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Quantifying the mitigation potential of SLCFs and potential co-benefits for regional air quality

Key Requirements of ESMs

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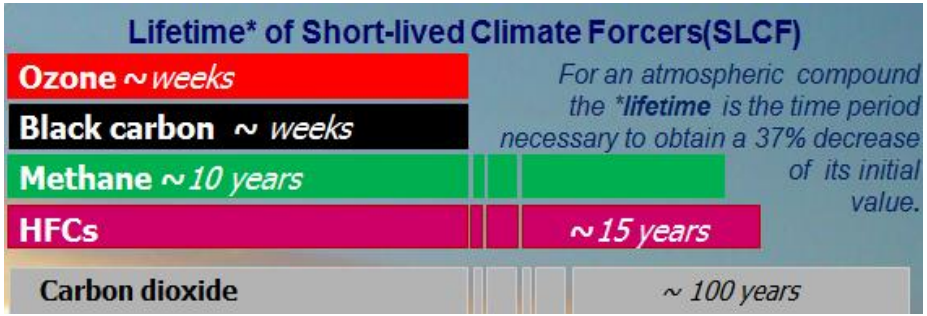
Met Office Hadley Centre

Outline of Presentation

- What are Short-Lived Climate Forcers (SLCFs)
- Why are they important?
- Historical Perspective: Emission changes
  Impact of emission changes on concentrations/AQ
  How well do ESMs reproduce historical changes?
  How well do ESMs represent climate forcing/response?
- Conclusions: Key Analysis and/or Requirements of future ESMs

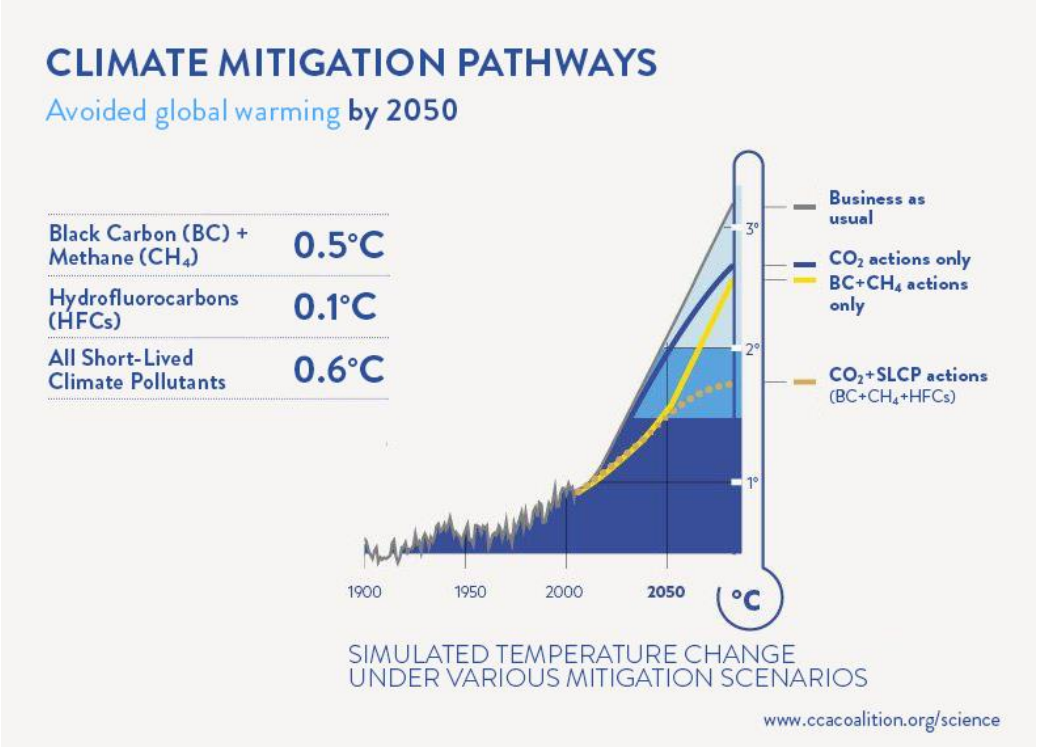
What are SLCFs?

- Gases & aerosols emitted or formed in the atmosphere
- Lifetimes shorter than CO_2 (100 yrs)
- **Forcers**: Impact on the Earth's radiation budget
- Include **greenhouse gases** (e.g. methane), **secondary pollutants** (e.g. ozone), and **aerosols** (e.g. black carbon)

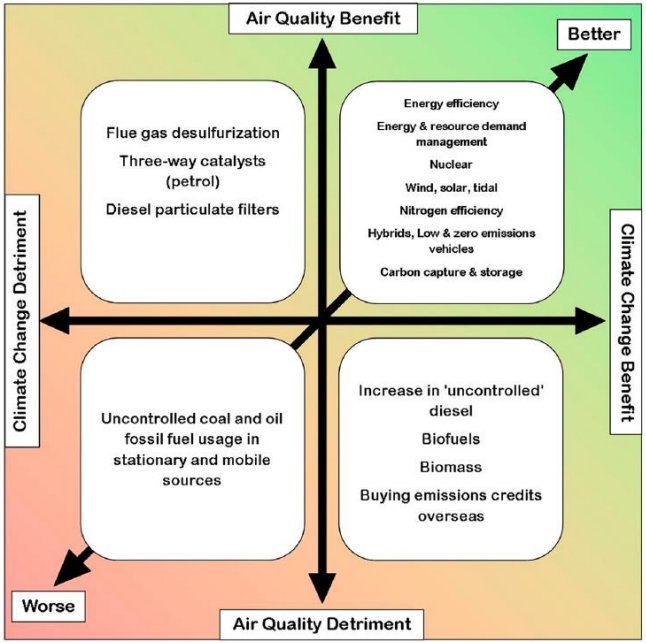


- Subset also referred to as Short-Lived Climate **Pollutants** (SLCPs) because of their impact on AQ (e.g. ozone, black carbon)

Why are SLCFs important?



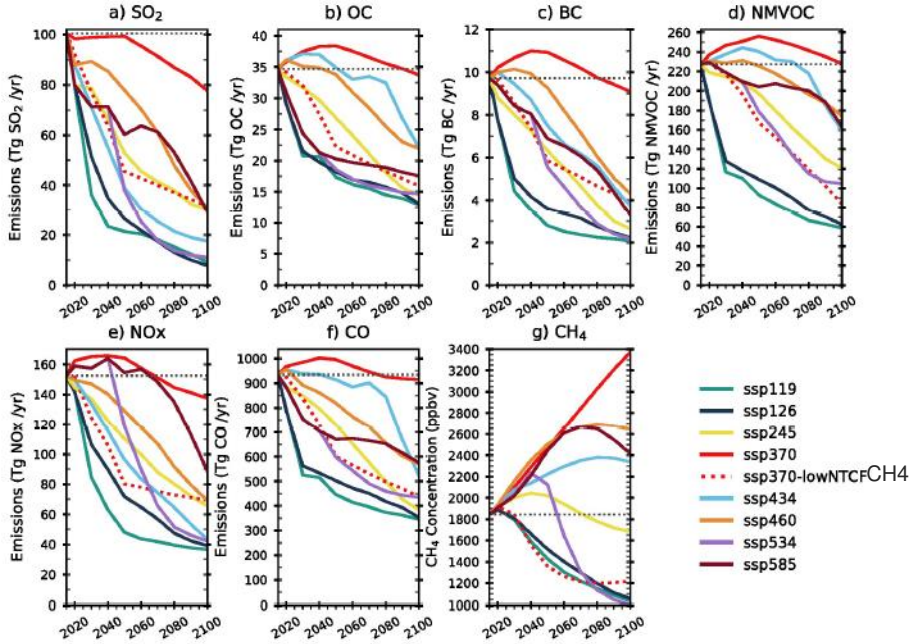
From: Climate and Clean Air Coalition
www.ccacoalition.org/science

