)	Primary	Hours to days		O_3, nitrate aerosols, CH_4	+/–	Ecosystems	40 µg m^{-3} annual mean 200 µg m^{-3} 1-hour mean
CO	Primary + Secondary	1 to 4 months		O_3, CH_4	+		No
NMVOCs[**]	Primary + Secondary	Hours to months		O_3, CH_4, organic aerosols	+/–		No
SO_2	Primary	Days (trop.) to weeks (strat.)		Sulphate and nitrate aerosols, O_3	–	Ecosystems	20 µg m^{-3} 24-hour mean 500 µg m^{-3} 10-minute mean
NH_3	Primary	Hours		Ammonium Sulphate, Ammonium Nitrate	–	Ecosystems	No
HCFCs	Primary	Months to years	HCFCs	O_3	+/–		No[c]
HFCs	Primary	Days to 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 6 months		Stratospheric O_3	–		No[c]
Sulphate aerosols	Secondary	Minutes to weeks	Sulphate		–	Clouds Ecosystems	as part of PM[d]
Nitrate aerosols	Secondary	Minutes to weeks	Nitrate		–	Clouds Ecosystems	as part of PM[d]
Carbonaceous Aerosols	Primary + Secondary	Minutes to Weeks	BC, OA		+/–	Cryo, Clouds Ecosystems	as part of PM[d]
Sea spray	Primary	Day to week	Sea spray		–	Clouds Ecosystems	as part of PM[d]
Mineral dust	Primary	Minutes to Weeks	Mineral dust		+/–	Cryo Cloud Ecosystems	as part of PM[d]

