Emissions for Global Modeling - Trends and Uncertainties

Greg Frost
NOAA/ESRL & University of Colorado/CIRES, Boulder, CO

- Motivation and Methods
- Global/Regional Inventory Comparisons
- Community Historic Emissions Efforts
- GEIA and ECCAD

Acknowledgements
Motivations for Understanding Emissions

Actions and decisions about the atmosphere focus on emissions.

Accurate emissions information is needed for many purposes.
- Quantify and predict
- Understand changes
- Make choices
- Evaluate mitigation
- Demonstrate compliance

Societal development and scientific innovation result in new challenges in emissions understanding.
- Dynamic economies
- Changing demographics
- Evolving land use
- Emerging energy sources
- New measurements
- Better process descriptions
- Improved models

Stakeholders and decision-makers have common requirements for emissions information, but challenges with emissions information persist.
- Transparency
- Consistency
- Accuracy
- Timeliness
- Uncertainty
- Complexity
- Development
- Analysis
- Communication

G. J. Frost et al., Atmos. Environ., 2012 & 2013

This is the Century of Accountability.
David Fahey

Figure courtesy of A.R. Ravishankara
Bottom-Up Inventory Methods

\[ E_X = \sum_S [EF_{X,S} \cdot A_S \cdot (1 - CE_{X,S})] \]

- **Total mass** of compound X emitted
- **Sum up all sources S**
- **Emissions factor** = mass of compound X emitted by source S per unit activity
- **Activity of source S**, e.g., amount of fuel burned
- **Effectiveness of control measures** for compound X at source S

**Example: On-road motor vehicles**

- **Vehicle fleet**
- **Fuel type**
- **Control technology**
- **Emissions source**
- **Fuel economy**
- **Vehicle condition**
- **Road type**
- **Distance driven**
- **Vehicle load**

Calculated for...
Specific region
Specific time
Also need...
Spatial allocation
Temporal variation
Speciation
Global/Regional Inventory Comparisons

- Update of C. Granier et al., *Climatic Change*, 2011
- Only public anthropogenic emissions datasets considered
- SO2, BC, OC, PM2.5/10 discussed here; CO, NOx, VOCs also analyzed

Global Datasets:
- MACCity (1980-2010) \(\approx\) AEROCOM-II (Community dataset; Granier et al., Clim Chg, 2011)
- ECLIPSE FP7 project (2005 and 2010) (IIASA, Austria)
- PNNL – SO2 (PNNL, USA)
- Bond (U Illinois, USA)
- Junker-Liousse (Laboratoire d’Aérologie, France)
- RCPs (CMIP5 & IPCC AR5 activities)

Regional Datasets:
- EPA NEI (1980-2010) for USA (US Environmental Protection Agency)
- TNO-MACC, TNO-MACCII (2003-2009) for Europe (EU’s MACC project)
- GAINS-GEA for Europe (2005 and 2010) (IIASA, Austria)
- REAS and REAS-v2 for Asia (1980-2020) (NIES, Japan)
- Lu-Streets for Asia (Argonne Natl Lab, USA & Tsinghua U, Beijing)
- MEIC for China (2008-2010) (not yet published - Tsinghua U, China)
- Lei for China (Lei et al., ACP 2011 - Tsinghua U, China)
- Cao-Zhao for China (Cao et al., AE, 2006 - CAMS, Beijing; Zhao ACP 2011 - Tsinghua U, Beijing)
- Garg for India (Garg et al., AE, 2006 - Denmark/India)
- SAFAR for India (Sahu et al., Atmos Polln Res, 2012 – IITM, India)
NOTE:
In the original presentation, 7 slides followed that showed historical inventory comparisons/evaluations carried out by Claire Granier. These slides contained data which have not yet been published, so the slides have been removed from the posted version of this presentation file.
If you are interested in participating in the inventory evaluation, please contact Claire: claire.granier@latmos.ipsl.fr
Spatial Distribution of Emissions

0.5 deg x 0.5 deg resolution

ECLIPSE/GAINS

TNO/MACC-II: anthro_PM2.5, 2005

ECLIPSE/GAINS

0.1 deg x 0.1 deg resolution

HTAPv2

From ECCAD-2

Unpublished data, contact C. Granier before citing.
Biomass burning emission datasets

C. Granier et al., *Climatic Change*, 2011
Existing Community Historical Inventories

**ACCMIP**

Emissions (anthropogenic & biomass burning) for ACCMIP: best estimate

- J.-F. Lamarque et al., *Atmos. Chem. Phys.*, 2010

**MACCity=AEROCOM-II** anthropogenic

**MACCity/AEROCOM-II** fires in Africa

- biomassBurning_CO, Sum sectors, total/region: MACCity, Africa

- C. Granier +25 co-authors, *Climatic Change*, 2011
New Community Historical Inventory

- Organized by Global Emissions InitiAative (GEIA)
- Uncertainty by emission and sector
  → Historical emissions ensembles
  → Inventory comparisons can inform uncertainty estimates
- Consistent historical trends
- Seasonality in anthropogenic emissions
- Consistent with CO₂ emissions
- Annual emissions by country (& state)
- Additional sectoral detail
- Better NMVOCs speciation
- 0.1x0.1 degree resolution when possible
- First data available in time for CMIP6 model runs
Community Emissions Data System

Produce timely estimates for emissions of aerosol (BC, OC) and aerosol precursor compounds (SO$_2$, NO$_x$, NH$_3$, CH$_4$, CO, NMVOC)

Instead of this

Produce

Uncertainty essential if extended to more recent years.

