HTAP Experiment Set 4: Future Emission and Climate Scenarios

Thanks to:

Bill Battye (EC/R) and Suvi Monni (JRC)
Ruth Doherty, Ian MacKenzie, David Stevenson
(University of Edinburgh)
HTAP Experiment Set 4: Future Emission and Climate Scenarios

Two parts:

FE: Future Emissions with 2001 Meteorology
  • Estimate a reasonable range of possible changes in the magnitude and spatial distribution of emissions

FC: Future Meteorology with 2001 Emissions
  • Explore the potential for future shifts in transport patterns due to climate change
RCP Scenarios

The Integrated Assessment Modeling Community is developing 4 Reference Concentration Pathways (RCPs) for analysis in IPCC AR5.

<table>
<thead>
<tr>
<th>Model</th>
<th>RF at 2100</th>
<th>Institute</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMAGE</td>
<td>2.6</td>
<td>MPN</td>
</tr>
<tr>
<td>MiniCAM</td>
<td>4.5</td>
<td>PNNL</td>
</tr>
<tr>
<td>AIM</td>
<td>6.0</td>
<td>NIES</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>8.5</td>
<td>IIASA</td>
</tr>
</tbody>
</table>
RCP Global Trends

- Sulfur emissions - Total
  - World - MaxCAM - RCP 4.5
  - World - IMAGE - RCP 2.6
  - World - MESSAGE - RCP 8.5
  - World - ID - RCPINV

- Organic carbon emissions - Total
  - World - MaxCAM - RCP 4.5
  - World - IMAGE - RCP 2.6
  - World - MESSAGE - RCP 8.5
  - World - ID - RCPINV

- CO emissions - Total
  - World - MaxCAM - RCP 4.5
  - World - IMAGE - RCP 2.6
  - World - MESSAGE - RCP 8.5
  - World - ID - RCPINV

- NOx emissions - Total
  - World - MaxCAM - RCP 4.5
  - World - IMAGE - RCP 2.6
  - World - MESSAGE - RCP 8.5
  - World - ID - RCPINV

- VOC emissions - Total
  - World - MaxCAM - RCP 4.5
  - World - IMAGE - RCP 2.6
  - World - MESSAGE - RCP 8.5
  - World - ID - RCPINV

- NH3 emissions - Total
  - World - MaxCAM - RCP 4.5
  - World - IMAGE - RCP 2.6
  - World - MESSAGE - RCP 8.5
  - World - ID - RCPINV

© RCP Database (Version 0.9.7rc5) generated: 2009-05-13 09:13:20
## Bounding the RCP Scenarios

<table>
<thead>
<tr>
<th>Pathway</th>
<th>2020</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO\textsubscript{X}</td>
<td>MESSAGE 8.5</td>
<td>IMAGE 2.6</td>
</tr>
<tr>
<td>VOC</td>
<td>IMAGE 2.6</td>
<td>IMAGE 2.6</td>
</tr>
<tr>
<td>SO\textsubscript{2}</td>
<td>MiniCAM 4.5</td>
<td>IMAGE 2.6</td>
</tr>
<tr>
<td>BC</td>
<td>IMAGE 2.6</td>
<td>MiniCAM 4.5</td>
</tr>
<tr>
<td>OC</td>
<td>IMAGE 2.6</td>
<td>MiniCAM 4.5</td>
</tr>
<tr>
<td>CO</td>
<td>MESSAGE 8.5</td>
<td>IMAGE 2.6</td>
</tr>
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<td>CH\textsubscript{4}</td>
<td>MESSAGE 8.5</td>
<td>IMAGE 2.6</td>
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<tr>
<td>NH\textsubscript{3}</td>
<td>MESSAGE 8.5</td>
<td>MiniCAM 4.5</td>
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</tbody>
</table>
Regional Distribution of SO₂ Emissions

OECD
Reforming econ
Mideast & Afr
Asia
Latin America
- Total (Tg)

SO₂
SO₂ Change by Region from 2000 to 2020

Change in emissions (%)

OECD
Reforming econ
Mideast & Afr
Asia
Latin America
Total

IMAGE - 2.6
MiniCAM - 4.5
MESSAGE - 8.5
IIASA GAINS

SO₂
SO₂ Change by Region from 2000 to 2050

- OECD
- Reforming econ
- Mideast & Afr
- Asia
- Latin America
- Total (Tg)

Change in emissions (%)

- IMAGE - 2.6
- MiniCAM - 4.5
- MESSAGE - 8.5

Graph showing the percentage change in SO₂ emissions by region from 2000 to 2050.
Regional Distribution of NO\textsubscript{X} Emissions

- **OECD**
- **Reforming econ**
- **Mideast & Afr**
- **Asia**
- **Latin America**
- **Total (Tg)**

Comparison between years 2000, 2020, and 2050.
NO$_x$ Change by Region from 2000 to 2020