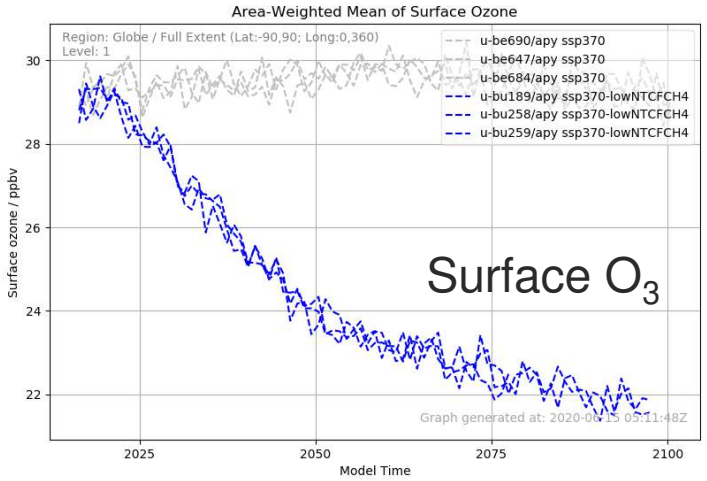


Von Schneidemesser & Monks (2013); Adapted from Williams (2012)

SLCF Mitigation in Action: Surface O_3

EMISSIONS



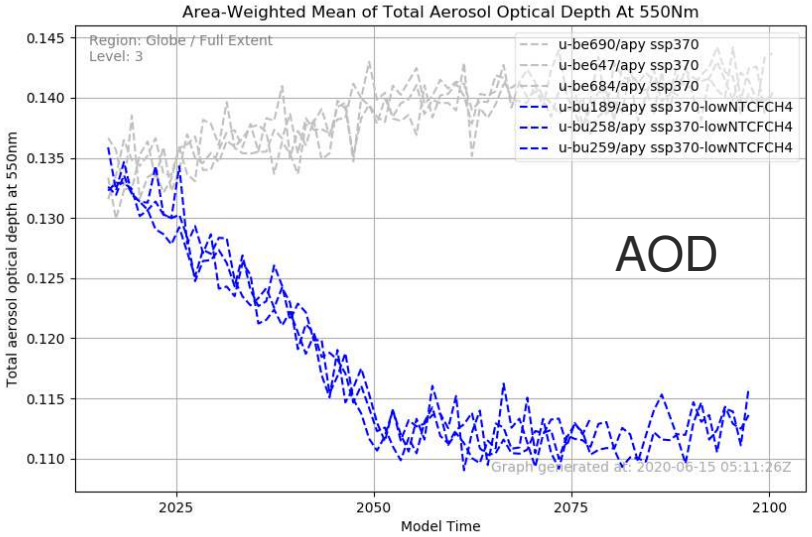


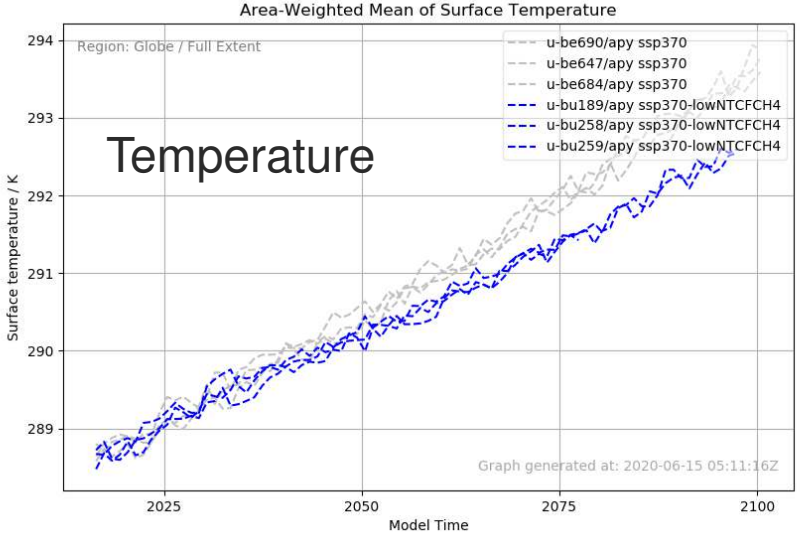
CONCENTRATIONS

“Strong” levels of air quality control measures and climate/methane mitigation: Collins et al., GMD (2017)

New AerChemMIP simulations courtesy of G. Folberth

SLCF Mitigation in Action: AOD and Climate Response





"Strong" levels of air quality control measures and climate/methane mitigation: Collins et al., GMD (2017)

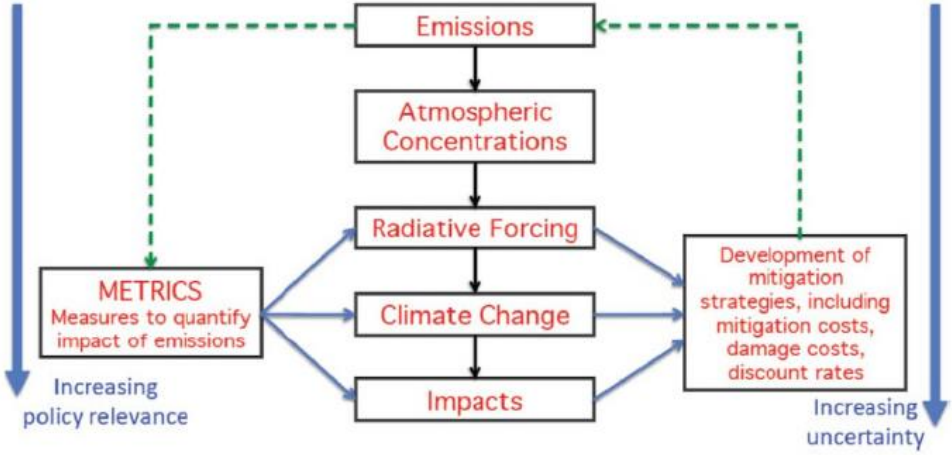
New AerChemMIP simulations courtesy of G. Folberth

Role of ESMs

Two Key Questions:

1. How well do ESMs represent all the steps in the chain from emissions through to burden through to climate forcing and climate response?

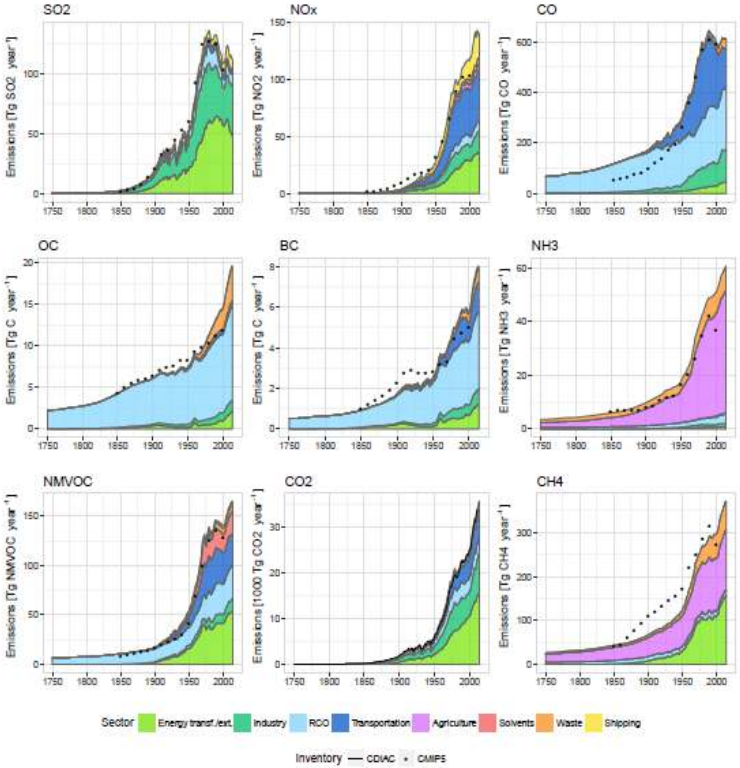
2. How well do ESMs represent regional responses in surface air quality to emission changes?