Produced using an open-source data system to increase data transparency and facilitate research advancements.

Steven Smith (PNNL/Univ. Maryland, USA)
Community Emissions Data System

System under development at PNNL/Univ. Maryland, USA (Steven Smith et al.)
Community Emissions Data System

System under development at Laboratoire d’Aérologie, France (Cathy Liousse et al.)
**Mission**

GEIA is a community initiative that builds bridges between environmental science and policy, by bringing together people, data, and tools to *create* and *communicate* the highest quality information about *emissions*.

**Goals**

GEIA aims to be a key forum for emissions knowledge serving stakeholders and decision-makers in a rapidly evolving global society.

---

*G. J. Frost et al., Atmos. Environ., 2013*
GEIA Leadership 2014-2016

Executive Committee

Co-Chairs: Gregory Frost, Leonor Tarrasón
Database Manager: Claire Granier
Network Manager: Paulette Middleton

Scientific Steering Committee*

Alexander Baklanov (Switzerland)  Zbigniew Klimont (Austria)
Beatriz Cardenas (Mexico)         Catherine Liousse (France)
Hugo Denier van der Gon (The Netherlands)  Paulette Middleton (USA)
Gregory Frost (USA)               Toshimasa Ohara (Japan)
Claire Granier (France, USA, Germany)  Martin Schultz (Germany)
Alex Guenther (USA)               Ute Skiba (UK)
Greet Janssens-Maenhout (Italy)   Leonor Tarrasón (Norway)
Johannes Kaiser (Germany)         Yuxuan Wang (China)
Terry Keating (USA)               

* SSC adding 1-2 new members in 2014, to replace outgoing members (J.-F. Lamarque, J. van Aardenne) and to increase representation from outside USA & Europe
ECCAD Emissions of Atmospheric Compounds & Compilation of Ancillary Data

GEIA’s emissions database & visualization/analysis platform

➢ Distributing data for research & assessment efforts

http://pole-ether.fr/eccad

Work underway on new ECCAD database, platform, and interface

• Any lat/lon resolution data
• Regrid to any lat/lon grid
• Adapted to interoperability
• Detailed documentation

Current Resolution
MACCity CO Emissions, 0.5° grid spacing

Future Resolution
HTAPv2 CO Emissions, 0.1° grid spacing
Many different inventories, including global and regional datasets:

