Synergies between multi-pollutant bottom-up emission inventories and satellite observations

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European Commission, Joint Research Centre
### Extract of available long-term supply of public inventories

<table>
<thead>
<tr>
<th>Data source</th>
<th>1. EMEP (+ CEIP gapfill)</th>
<th>2. UNFCCC</th>
<th>3. US EPA</th>
<th>4. MICS-ASIA (REAS 2.1)</th>
<th>5. EDGARv4.3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CO</strong></td>
<td>grid /yr</td>
<td>voluntary</td>
<td>grid /m /height</td>
<td>grid /m (no AWB)</td>
<td>grid /m or /yr</td>
</tr>
<tr>
<td><strong>NOx</strong></td>
<td>grid /yr</td>
<td>voluntary</td>
<td>grid /m /height</td>
<td>grid /m (no AWB)</td>
<td>grid /m or /yr</td>
</tr>
<tr>
<td><strong>SO2</strong></td>
<td>grid /yr</td>
<td>voluntary</td>
<td>grid /m /height</td>
<td>grid /m (no AWB)</td>
<td>grid /m or /yr</td>
</tr>
<tr>
<td><strong>NMVOC</strong></td>
<td>grid /yr</td>
<td>voluntary</td>
<td>grid /m /height /species</td>
<td>grid /m</td>
<td>grid /m or /yr</td>
</tr>
<tr>
<td><strong>NH3</strong></td>
<td>grid /yr</td>
<td></td>
<td>grid /m /height</td>
<td>grid /m</td>
<td>grid /m or /yr</td>
</tr>
<tr>
<td><strong>CH4</strong></td>
<td>voluntary</td>
<td>/yr</td>
<td></td>
<td>grid /yr</td>
<td>grid /m or /yr</td>
</tr>
<tr>
<td><strong>PM2.5</strong></td>
<td>grid /yr</td>
<td></td>
<td>grid /m /height</td>
<td>grid /m (no AWB)</td>
<td>grid /m or /yr</td>
</tr>
<tr>
<td><strong>PM10</strong></td>
<td>grid /yr</td>
<td></td>
<td>grid /m /height</td>
<td>grid /m (no AWB)</td>
<td>grid /m or /yr</td>
</tr>
<tr>
<td><strong>OC</strong></td>
<td></td>
<td></td>
<td>grid /m /height</td>
<td>grid /m (no AWB)</td>
<td>grid /m or /yr</td>
</tr>
<tr>
<td><strong>BC</strong></td>
<td></td>
<td></td>
<td>grid /m /height</td>
<td>grid /m (no AWB)</td>
<td>grid /m or /yr</td>
</tr>
</tbody>
</table>

**geo-coverage**

USA, also Canada?
### Strengths/weaknesses of bottom-up/top-down inventories

<table>
<thead>
<tr>
<th></th>
<th>Bottom-up inventory</th>
<th>Top-down inventory</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>strength</strong></td>
<td>consistency over multiple polluting gases</td>
<td>completeness for single polluting gas</td>
</tr>
<tr>
<td></td>
<td>long time-series</td>
<td>no time-lag</td>
</tr>
<tr>
<td></td>
<td>country well confined with the national statistics</td>
<td>real location of hotspots</td>
</tr>
<tr>
<td><strong>weakness</strong></td>
<td>incompleteness for certain sectors</td>
<td>not solely the human activity</td>
</tr>
<tr>
<td></td>
<td>2 years time-lage</td>
<td>no long historic time-series</td>
</tr>
<tr>
<td></td>
<td>The assumed representative geospatial proxy has</td>
<td>country totals are subject to relative large border</td>
</tr>
<tr>
<td></td>
<td>large uncertainty and its updates are work-intensive</td>
<td>issues</td>
</tr>
</tbody>
</table>

How to make best use of the combination bottom-up and top-down inventories?

1. Use of satellite-derived ancillary data to distribute the emissions geospatially more dynamically (for greenhouse gases)
2. Compare & combine bottom-up and top-down derived inventories (for air pollutants)
3. Use of emission ratios of air pollutants over greenhouse gases? Not evident…
1. Improve bottom-up inventory with satellite-derived ancillary data

Source: Janssens-Maenhout et al. (2017) ESSDD
Global Human Settlement Layer (GHSL) for Lagos (Nigeria) and its hinterland.