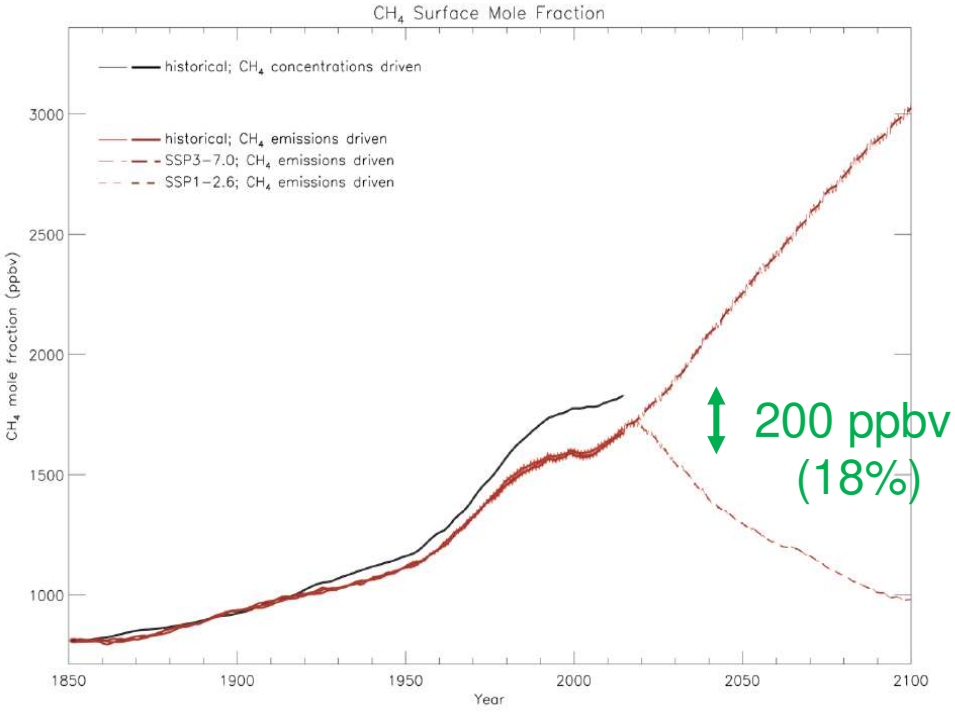
Myhre et al., IPCC AR5 (2013)

Historical emissions & methane

EMISSIONS

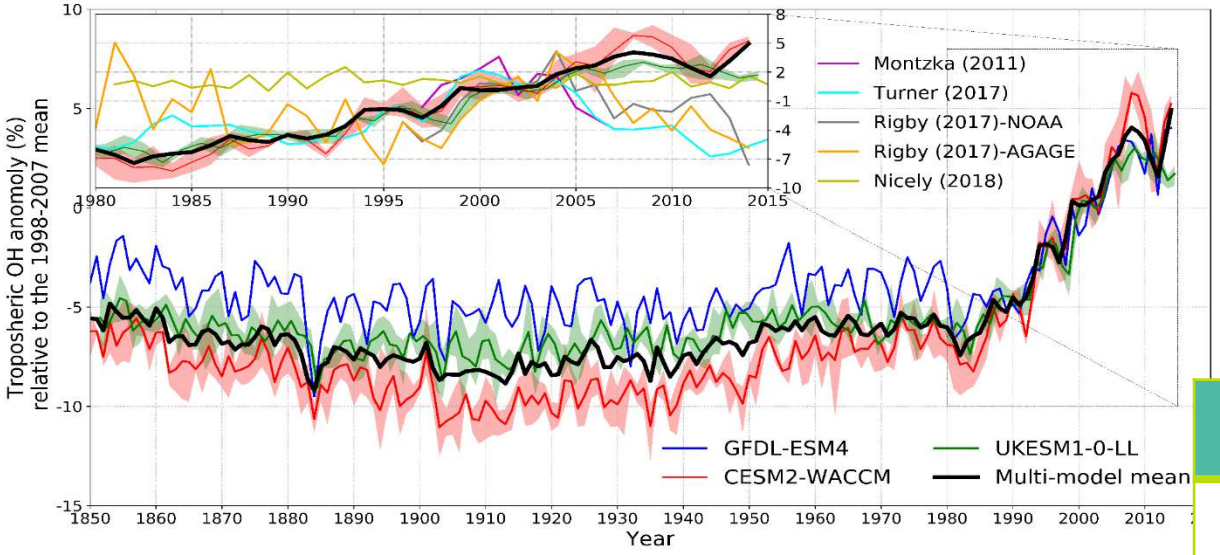


Hoesly et al., GMD (2018)



Folberth et al., Submitted (2020)

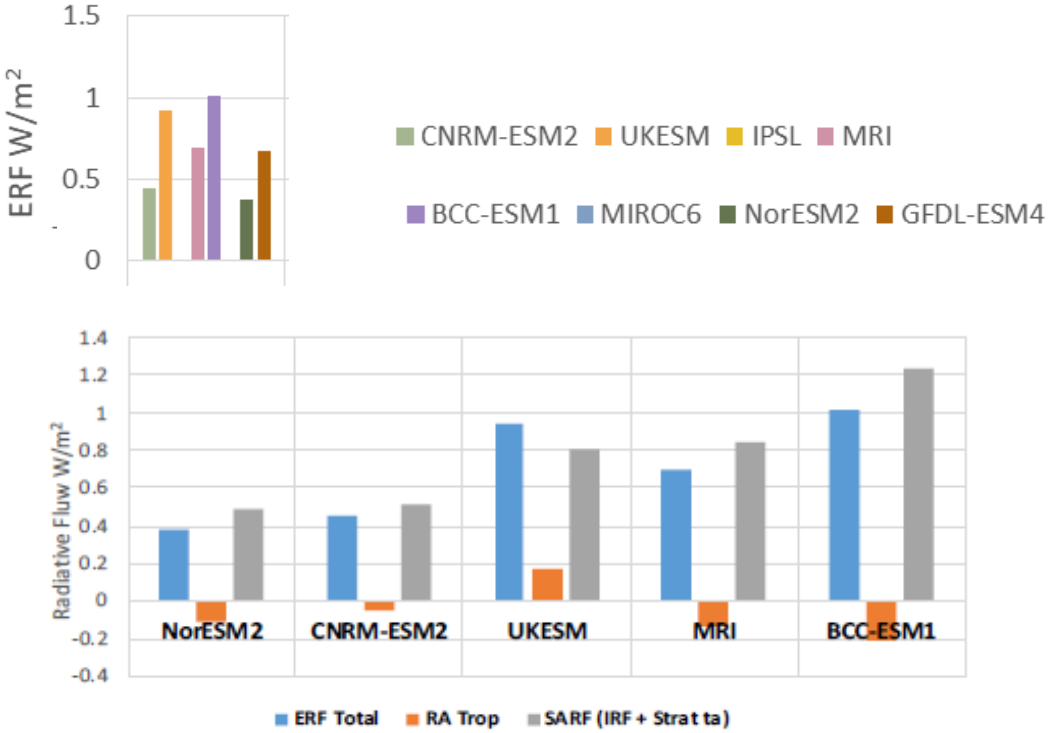
Methane Lifetime



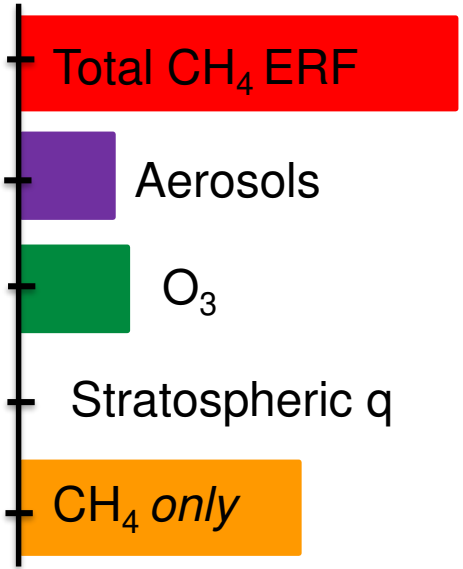
Stevenson et al., ACPD (2019)

