Uncertainty associated with fossil fuel carbon dioxide (CO$_2$) gridded emission datasets

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ODIAC - Global 1km fossil fuel emission model

Movie credit: NASA Megacities Carbon Project
Use of satellite obs for mapping emissions

Population

Nightlight

Population

Nightlight

Moscow

Paris

Dubai

1996-97

1999

2006

Suomi-NPP/VIIRS 2012
Global (N=1)

Source: GCP
FFCO2 agree on the global total

Andres et al. (2015) reported 8% uncertainty (2 sigma)
Disaggregation of national emissions

\[ E_{i,j} = M_{Total} \times W_{i,j} \quad (1) \]

\[ W_{i,j} = \frac{P_{i,j}}{\sum_{i=1}^{m} \sum_{j=1}^{n} P_{i,j}} \quad (2) \]

Emission fields

Weight (proxy)

\[ = 10 \text{ PgC} \times \]

Note: This is really simplified view to emission modeling
When distributed in space (only land)

Caution: Highly depending on proxy used.

unit: $10^6$ tonne C/yr
Uncertainty calculation

\[ E_{i,j} = M_{Total} \times W_{i,j} \quad (1) \]

\[ W_{i,j} = \frac{P_{i,j}}{\sum_{i=1}^{m} \sum_{j=1}^{n} P_{i,j}} \quad (2) \]

Using combined uncertainty rule...

\[ \frac{\delta E_{i,j}}{E_{i,j}} = \sqrt{\left(\frac{\delta M_{Total}}{M_{Total}}\right)^2 + \left(\frac{\delta W_{i,j}}{W_{i,j}}\right)^2} \quad (3) \]

1. Uncertainty in emissions (%)  
2. Uncertainty in weight (%)
How can we deal with/account for inter-model uncertainty?

Caution: Highly depending on proxy used.

unit: $10^6$ tonne C/yr
Normalized to the same total

Note: only emissions over land are shown.
To get inter-inventory uncertainty

\[
\frac{\delta E_{i,j}}{E_{i,j}} = \sqrt{\left(\frac{\delta M_{\text{Total}}}{M_{\text{Total}}}\right)^2 + \left(\frac{\delta W_{i,j}}{W_{i,j}}\right)^2}
\] (3)

Caution: Many limitations are present
1x1 degree FFCO2 uncertainty map

Note: This is not yet combined with the 8% emission uncertainty
ODIAC fossil fuel CO2 Emission: Emissions from fossil fuel combustion is the largest input in the global carbon cycle over decadal time scales and is the main contributor to the recent increased atmospheric CO2. The Open-source Inventory for Anthropogenic CO2 (ODIAC) model employs satellite-observed nighttime lights to keep track of the emissions that are rapidly changing in space and time. The ODIAC model also utilizes geolocation of intense point sources such as power plants. The high-resolution (1x1km) ODIAC emission information will be used for the carbon cycle analysis using high-density CO2 data collected by NASA's Orbiting Carbon Observatory 2 (OCO2).
The 1x1 deg approach not going to work at a high-resolution

Emissions from different sources need to be treated in appropriate ways

Oda and Makyutov 2011 ACP
Case in Ukraine

Error = 6.185 km

Work by Topylko and Halushchak
Case in Ukraine

Emission correlation = 0.77
Emission abs. error in % = 77 %

Oda, Topylko, Halushchak et al. working progress
Location error > 350km

Biases needs to be understood and fixed.
Uncertainty in ODIAC LPS emissions over Ukraine

Fraction to the total (%) vs. Spatial resolution (km)

<table>
<thead>
<tr>
<th>Res (km)</th>
<th>N of LPS</th>
<th>Frac N (%)</th>
<th>Frac E (%)</th>
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<td>2</td>
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<td>90.7263</td>
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<tr>
<td>100.000</td>
<td>29</td>
<td>96.666</td>
<td>90.7263</td>
</tr>
</tbody>
</table>

Res (km) / N of LPS / Frac N (%) / Frac E (%)

- 0.1 deg
- 0.25 deg
- 0.5 deg
- 1 deg
Case in Japan

Grid cell size = approx. 1x1km

Osaka bay

Osaka

- National database
- Searched by address
- Identified using Google Maps

Mori and Oda working progress
Data collection is not for our purpose: eGRID

Form EIA-860 collects data on the status of existing electric generating plants and associated equipment (including generators, boilers, cooling systems and air emission control systems) in the United States, and those scheduled for initial commercial operation within 5 or 10 years, as applicable. The data from this form appear in EIA publications and public databases. The data collected on this form are used to monitor the current status and trends of the electric power industry and to evaluate the future of the industry.

Note: Data is not collected for emission modeling
Summary

• A method for calculating uncertainty associated with spatial distributions is proposed and implemented at a 1x1 degree.

• The uncertainty calculation method allows us to take into account the inter-dataset differences due to proxy data used. This is particularly useful for analyses where FFCO2 is assumed to be perfect.

• The magnitude of uncertainty at 1x1 degree typically ranges from 40-180% inversely correlated with emission magnitude.

• At high resolution, ideally we should stay away from proxy based methods as possible (e.g. location should be determined) for both improving our modeling ability and reducing error/uncertainty.

• Currently our ability for assessing uncertainty at high resolution seems to be very, very limited (e.g. data and method). We should educated data collectors about what we can do and what we need.

Any question? tom.Oda@nasa.gov