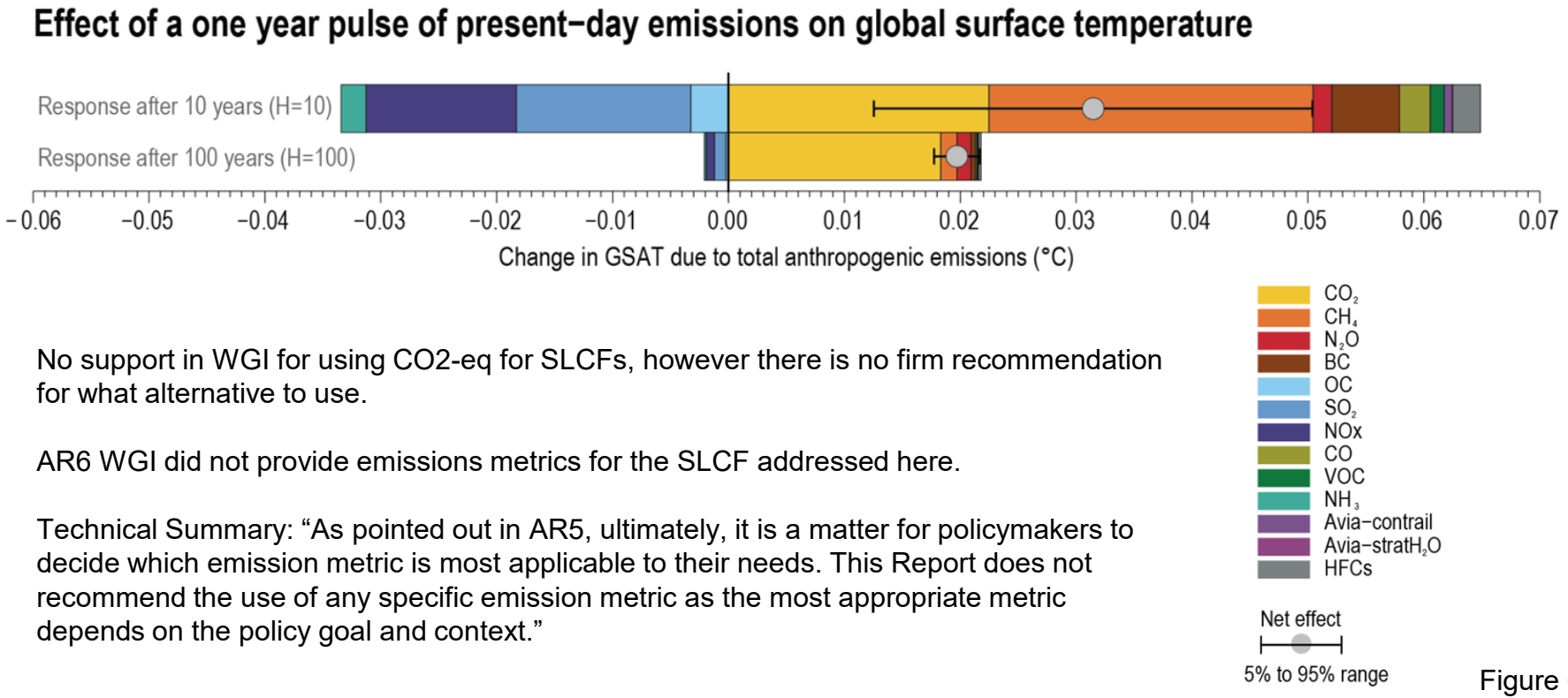
Table 6.1

From the Executive Summary in report from the 2018 Expert Meeting

"Reporting of SLCF and GHG inventories should be in mass units for each individual emitted compound. Some SLCF species (e.g., VOC) comprise multiple different chemical compounds and thus mass-based emissions must be carefully defined. It should be noted that the existing inventory methodology on GHGs (2006 IPCC Guidelines) does not require inventory compilers to calculate and report national total emissions in CO2 equivalent unit. The understanding of emission metrics and how they can be used, particularly in the context of SLCF emissions, has advanced but there is currently no agreed recommendation. **The meeting participants concluded that SLCF emissions addressed in this meeting report should not be converted to CO2 equivalent units in the same way as done based on GWP100 in the inventory reporting under the UNFCCC.** The meeting agreed that the issue of metrics and how they can be used may be further considered based on new scientific literature for coordination across Working Group reports, particularly those of Working Group I and Working Group III, towards the synthesis report (SYR) of the sixth assessment report (AR6)."

The "key category analysis" (KCA) is an integral step in the national GHG inventory compilation cycle. In this analysis, all GHGs are aggregated in terms of CO2-equivalents.

Which metrics to use for SLCFs? Very dependent on time horizon



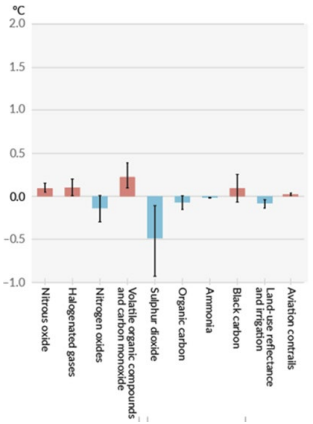
- No support in WGI for using CO2-eq for SLCFs, however there is no firm recommendation for what alternative to use.
- AR6 WGI did not provide emissions metrics for the SLCF addressed here.
- Technical Summary: “As pointed out in AR5, ultimately, it is a matter for policymakers to decide which emission metric is most applicable to their needs. This Report does not recommend the use of any specific emission metric as the most appropriate metric depends on the policy goal and context.”

Figure 6.16

In Summary

- Key SLCFs of importance, based on **current forcing** on climate, are:
  - Sulphur dioxide
  - Volatile organic carbon (VOCs) & carbon monoxide
  - Nitrogen oxides
  - Black carbon
  - (Halogenated gases)
  - Organic carbon
  - Ammonia

overall warming
overall cooling



- PM2.5 is important when considering air quality and health effects - but not relevant as such for climate
- The positive radiative forcing of Black carbon has been reduced in AR6 compared to AR5
- SLCF emissions are evolving rapidly at the regional level due to implementation of AQ policies
- Since AR5, the quality and completeness of activity and emission-factor data and applied methodology, have improved, raising confidence in methods used to derive emissions.
- But emission uncertainties are still large, particularly on the regional and sectoral level. Improved emission inventories will also help to reduce uncertainties related to quantifications of climate effects

Thank you for your attention.

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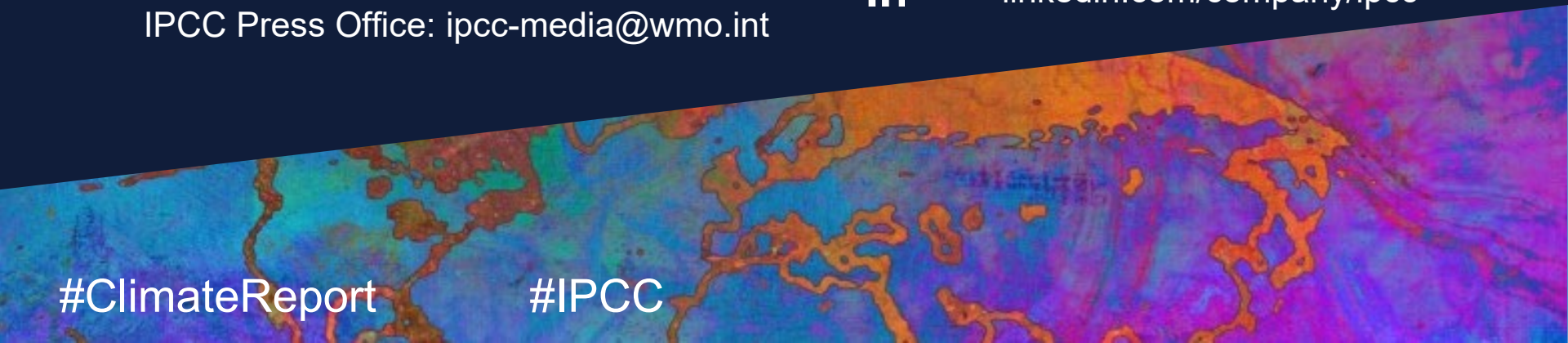

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