Model	PI Lifetime	PD Lifetime
CESM2	9.49 ±0.06	8.19 ±0.06
UKESM1	8.95 ±0.07	8.08 ±0.06
GFDL	9.86 ±0.07	8.60 ±0.07

Methane Forcing



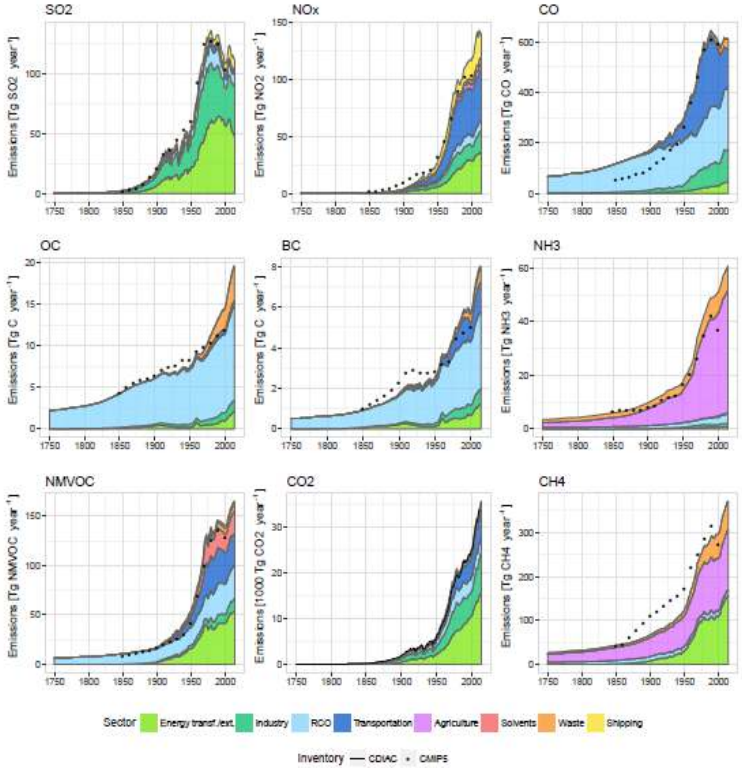
Thornhill et al., ACPD (2019)



O'Connor et al., Submitted.

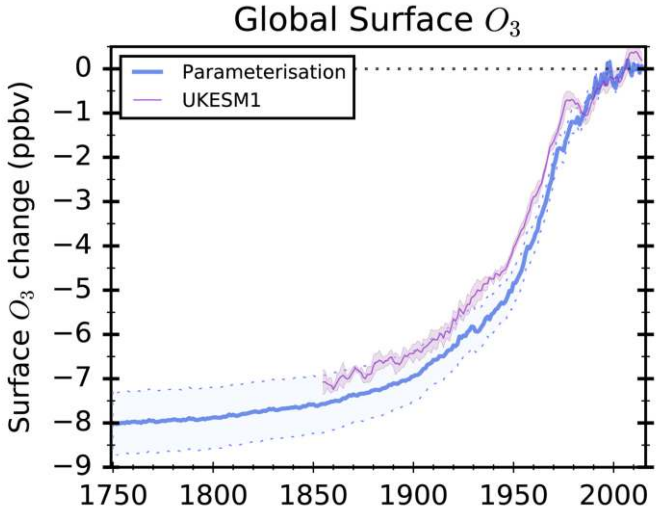
Historical emissions & Surface O_3

EMISSIONS



Hoesly et al., GMD (2018)

CONCENTRATIONS

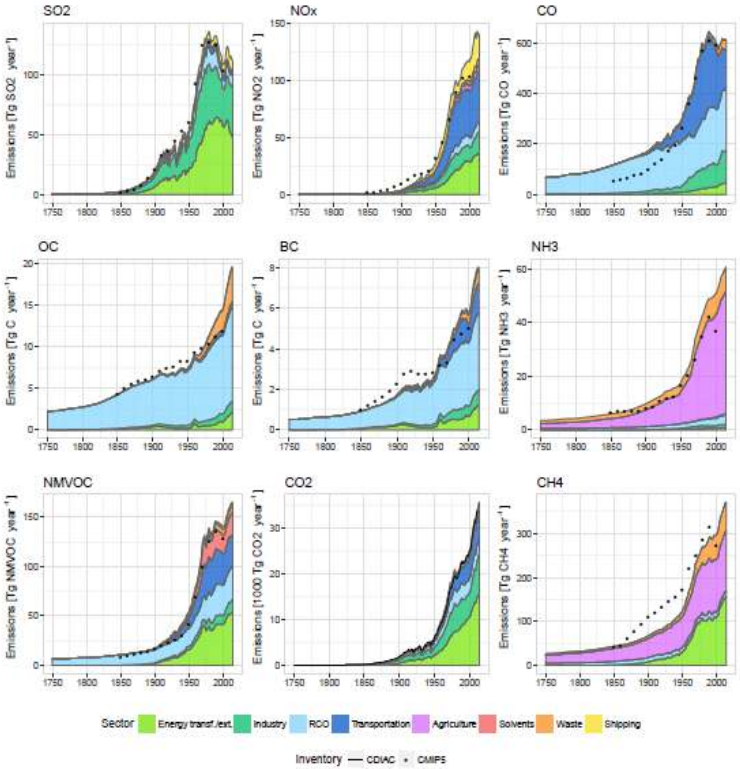


Historical Evolution from HTAP O_3 Parametric Model and UKESM1

Turnock et al., Atmos. Environ. (2018)

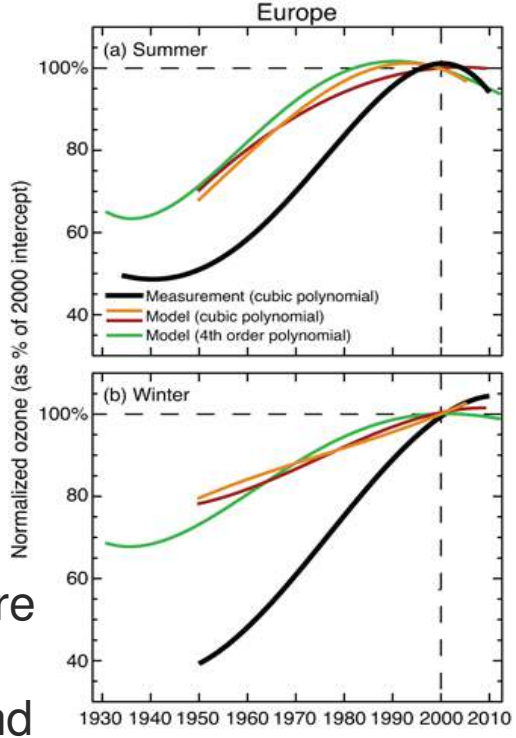
Historical emissions & Surface O_3

EMISSIONS



Hoesly et al., GMD (2018)

