Air Quality and Climate Connections

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Tropospheric ozone and precursors contribute to climate forcing from pre-industrial to present-day

Adapted by E. Leibensperger (SUNY Plattsburgh) from IPCC, 2013 for Fiore, Naik, Leibensperger, in press

Radiative Forcing components: CO₂, CH₄, Strat. H₂O, Trop. O₃

Emitted Species:
- CO₂
- CH₄
- CO
- NMVOC
- NOₓ

Radiative Forcing Since 1750 (W/m²)
PM and precursors also contribute to climate forcing from pre-industrial to present-day

![Radiative Forcing components](image)

**CO$_2$, CH$_4$, Strat. H$_2$O, Trop. O$_3$ sulfate, nitrate, dust BC (BF+FF; BB; snow albedo) OC (BF+FF; BB)

Net impact of aerosols (-0.9 W m$^{-2}$) opposes warming from GHGs

Adapted by E. Leibensperger (SUNY Plattsburgh) from IPCC, 2013 for Fiore, Naik, Leibensperger, in press
Air pollutants are Near-Term Climate Forcers (NTCFs); CO\(_2\) dominates long-term climate (peak warming)

Short-Lived Climate Pollutants (SLCPs) = warming NTCFs

Adapted by E. Leibensperger (SUNY Plattsburgh) from IPCC, 2013 for Fiore, Naik, Leibensperger, in press
Reducing air pollutant SLCPs lessens near-term climate warming (and improves air quality by decreasing background $O_3$; $PM_{2.5}$)

Target $CH_4$ and some BC-rich sources to offset near-term warming from health-motivated controls on $SO_2$ emissions

Adapted from Fig 12 Fiore et al. 2015
Mitigate BOTH near-term AND long-term climate change by reducing SLCPs AND CO$_2$

CO$_2$ and SLCPs can induce other climate responses that affect pollution levels:
- Hydrologic cycle
- Circulation patterns (including “air pollution meteorology”)

Adapted from Fig 12 Fiore et al. 2015

- **CH$_4$ measures**: for oil and gas production, long distance gas transmission, coal mines, municipal waste/landfills, wastewaters, livestock manure, rice paddies.
- **BC measures**: (tech) for diesel vehicles, clean biomass stoves, brick kilns, coke ovens; (regulatory) bans on agricultural burning, eliminate high emitting vehicles, modern cooking and heating.

Shindell et al., 2012

Shoemaker & Schrag, 2013
Ozone and particulate matter build up during heat wave; cold fronts ventilate the polluted boundary layer.

Warmer climate $\rightarrow$ more heat waves $\rightarrow$ more pollution?

Figure 7 of Fiore, Naik, Leibensperger, JAWMA, 2015
O₃ correlates with surface temperature on daily to inter-annual time scales in polluted regions [e.g., Bloomer et al., 2009; Camalier et al., 2007; Cardelino and Chameides, 1990; Clark and Karl, 1982; Korsog and Wolff, 1991]

Observations at U.S. EPA CASTNet site Penn State, PA 41N, 78W, 378m

→ Implies that changes in climate (via regional air pollution meteorology) will influence air quality
→ Downward trend in O₃ as EUS NOₓ emission controls are implemented
Decreasing NOx emissions reduces sensitivity of O3 to temperature; helps to guard against any “climate penalty” [e.g., Bloomer et al., 2009; Rasmussen et al., 2012; Brown-Steiner et al., 2015]

Historically observed relationships may not hold as emissions change
Meteorology may also change [e.g., Barnes & Fiore, 2013; Shen et al., 2015]

Figure 6b of Fiore, Naik, Leibensperger, JAWMA, 2015
Projected changes in U.S. surface ozone in summer (JJA) under climate and precursor emission scenarios: declines due to continued controls on precursor emissions

Figure 10a of Fiore, Naik, Leibensperger, JAWMA, 2015

CMIP5 and ACCMIP models
Projected air quality changes over the Midwest mainly follow precursor emission trajectories.

SUMMER (JJA) $O_3$ (ppb)

WINTER (DJF) $O_3$

Annual mean PM$_{2.5}$ ($\mu$g m$^{-3}$)

Methane doubling in RCP8.5 raises background ozone all year, most pronounced in winter [see also Clifton et al., 2014]

CMIP5 and ACCMIP models

Figure 10 of Fiore, Naik, Leibensperger, JAWMA, 2015
Climate variability can modulate background ozone sources: e.g., frequency of deep stratospheric intrusions over WUS.
Connection of frequent deep stratospheric intrusions over WUS to known mode of climate variability (La Niña)

→ May offer a few months lead time to aid WUS preparations for an active stratospheric intrusion season

Improved accuracy and trends in emission inventories are critical for accountability analyses of historical and projected air pollution and climate mitigation policies [AQAST!]

Translating research into digestible products and training air managers in using data products and analysis tools [AQAST! Jacob et al., 2014; Duncan et al., 2014; Streets et al., 2014; Witman et al., 2014]