Air Quality and Climate Interactions

Fiona O’Connor
Met Office Hadley Centre

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Outline of Presentation

- Air Quality → Climate Change
- Climate Change → Air Quality
- Challenges & Synergies
- Conclusions

Figure from von Schneidemesser et al. (2015)
Impact of Air Quality on Climate
Impact of Air Quality on Climate (1)

Abundance-based RF

Fig 8.15: IPCC 5th assessment report

Emissions-based RF updated from Shindell et al. (2005)
Impact of Air Quality on Climate (2)

- Ozone damage reduces the amount of carbon removed from the atmosphere by plants.

- Indirect forcing from the extra CO₂ is comparable to the direct radiative forcing from ozone.

More recently, Arnold et al. (2018) found that including the effect of ozone on plant transpiration has a strong local effect on clouds and climate and should be included in future climate projections.
• Variations in diffuse fraction enhance the land carbon sink
• Estimated at 25% between 1960 and 1999
• This ‘diffuse-radiation’ fertilization effect could decline in response to reducing particulate matter
Impact of Air Quality on Climate (4)

Zaehle et al. (2015)

- Potential for nitrogen deposition to influence carbon uptake by the biosphere
- Aim of C4MIP is to quantify the role of nitrogen deposition
Impact of Climate on Air Quality
Impact of Climate on Air Quality (1) - Ozone

Consensus that background ozone is expected to decrease
Ozone in peak episodes expected to increase – the so-called “climate penalty”

Doherty et al. (2017)

- **↑ Temperature**
  - **Impacts:**
    - a) increases chemical reaction rates for $O_3$ production and destruction notably: Less PAN more $NO_x$ locally near emission source
    - b) increases emissions of: biogenic VOCs; wildfires; $CH_4$ from wetlands; $NO_x$ from lightning and soils

- **↑ Water vapour**
  - **Impacts:** enhanced $O_3$ destruction in unpolluted regions

- **↑ Ventilation/mixing depth**
  - **Impacts:** less pollution build-up

- **↑ Stratospheric tropospheric $O_3$ exchange**
  - **Impacts:** high $O_3$ transported to lower altitudes

- **↓ Cloud amounts**
  - **Impacts:** reduced photolysis of $NO_2$, that leads to $O_3$ production

- **↓ Rainfall**
  - **Impacts:** Reduced soil moisture and $O_3$ dry deposition

- **↑ Blocking highs/stagnation**
  - **Impacts:** more pollution build-up
Emissions, rather than climate, drive future surface ozone changes in the near term

Fiore et al. (2012)
Impact of Climate on Air Quality (3) – Particulate Matter

- Multi-model increase in most aerosol species
- Over the tropics and NH mid-latitudes
- Attributed to a decrease in wet deposition
- Implications for future air quality

Allen et al. (2016)
Impact of Climate on Air Quality (4) – Particulate Matter

- Some evidence of a “climate penalty” on PM
- However, no real consensus on impact of climate on PM
- Shorter lifetime, largely determined by precipitation

Doherty et al. (2017)

- **Temperature**
  - **Impacts:**
    - a) higher biogenic VOC, wildfire emissions and NOx emissions from lightning and soils
    - b) greater oxidation to sulphate aerosol

- **Water vapour**
  - **Impacts:** increased oxidation to sulphate aerosol

- **Relative humidity**
  - **Impacts:** increased hygroscopic aerosol growth

- **Cloud amounts**
  - **Impacts:** reduced photolysis of SO2

- **Ventilation/mixing depth**
  - **Impacts:** less pollution build-up

- **Blocking highs/stagnation**
  - **Impacts:** more pollution build-up

- **Rainfall**
  - **Impacts:** increased wet deposition
Impact of Climate on Air Quality (5) - Feedbacks

• Potential for climate to feed back on natural emissions: Implications for future air quality and climate

• Strength of these feedbacks being evaluated in a multi-model context within AerChemMIP

Challenges & Synergies
Challenges & Synergies (1)

- Air quality & climate are intricately interlinked
- Need for policies to address both together
- Major challenge to identify policies that provide “win-win” solutions
- Also, need to identify and quantify trade-offs

Von Schneidemesser & Monks (2013)
Challenges & Synergies (2)

Jones et al., ASL (2018)

UNEP (2011): CH₄ Emission Reductions:
• Technologically feasible although investment required
• Offers a near-term climate benefit
• Reduce tropospheric O₃ and improve air quality
Challenges & Synergies (3)

Turnock et al. (2018)

Difference in surface ozone and PM in the 2050s from climate mitigation and from carbon mitigation policies
Challenges & Synergies (4)

Turnock et al. (2018)

Co-benefit of carbon mitigation policies on air quality & health

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Effective Radiative Forcing (ERF) in 2050 relative to 2000 (Wm⁻²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RCP 4.5</td>
</tr>
<tr>
<td>Ozone</td>
<td>+0.06 +/- 0.03</td>
</tr>
<tr>
<td>Aerosols (All-Sky)</td>
<td>+0.93 +/- 0.11</td>
</tr>
<tr>
<td>CO₂</td>
<td>+1.47 +/- 0.04</td>
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</tbody>
</table>
Conclusions
Conclusions

- Air quality & climate are intricately interlinked

- Atmospheric constituents, relevant, to air quality, have an impact on climate

- Climate change can impact on air quality but in the short term, changes are dominated by emissions changes

- Need for policies to address both air quality & climate together

- Major challenge to identify policies that provide “win-win” solutions i.e. a “win” for air quality and a “win” for climate

- Need to identify and quantify trade-offs