![Graph showing NO$_x$ change by region from 2000 to 2020. The graph compares different models (IMAGE, MiniCAM, MESSAGE, IIASA GAINS) for regions such as OECD, Reforming econ, Middle East & Africa, Asia, Latin America, and Total.](image)
NO\textsubscript{X} Change by Region from 2000 to 2050

- OECD: IMAGE - 2.6
- Reforming econ: MiniCAM - 4.5
- Mideast & Afr: MESSAGE - 8.5
- Asia: IMAGE - 2.6
- Latin America: IMAGE - 2.6
- Total (Tg): IMAGE - 2.6
NO$_X$ Emissions by Source Category

- Energy
- Industry
- Aviation
- Intl shipping
- Surf transport
- Solvents
- Res & comml
- Waste
- Animals & crops
- Ag burning
- Savannah burn
- Deforestation

- Total (Tg)

Years:
- 2000
- 2020
- 2050
Regional Distribution of VOC Emissions

VOC (Total Tg)
VOC Change by Region from 2000 to 2020

- **OECD**
- Reforming econ
- Mideast & Afr
- Asia
- Latin America
- Total

Change in emissions (%)

- IMAGE - 2.6
- MiniCAM - 4.5
- MESSAGE - 8.5
- IIASA GAINS
VOC Change by Region from 2000 to 2050

- **OECD**: IMAGE - 2.6, MiniCAM - 4.5, MESSAGE - 8.5
- **Reforming econ**: IMAGE - 2.6, MiniCAM - 4.5, MESSAGE - 8.5
- **Mideast & Afr**: IMAGE - 2.6, MiniCAM - 4.5, MESSAGE - 8.5
- **Asia**: IMAGE - 2.6, MiniCAM - 4.5, MESSAGE - 8.5
- **Latin America**: IMAGE - 2.6, MiniCAM - 4.5, MESSAGE - 8.5
- **Total (Tg)**: IMAGE - 2.6, MiniCAM - 4.5, MESSAGE - 8.5
Regional Distribution of CO Emissions

- OECD
- Reforming econ
- Mideast & Afr
- Latin America
- Asia
- Total (Tg)

CO
CO Change by Region from 2000 to 2020

![Graph showing CO change by region from 2000 to 2020. The regions include OECD, Reforming econ, Mideast & Afr, Asia, Latin America, and Total. The change is measured in percentage. The models used are IMAGE, MiniCAM, and MESSAGE. The change values are -2.6%, -4.5%, and -8.5% respectively.]
Regional Distribution of BC Emissions

- OECD
- Reforming econ
- Mideast & Afr
- Asia
- Latin America
- Total (Tg)

2000 2020 2050
BC Change by Region from 2000 to 2020

Change in emissions (%)

-75 -50 -25 0 25 50 75 100 125 150

OECD Reforming econ Mideast & Afr Asia Latin America Total

IMAGE - 2.6 MiniCAM - 4.5 MESSAGE - 8.5 IIASA GAINS

BC
BC Change by Region from 2000 to 2050

- OECD
- Reforming econ
- Mideast & Afr
- Asia
- Latin America
- Total (Tg)

- IMAGE - 2.6
- MiniCAM - 4.5
- MESSAGE - 8.5
Regional Distribution of OC Emissions

- OECD
- Reforming econ
- Mideast & Afr
- Asia
- Latin America
- Total (Tg)

Year:
- 2000
- 2020
- 2050

Emissions (Tg):
- 2000
- 2020
- 2050
OC Change by Region from 2000 to 2020

<table>
<thead>
<tr>
<th>Region</th>
<th>IMAGE - 2.6</th>
<th>MiniCAM - 4.5</th>
<th>MESSAGE - 8.5</th>
<th>IIASA GAINS</th>
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<tbody>
<tr>
<td>OECD</td>
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<tr>
<td>Mideast &amp; Afr</td>
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<tr>
<td>Latin America</td>
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<td></td>
</tr>
<tr>
<td>Total</td>
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</tbody>
</table>

Change in emissions (%)
OC Change by Region from 2000 to 2050

Change in emissions (%)

-75 -50 -25 0 25 50 75 100 125 150

OECD Reforming econ Mideast & Afr Asia Latin America Total (Tg)

IMAGE - 2.6
MiniCAM - 4.5
MESSAGE - 8.5
Regional Distribution of NH$_3$ Emissions

- OECD
- Reforming econ
- Mideast & Afr
- Asia
- Latin America

NH$_3$
NH₃ Change by Region from 2000 to 2020

- OECD
- Reforming econ
- Middle East & Africa
- Asia
- Latin America
- Total

Change in emissions (%)

- IMAGE - 2.6
- MiniCAM - 4.5
- MESSAGE - 8.5
- IIASA GAINS

NH₃
NH₃ Change by Region from 2000 to 2050

Change in emissions (%)

