On the validity of the incremental approach to calculate the impact of cities on air quality

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Motivations

- Determine at which level/scale air quality measures should be taken to abate air pollution in the most efficient manner.

- How can we quantify the contribution of city emissions on its own air pollution?

- Two main approaches:
  - Incremental
  - CTM scenarios
Urban impact & urban increment

\[ C^{\text{city}} \]

\[ C^{\text{rur}}(d) \]
Urban impact & urban increment

- $C^{city}$
- $C^{rur}(d)$
- $B^{city}_{cf}$
- $B^{rur}(d)$

Diagram showing urban and rural concentration levels.
1. CTM-scenario

\[ B_{cf}^{city} \cong B_{cf}^{city}(CTM) \]

2. Lenschow

\[ B_{cf}^{city} \cong C_{rur}^{city}(d) \]
Urban impact & urban increment

\[ C_{\text{city}} = B_{\text{cf}}^{\text{city}} + I_{\text{cf}}^{\text{city}} \]

\[ C_{\text{rur}}(d) = B_{\text{cf}}^{\text{rur}}(d) + I_{\text{cf}}^{\text{rur}}(d) \]

\[ I_{\text{cf}}^{\text{city}} = \left[ C_{\text{city}} - C_{\text{rur}}(d) \right] \]

\[ + I_{\text{cf}}^{\text{rur}}(d) \]

\[ + \left[ B_{\text{cf}}^{\text{rur}}(d) - B_{\text{cf}}^{\text{city}} \right] \]
**Urban impact & urban increment**

\[
I_{city}^{cf} = \left[ C_{city}^{\text{city}} - C_{rur}^{rur}(d) \right] + I_{rur}^{rur}(d) + \left[ B_{rur}^{rur}(d) - B_{city}^{city} \right]
\]

**Assumption I**: the city spread is negligible \(I_{cf}^{rur}(d) \approx 0\)

The rural background location is far enough from the city not to feel its influence

**Assumption II**: the background is homogeneous \(B_{cf}^{rur}(d) \approx B_{cf}^{city}\)

The city and rural background locations should not be too far from each other
How do these components vary

- with distance (d)
- With city fraction (cf)
- With pollutant: PM$_{2.5}$ and NO$_{2}$
SHERPA assessment in 4 cities

City fractions

- FUA
- Urban core
- Inner city

12 8 3

12 9 2

5 3.5

2.4 1.1
PM$_{2.5}$ for cf = FUA

- **London**
  - Background deviation
  - Lenschow increment
  - City spread

- **Paris**
  - Background deviation
  - Lenschow increment
  - City spread

- **Berlin**
  - Background deviation
  - Lenschow increment
  - City spread

- **Bruxelles**
  - Background deviation
  - Lenschow increment
  - City spread
**PM$_{2.5}$ for $cf = \text{urban core}$**

- **Berlin**
- **Paris**
- **London**
- **Bruxelles**

- Background deviation
- Lenschow increment
- City spread
PM2.5 for $c_f = \text{inner city}$

\[
B_{c_f}^{city} > B_{c_f}^{rur}(d)
\]
PM2.5 for cf = inner city

**Paris**

**London**

- **Background deviation**
- **Lenschow increment**
- **City spread**
Summary overviews

PM2.5

NO2

Percentage

Bruxelles  Paris  Berlin  London

Inner City Impact  Urban Core Impact  FUA Impact  Lenschow increment
Comparison of obs. and mod. Increments (PM$_{2.5}$)

- **Berlin**
  - East
  - West
  - South
  - North

- **Paris**
  - East
  - West
  - South
  - North

- **London**
  - East
  - West
  - South
  - North

- **Bruxelles**
  - East
  - West
  - South
  - North
Conclusions

- The urban increment ($LUI$) is an appropriate estimate of the urban impact ($I$) only when two assumptions are fulfilled:
  - The city spread is negligible
  - The background deviation is negligible

- For PM$_{2.5}$, these two assumptions are never fulfilled for large or medium cities and the LUI underestimates the urban impact by 30 to 50%. Although it works better for NO$_2$ some underestimation is also found for this pollutant.
Conclusions (cont.)

- Given that:
  - The urban impact is very sensitive to the size of the city fraction
  - The urban increment is very sensitive to distance (d) and location

  The urban increment seems to be a poor proxy for estimating the urban impact.

- Studies based on the incremental approach are very likely to underestimate (heavily for PM$_{2.5}$) the impact of cities to their air pollution