From uncertainties on emissions from fossil fuel combustion to climate change

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Objective: how do the uncertainties on emissions associated to fossil fuel combustion influence the climate change?

1. Evaluation of CO\textsubscript{2} emissions from fossil fuel combustion
2. Impact on climate change
3. Evaluation of co-emissions from fossil fuels
4. Impact on climate change
Historical + 3 projections of extraction
- 4 sets of carbon contents: "Methods"
- Compared to CO₂ inventories of CDIAC and EDGAR
The resources composing a broad category are not depleted at the same rate, but the carbon content of the category is constant.

Uncertainties due to parameters of non-conventional oils.
Impact on the climate from these discrepancies

OSCAR:
Gasser (2010): tel.archives-ouvertes.fr/tel-01135456
Li, Gasser et al (2016): doi:10.1038/nature17165
Impact on the climate from these discrepancies

Effect of uncertainty on CO₂ emissions on projected climate change

Small but significant uncertainty from CO₂ emission factors

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Co-emitted species associated with fossil fuel extraction or use

- Leaks
  - CH₄, VOC
  - NH₃

- Fugitive Content
  - N₂O
  - NOₓ, SO₂

- Incomplete combustion & Combustion process
  - CO, VOC, BC
  - OC
  - NOₓ
Evaluation of co-emissions

Principle: co-emission ratios using EDGAR v4.3

→ uncertainty from the technology, fuel, operating conditions, ...

⇒ Hypothesis: Range in 1970-2012 representative of 1700-2300

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Productions of scenarios from 1700: uncertainty in 2010
→ Historic emissions close to the mean of trajectories
→ Most of the uncertainty from the co-emissions
Effect of uncertainty on co-emission factors on projected climate change

Emissions of CO$_2$ from fossil fuel combustion

Excess atmospheric CO$_2$ to 1750

Radiative forcing to 1750

Global mean temperature change to 1750

- $6.3^\circ$C $\pm 0.3^\circ$C $\pm 0.1^\circ$C
- $4.9^\circ$C $\pm 0.2^\circ$C $\pm 1.1^\circ$C

mean, uncertainty from co-emissions, Covariance, uncertainty from CO2 emissions
<table>
<thead>
<tr>
<th>Extraction</th>
<th>2100</th>
<th>CO$_2$</th>
<th>non CO$_2$</th>
<th>2300</th>
<th>CO$_2$</th>
<th>non CO$_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High</strong></td>
<td>4.9°C</td>
<td>±0.2</td>
<td>±1.1</td>
<td>6.3°C</td>
<td>±0.3</td>
<td>±0.1</td>
</tr>
<tr>
<td><strong>Best Guess</strong></td>
<td>4.1°C</td>
<td>±0.2</td>
<td>±0.7</td>
<td>5.0°C</td>
<td>±0.2</td>
<td>±0.1</td>
</tr>
<tr>
<td><strong>Low</strong></td>
<td>3.4°C</td>
<td>±0.1</td>
<td>±0.4</td>
<td>4.1°C</td>
<td>±0.1</td>
<td>±0.0</td>
</tr>
</tbody>
</table>

- Decreasing uncertainty from non-CO$_2$ from fossil fuels
- Shorter lifetimes for non-CO$_2$
- Increasing uncertainty from CO$_2$ with time and with amount of fossil fuels burnt
- Accumulation of uncertainties
- Uncertainty on co-emission factors dominates the one on CO$_2$ emissions
- Compared to the uncertainty on climate sensitivity, it represents:
  - 2081-2100 → 45-120%
  - 2281-2300 → 2-8%
Perspectives

1. Limited access to information on detailed data (fuel types, carbon contents, ...)
2. Impact of the categorization: up to \( \pm 0.3^\circ C \)
3. Impact of the uncertainty on co-emissions: up to \( \pm 1.1^\circ C \)
4. How to reduce this uncertainty?
   \( \Rightarrow \) More frequently updated estimates of factors to account for
   ongoing technical progress and fuel mix
5. *Importance for a consistent treatment of co-emitted species from different sectors in IAM*

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Population : stabilization at 11 billions ($\sim$ SRES B2)

Per capita demand : constant from 1973

Resources available : Low (48 409EJ), Best Guess (75676 EJ), High (141488 EJ)

Mohr (2010) : "Projection of world fossil fuel production with supply and demand interactions" (http://www.theoildrum.com/node/6782)
Mohr et al, 2015 : "Projection of world fossil fuels by country" (http://dx.doi.org/10.1016/j.fuel.2014.10.030)
"Data" : CDIAC < Mohr around 1900, up to 15% (from Coal)
"Data" : EDGAR < Mohr (around 5%)
"Methods" : IPCC < CDIAC < Mohr, up to 10% (from Gas then Oil)
"Methods" : CDIAC out of the range for Gas and Coal during 1900-2000
World emissions (GtC/yr)

- Coal
- Gas
- Oil

Data sources:
- High data with Mohr
- High data with CDIAC
- High data with IPCC2006
- High data with RevisedIPCC1996
- BG data with Mohr
- BG data with CDIAC
- BG data with IPCC2006
- BG data with RevisedIPCC1996
- Low data with Mohr
- Low data with CDIAC
- Low data with IPCC2006
- Low data with RevisedIPCC1996

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adapted from [Clausen, 2000]
OSCAR is another carbon-cycle box-model, close to MAGICC:

- with regionalized biosphere
- coupled to a regionalized climate impulse response function
- focusing on the integration of the Earth system
- reproducing the behaviours of models of greater degree of spatial representation
- able to combine the sensibilities between modules

OSCAR v2.1, Gasser (2014) : ”Attribution rgionalise des causes anthropiques du changement climatique”
https://tel.archives-ouvertes.fr/tel-01135456
Li, Gasser et al (2016) : ”The contribution of China’s emissions to global climate forcing” (doi :10.1038/nature17165) OSCAR v2.2, Gasser et al (working paper) : ”The compact Earth sytem model OSCAR v2.2 : description and first results”
1. Different estimations of CO$_2$ : 6
2. Values for each one of 9 gases co-emitted : Low, Mean, High
3. Using log-normal distribution from factors to weight each one of the 6 x 243 trajectories
4. Evaluating variances from each contribution to scale the 95% range
Impact on climate on High Resources projection with background RCP2.6

Emissions of CO₂ from fossil fuel combustion

Excess atmospheric CO₂ to 1750

Radiative forcing to 1750

Global mean temperature change to 1750

- mean
- fraction from non-CO₂ emissions
- fraction from co-variance
- fraction from CO₂ emissions
- Shortening the time of development of scenarios
- CM & ESM: uncertainty induced by the climate system
- IAM: identification of the range of different technological, socioeconomic and policy futures that lead a specific RCP.

(Moss et al, 2010)