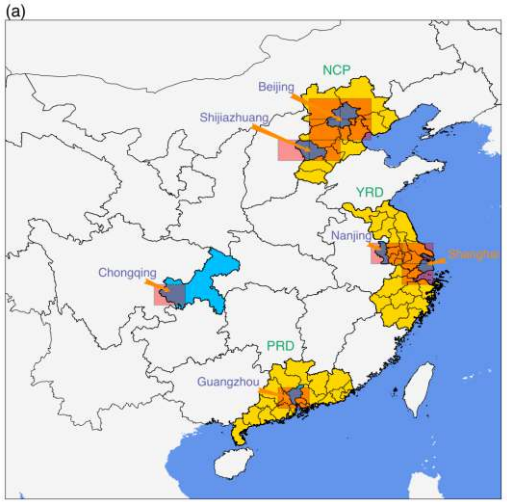
Models capture only *half* the long-term trend



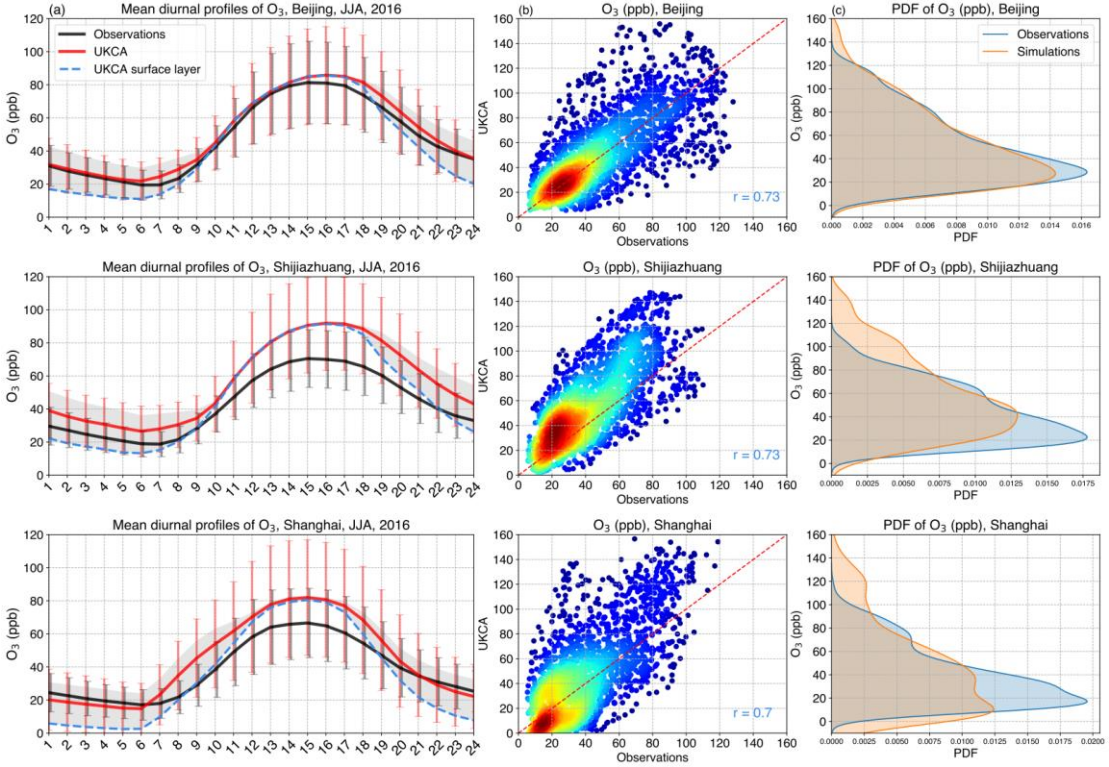
Young et al., Elementa (2018)

CONCENTRATIONS

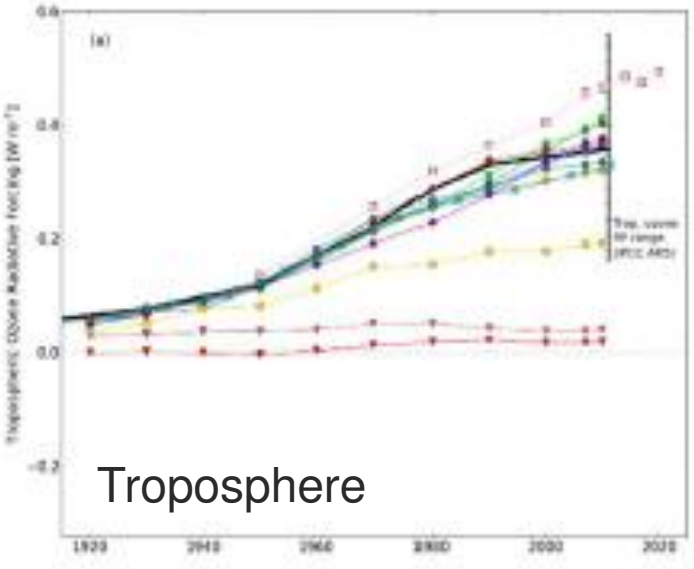
Diurnal Cycle in Surface O_3

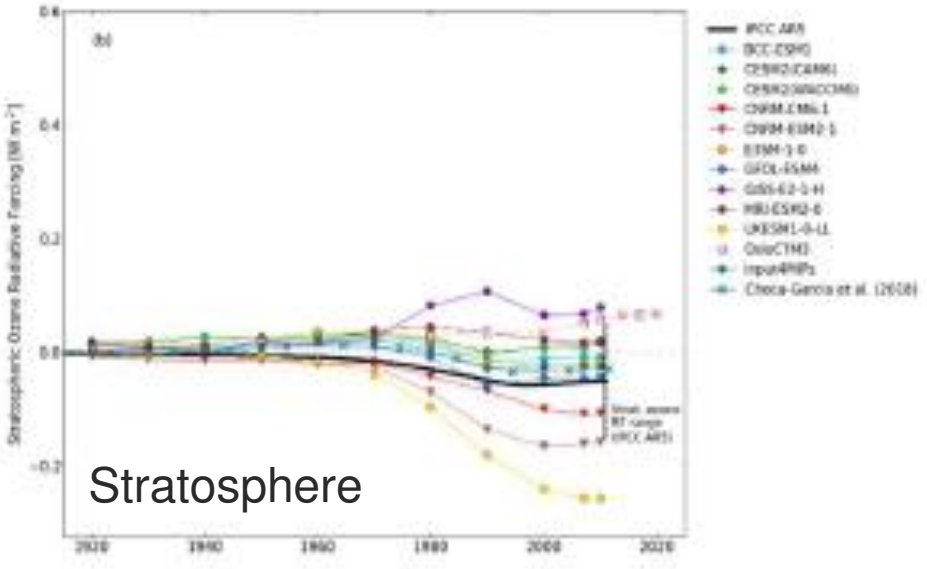


Liu et al., to be submitted (2020)