<table>
<thead>
<tr>
<th>Region</th>
<th>IMAGE - 2.6</th>
<th>MiniCAM - 4.5</th>
<th>MESSAGE - 8.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>OECD</td>
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<tr>
<td>Reforming econ</td>
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<td>Mideast &amp; Afr</td>
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<tr>
<td>Asia</td>
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</tr>
<tr>
<td>Latin America</td>
<td></td>
<td></td>
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<tr>
<td>Total (Tg)</td>
<td></td>
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</tbody>
</table>
Proposed FE Experiments

• FE1: 2020 High Emissions (~ SR1)
• FE2: 2050 Low Emissions (~ SR1)
• FE3: 20% dec of all polls from FE1 (~ SR6)
  – NA, EU, EA, SA, GL
• FE4: 20% dec of all polls from FE2 (~SR6)
  – NA, EU, EA, SA, GL

Temporal allocation will be proportional to 2001
Some Issues with FE Experiments

• How do we capture the range of possible futures?

• Min-Max Approach
  – No one model is consistently low or high
  – Mixing models creates inconsistent spatial distributions
  – Easily communicated and implemented

• Sensitivity Analyses

• Timing of Simulations
Proposed FC Experiments

• FC1: SR1 with “2000” A2 Climate (3 years)
  – Capture some interannual variability around SR1?
• FC2: SR1 with “2100” A2 Climate (3 years)
  – Capture some shift in transport patterns?
• FC3: 20% dec of all polls from FC1 (~ SR6)
  – NA, EU, EA, SA, GL
• FC4: 20% dec of all polls from FC2 (~ SR6)
  – NA, EU, EA, SA, GL

Use “native” SSTs from group’s coupled GCM
Some Issues with FC Experiments

• RCP results will not be ready in time
• Fall back to SRES: A2 or A1B
• Maintaining Comparibility to SR runs
• Future Climate & Future Emissions?
• Which Models?
• Timing? Step-wise approach?
In 2050
Stabilization level
<table>
<thead>
<tr>
<th>RCPs</th>
<th>Radiative forcing (W/m²)</th>
<th>CO₂ concentration (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMAGE 2.6</td>
<td>3.20</td>
<td>449</td>
</tr>
<tr>
<td>MiniCAM 4.5</td>
<td>4.01</td>
<td>489</td>
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<tr>
<td>MESSAGE 8.5</td>
<td>4.80</td>
<td>552</td>
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</tbody>
</table>

SRES
| b1         | 4.10                     | 485                     |
| b1_low     | 4.07                     | 488                     |
| b1_high    | 4.13                     | 491                     |
| b2         | 4.44                     | 513                     |
| a1b        | 4.90                     | 562                     |
| a1f        | 4.98                     | 576                     |
| a1f_lo     | 4.95                     | 576                     |
| a1f_hi     | 5.02                     | 582                     |
| a1t        | 4.72                     | 542                     |
| a2         | 4.37                     | 539                     |

Notes:
- Levels do not stabilize by 2100.
Comparison of SR1 with RCP baseline emissions for NO\textsubscript{x}
Comparison of SR1 with RCP baseline emissions for SO$_2$

- **SR1 total**
- **SR1 anthropogenic**
- **RCP**

<table>
<thead>
<tr>
<th>Region</th>
<th>Emissions (Tg/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global</td>
<td></td>
</tr>
<tr>
<td>Northern Hem</td>
<td></td>
</tr>
<tr>
<td>Southern Hem</td>
<td></td>
</tr>
<tr>
<td>Europe</td>
<td></td>
</tr>
<tr>
<td>North America</td>
<td></td>
</tr>
<tr>
<td>South Asia</td>
<td></td>
</tr>
<tr>
<td>East Asia</td>
<td></td>
</tr>
</tbody>
</table>
Comparison of SR1 with RCP baseline emissions for VOC

Emissions (Tg/yr)

- Global
- Northern Hem
- Southern Hem
- Europe
- North America
- South Asia
- East Asia

SR1 total
SR1 anthropogenic
RCP
Comparison of SR1 with RCP baseline emissions for BC

Emissions (Tg/yr)

- Global
- Northern Hem
- Southern Hem
- Europe
- North America
- South Asia
- East Asia

SR1 total
SR1 anthropogenic
RCP
Comparison of SR1 with RCP baseline emissions for OC

Global
Northern Hem
Southern Hem
Europe
North America
South Asia
East Asia

SR1 total
SR1 anthropogenic
RCP

Emissions (Tg/yr)
Comparison of SR1 with RCP baseline emissions for CO

- SR1 total
- SR1 anthropogenic
- RCP

Emissions (Tg/yr)

- Global
- Northern Hem
- Southern Hem
- Europe
- North America
- South Asia
- East Asia
Comparison of SR1 with RCP baseline emissions for NH$_3$

- **Global**
- **Northern Hem**
- **Southern Hem**
- **Europe**
- **North America**
- **South Asia**
- **East Asia**

**SR1 total**

**SR1 anthropogenic**

**RCP**

Emissions (Tg/yr)