The population of Lagos increased from about 2 million in 1975 to 13 million in 2015, as reflected in the increase in built-up areas. Note the growth corridors along the major arterial roads and the creation of large satellite cities.

Source: GHSL, 2016

GHSL Contacts at JRC: Martino Pesaresi, Thomas Kemper
8% of Africa’s soils are optimal for crop production, but 98% of the calories come from the land.
Yield gaps, decreased productivity, livestock density and chronic low-income are putting pressure on much of the Sahel and East Africa in terms of Land degradation pressures.
Example: Forest clearance
Almost 90% of all wood removals in Africa are used for energy. Fuelwood meets 85% of rural energy demands, charcoal most of the rest. Charcoal and wood burning cause relatively large BC emissions in the residential sector!

Source: The role of wood energy in Africa Samir Amousa, FAO
Photo: Andreas Brink JRC

World Bank Open Data, 2017
Annual BC - Black carbon (elemental carbon) emissions in Africa:
- In 2012, 66% of total African black carbon emissions were produced by only seven of Africa's 54 countries: Nigeria, Ethiopia, D.R. Congo, Tanzania, South Africa, Kenya, Uganda, Sudan.
- Africa has the highest annual per capita emissions of black carbon in the world (~0.8 kg/cap/yr). (Mainly from household (0.46 kg /person/year) but also from industry).
- From 1970 to 2012, black carbon emissions increased by a factor of four in northern Africa, 2.8 in eastern Africa, 3 in western Africa and 1.7 in southern Africa.
2a. Comparing bottom-up and top-down NOx inventories

Bottom-up emission inventories for Asia:

- EDGAR v4.3.1
- REAS v2.1
- REAS v2.2
- MIX

DECSO algorithm using data from one satellite instrument: OMI respectively GOME2

- DECSO-OMI
- DECSO-GOME2a

EnKF (Kalman Filter) algorithm optimising data from 3 satellite instruments: SCHIAMACHY, OMI and GOME2

- Average
- EnKF-MIROC
- EnKF-CHASER

Source: J. Ding al. ACP (2017)
Comparing OMI/GOME2 data with bottom-up NOx inventories

Source: J. Ding al. ACP (2017)
2b. Improving bottom-up SO2 inventory with top-down data

HTAPv2.2. inventory for gaseous and particulate air pollutants

Source: Janssens-Maenhout et al. (2015) ACP
OMI data enhancing the SO2 inventory

Geographic distribution of SO2 sources in the OMI-based emission catalogue (Fioletov et al., 2011). SO2 sources identified that were found to be missing from bottom-up inventories are color coded by blue. The background is the global mean SO2 distribution (in DU) map for 2005–2014.

Source: F. Liu et al. (2018) submitted to ACP
OMI-HTAP enhanced SO2 inventory

(a) SO2 emissions in the OMI-HTAP inventory 2010

(b) The differences between the OMI-HTAP and the HTAP inventory for 2010. SO2 emissions in the HTAP inventory are subtracted from those in the OMI-HTAP inventory to derive the differences.

*Emissions are regridded at the resolution of 1° x 1° for illustration. The unit is Gg-SO2 per grid cell.*

Source: F. Liu et al. (2018) submitted to ACP
3. Evaluation of emission ratios of multipollutant bottom-up inventory

EDGARv4.3.2 inventory for greenhouse gases and particulate air pollutants

Source: Crippa et al. (2018) submitted to ESSDD
Bottom-up change in strength of NOx point sources

Relative change over 5 years (2012 versus 2007) in NOx emission of point sources in EDGARv4.3.2

circle size = point source strength

colour = relative change
Green stable within 20%
Yellow increase 20% - 60%
Blue decrease -20% - -60%

These changes are not present in the CO2 data with these strengths!

Source: Crippa et al. (2018) submitted to ESSDD
Conclusion

Moving towards a dynamic update of static inventories

① Different info sources are sometimes our best defence
② Combining data into knowledge needs to flow to the right people at the right time
③ With Copernicus and Galileo the EU produces, collates and distributes data, information and knowledge on a free and open basis
④ We need to build capacity, especially in those parts of the world with less data infrastructure

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