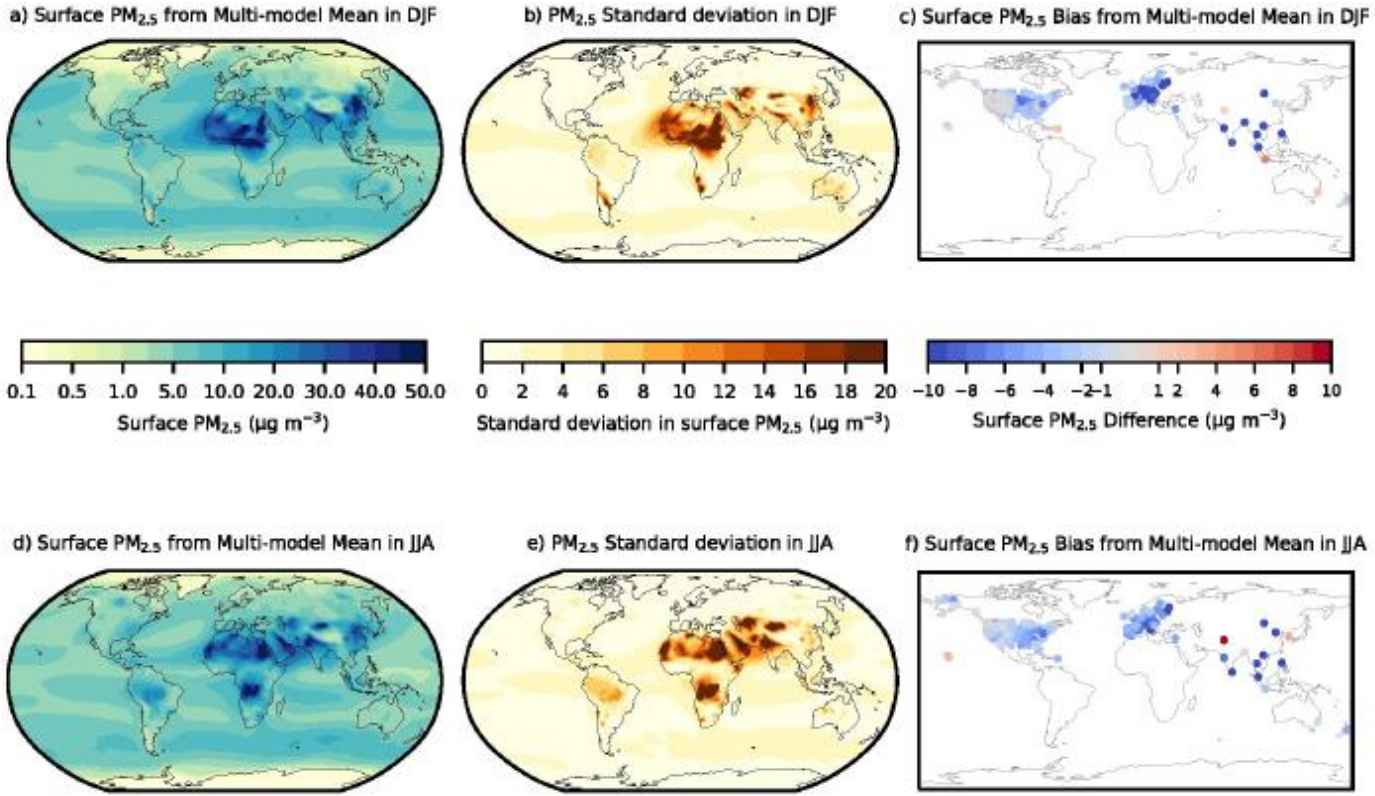
Radiative Forcing by O_3





Skeie et al., npj Clim Atmos Sci., Accepted (2020)

Historical emissions & AQ

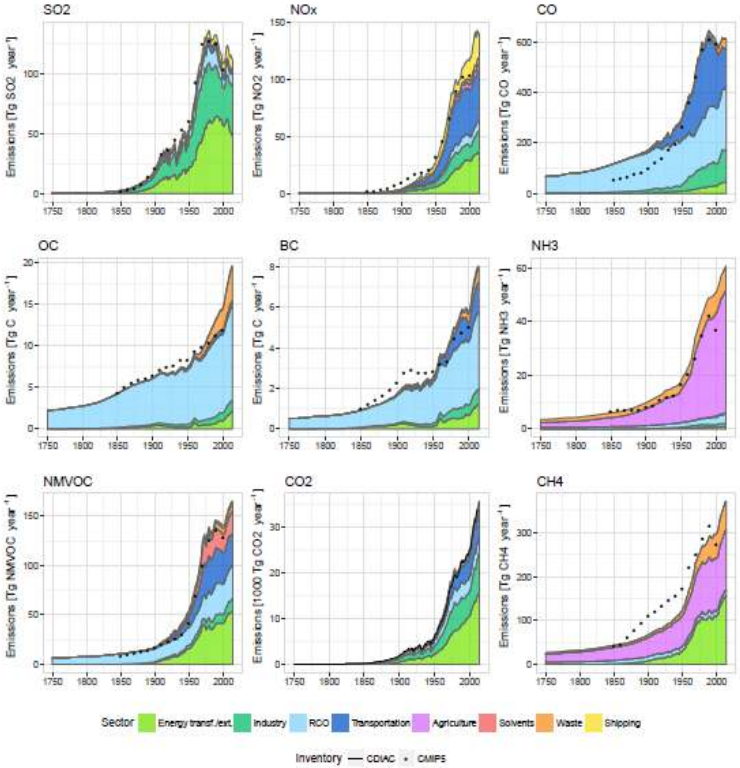


CONCENTRATIONS

Turnock et al., ACPD (2019)

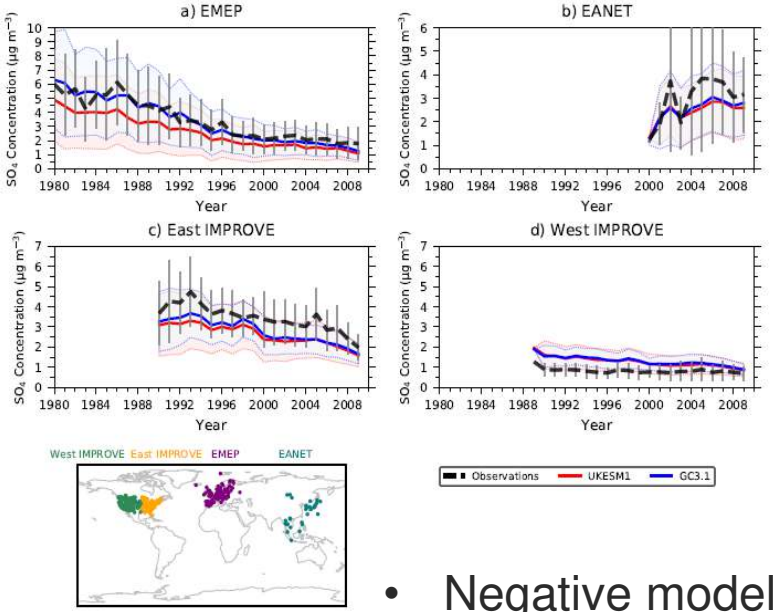
Historical emissions & AQ

EMISSIONS



Hoesly et al., GMD (2018)

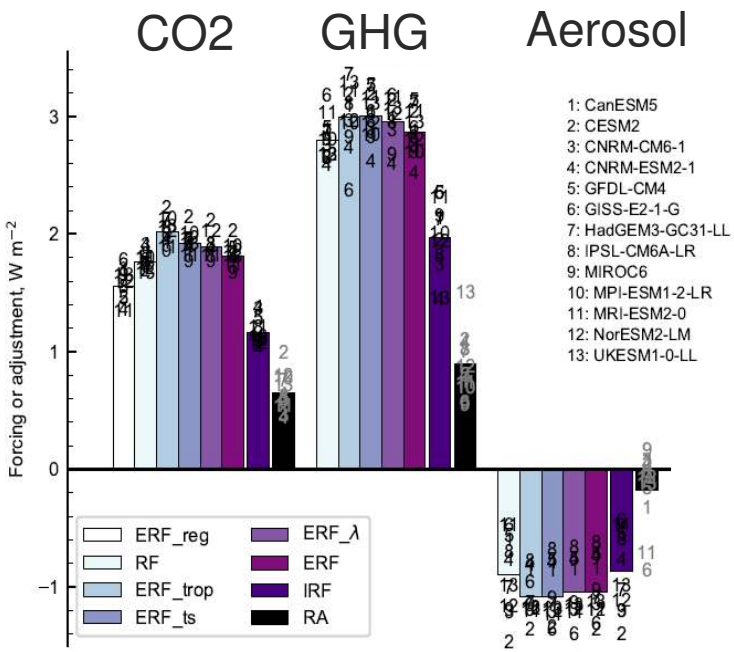
CONCENTRATIONS



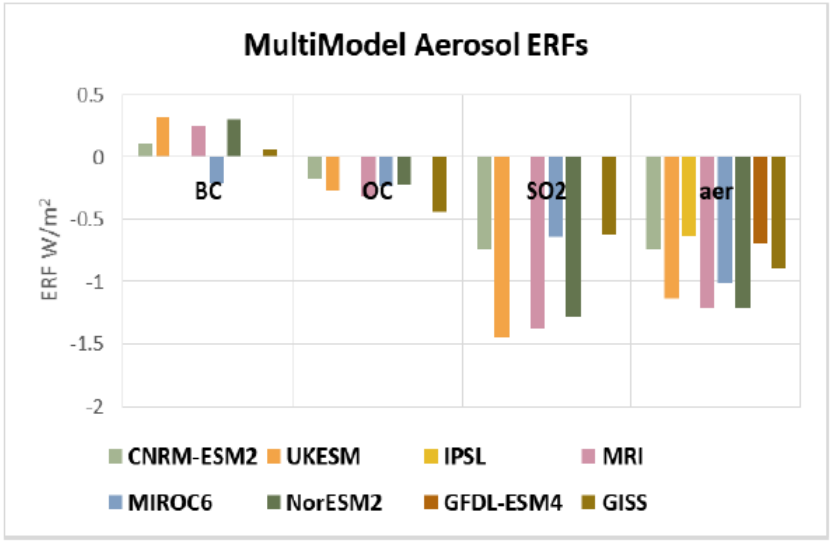
- Negative model bias
- Model capturing trend

Mulcahy et al., GMDD (2019)

Aerosol Forcing



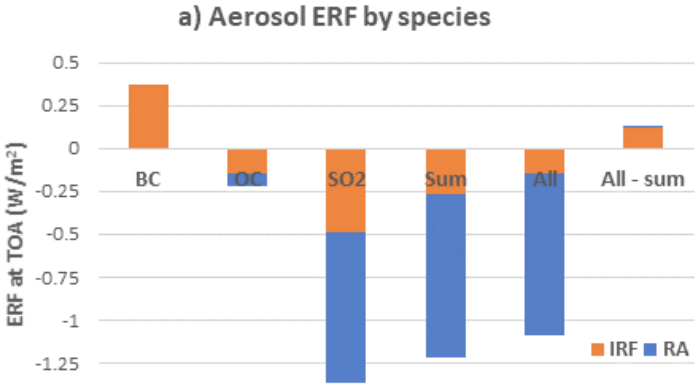
Smith et al., ACPD (2019)

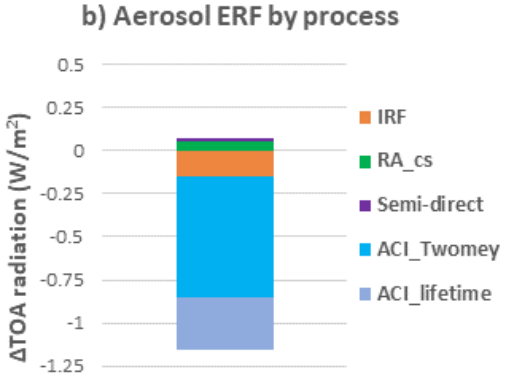


Aerosol ERF dominated by SO_2

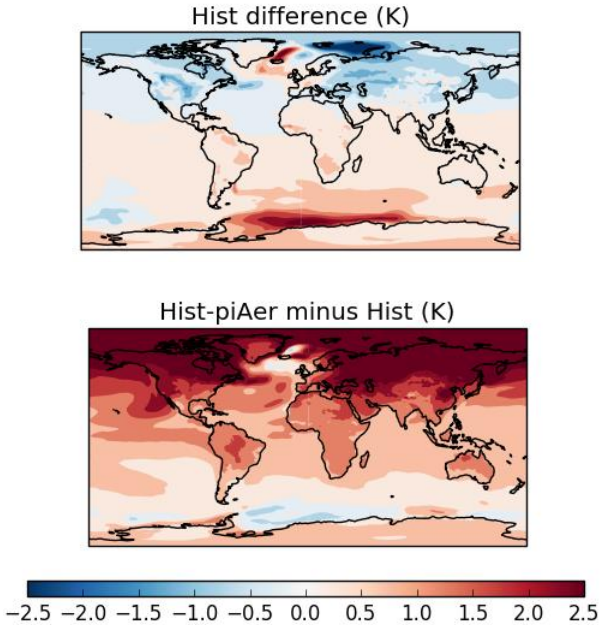
Thornhill et al., ACPD (2019)

UKESM1 Aerosol Forcing & Climate Response





O'Connor et al., ACPD (2019)



PD – PI ΔT

No Aerosol
minus
With Aerosol

Next Steps/Key Requirements (1)

Methane:

- Emissions-driven capability
- Analysis of drivers of methane/OH and methane lifetime
- Improved understanding of ERF estimates from ESMs

Ozone:

- Investigate biases in historical evolution of O3
- Model sensitivities – role for composition-equivalents to 1ptCO2 and 4xCO2?
- Statistical Approaches to explore model uncertainties/sensitivities
- Improved diurnal cycle & coupling with biosphere
- Improved understanding of role of resolution
- Chemistry mechanism intercomparison
- Evaluation of nitrogen species/budget & coupling with biosphere

Next Steps/Key Requirements (2)

Aerosols:

- Statistical Approaches to explore model uncertainties
- Inclusion of nitrate aerosol: Aerosol and NOx ERF
- Improved understanding of rapid adjustments in aerosol forcing
- Role of resolution and scale effects in aerosol forcing
- Inclusion of indirect forcings e.g. aerosol effects on vegetation & carbon uptake

Thank you for listening!

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Extra Slides

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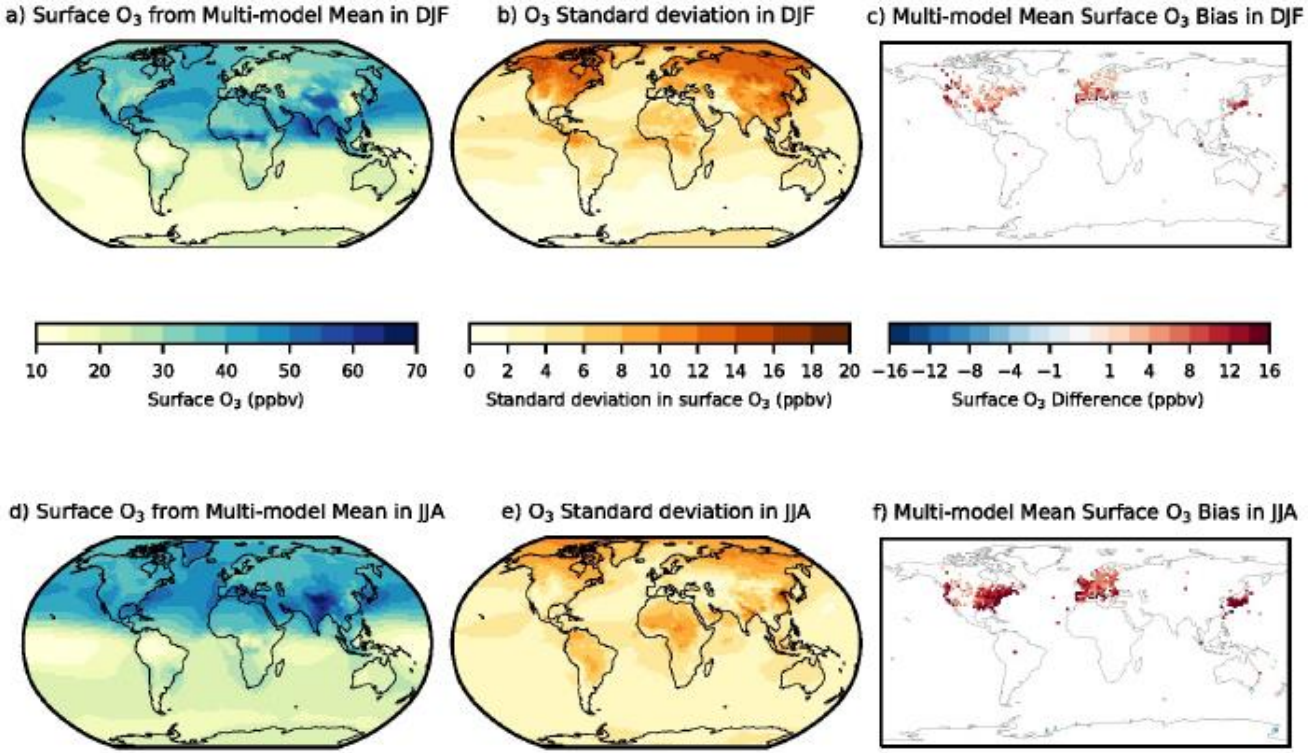
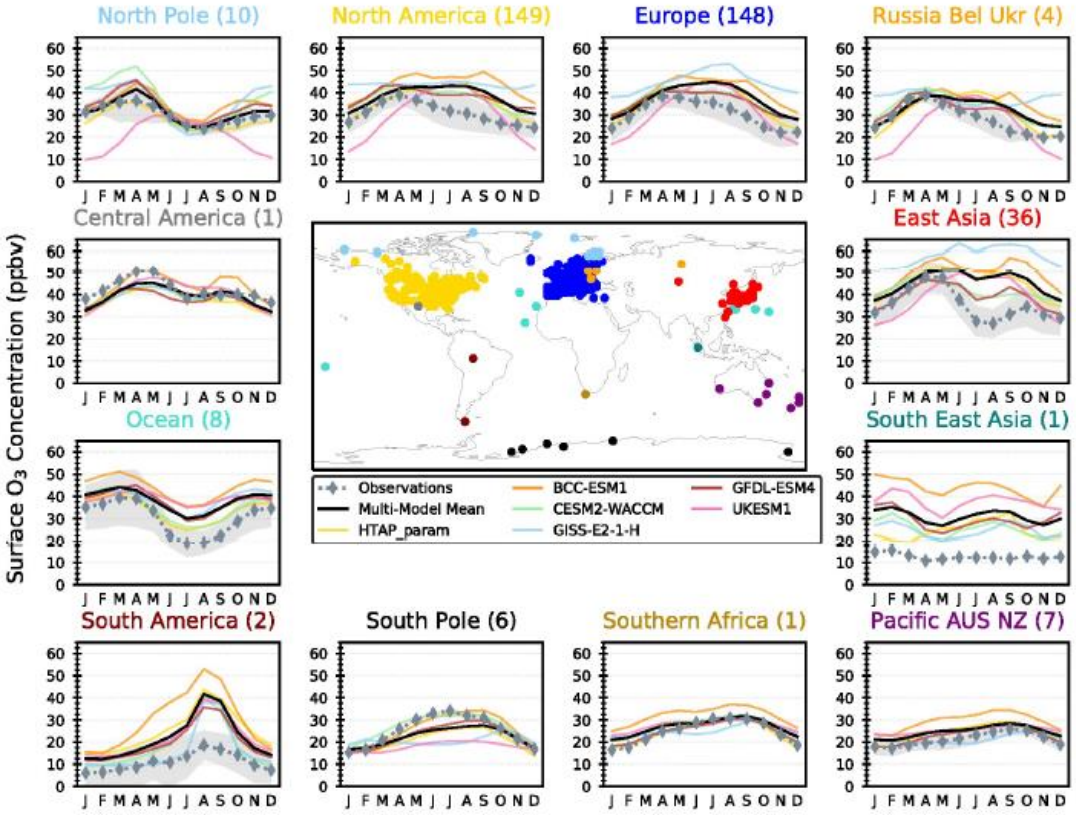
Surface O3 Evaluation



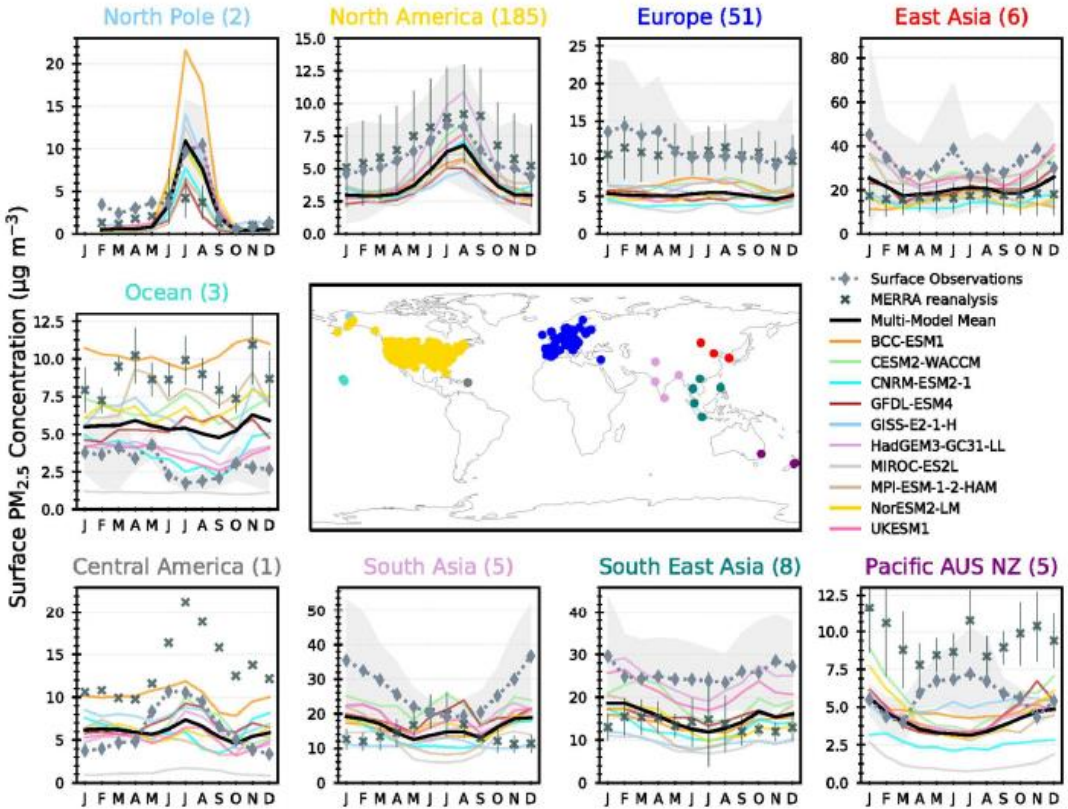
Turnock et al., ACPD (2019)

Surface O3 Evaluation



Turnock et al., ACPD (2019)

Surface PM2.5 Evaluation



Turnock et al., ACPD (2019)

BC vs OC Forcing