### Global Inventories (22)

<table>
<thead>
<tr>
<th>Product</th>
<th>Time Period</th>
<th>Time Resolution</th>
<th>Category</th>
<th>Grid Size</th>
<th>Data Provider</th>
<th>Metadata</th>
</tr>
</thead>
<tbody>
<tr>
<td>MACCv4</td>
<td>2010</td>
<td>Monthly</td>
<td>Anthropogenic Biomass burning</td>
<td>0.5°</td>
<td>macc</td>
<td>ECCAD</td>
</tr>
<tr>
<td>ACCMIP</td>
<td>2010</td>
<td>Decadal-Decadal-Monthly</td>
<td>Anthropogenic Biomass burning</td>
<td>0.5°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RCPs</td>
<td>2010</td>
<td>Decadal-Decadal-Monthly</td>
<td>Anthropogenic Biomass burning</td>
<td>0.5°</td>
<td></td>
<td>RCPs</td>
</tr>
<tr>
<td>PEGASOS PBL</td>
<td>2013</td>
<td>2-1000</td>
<td>Yearly</td>
<td>Anthropogenic Biomass burning</td>
<td>0.5°</td>
<td>PEGASOS</td>
</tr>
<tr>
<td>EDGARv4.2</td>
<td>2011</td>
<td>Yearly</td>
<td>Anthropogenic Biomass burning</td>
<td>0.5°</td>
<td>EDGAR</td>
<td></td>
</tr>
<tr>
<td>EDGARv3.2FT2000</td>
<td>2005</td>
<td>Yearly</td>
<td>Anthropogenic Biomass burning</td>
<td>1°</td>
<td>EDGAR</td>
<td></td>
</tr>
<tr>
<td>RETRO</td>
<td>2005</td>
<td>Monthly</td>
<td>Anthropogenic Biomass burning</td>
<td>0.5°</td>
<td>RETRO</td>
<td></td>
</tr>
<tr>
<td>ECLIPSE GAINS 4a</td>
<td>2013</td>
<td>Yearly</td>
<td>Anthropogenic Biomass burning</td>
<td>0.5°</td>
<td>ECLIPSE</td>
<td></td>
</tr>
<tr>
<td>Junker-Lousse</td>
<td>2006</td>
<td>Decadal-Yearly</td>
<td>Anthropogenic Biomass burning</td>
<td>1°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HYDE13</td>
<td>2001</td>
<td>Decadal</td>
<td>Anthropogenic Biomass burning</td>
<td>1°</td>
<td>EDGAR</td>
<td></td>
</tr>
<tr>
<td>Andrea_C02 v013</td>
<td>2013</td>
<td>Yearly</td>
<td>Anthropogenic Biomass burning</td>
<td>1°</td>
<td>Andrea_C02 v013</td>
<td></td>
</tr>
<tr>
<td>AMAP_Mercury</td>
<td>2005</td>
<td>Half-decadal</td>
<td>Anthropogenic Biomass burning</td>
<td>0.5°</td>
<td>macc</td>
<td></td>
</tr>
<tr>
<td>GFEDv1.0</td>
<td>2012</td>
<td>Daily</td>
<td>Biomass burning</td>
<td>0.5°</td>
<td>GFED</td>
<td></td>
</tr>
<tr>
<td>GFED3</td>
<td>2010</td>
<td>Monthly</td>
<td>Biomass burning</td>
<td>0.5°</td>
<td>GFED</td>
<td></td>
</tr>
<tr>
<td>GFED2</td>
<td>2005</td>
<td>Monthly</td>
<td>Biomass burning</td>
<td>1°</td>
<td>GFED</td>
<td></td>
</tr>
<tr>
<td>GSICG</td>
<td>2005</td>
<td>Decadal-Monthly</td>
<td>Biomass burning</td>
<td>0.5°</td>
<td>GSICG</td>
<td></td>
</tr>
<tr>
<td>AMMABB</td>
<td>2009</td>
<td>Daily</td>
<td>Biomass burning</td>
<td>0.5°</td>
<td>AMMABB</td>
<td></td>
</tr>
<tr>
<td>MEGAN-MACC</td>
<td>2012</td>
<td>Monthly</td>
<td>Biogenic</td>
<td>0.5°</td>
<td>macc</td>
<td></td>
</tr>
<tr>
<td>MEGANv2</td>
<td>2009</td>
<td>Monthly</td>
<td>Biogenic</td>
<td>0.5°</td>
<td>NCLAR</td>
<td></td>
</tr>
<tr>
<td>MEGANv2-CHIDH</td>
<td>2017</td>
<td>Yearly (seasonal)</td>
<td>Biogenic</td>
<td>0.5°</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>GEIA1</td>
<td>1990</td>
<td>Yearly-Monthly</td>
<td>Anthropogenic Biomass burning Biogenic Oceanic Lightning Volcanic Total</td>
<td>1°</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>POET</td>
<td>2003</td>
<td>Yearly</td>
<td>Anthropogenic Biomass burning Biogenic Oceanic</td>
<td>1°</td>
<td>POET</td>
<td></td>
</tr>
</tbody>
</table>

### Global Inventories Developed for Ongoing Projects (3)

<table>
<thead>
<tr>
<th>Project</th>
<th>Time Period</th>
<th>Time Resolution</th>
<th>Category</th>
<th>Grid Size</th>
<th>Data Provider</th>
<th>Metadata</th>
</tr>
</thead>
<tbody>
<tr>
<td>IS4FIRES</td>
<td>2012</td>
<td>Daily</td>
<td>Biomass burning</td>
<td>0.5°</td>
<td>ccmi</td>
<td></td>
</tr>
<tr>
<td>GUESS-ES</td>
<td>2011</td>
<td>Monthly</td>
<td>Biomass burning Biogenic</td>
<td>1°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CCMI</td>
<td>2013</td>
<td>Yearly-Monthly</td>
<td>Anthropogenic Biomass burning Biogenic Oceanic Volcanic</td>
<td>0.5°</td>
<td>ccmi</td>
<td></td>
</tr>
</tbody>
</table>

ECCAD Datasets

http://pole-ether.fr/eccad
ECCAD Tools

Visualization of emissions maps

Total emitted for different regions

Temporal variation of national biogenic isoprene, total/region: GUESS-ES, USA

Temporal profile at 0.5/0.5 from 1970-01-01 to 2009-12-31

Ancillary data

Currently under development: maps of comparison calculations, scatter plots
Be Active in the Emissions Community

- Contact us to get involved in any projects discussed here
- Use GEIA/ECCAD platforms to access & analyze data
- Tell us about errors and ask questions about the data
- Contribute to next community historic emissions meeting
  - 4 November, Amsterdam (NCGG7): [http://doodle.com/zacdaxbdi8zac9pg](http://doodle.com/zacdaxbdi8zac9pg)
- Let us know what you think about any of these activities

Contacts

*Inventory comparisons*: Claire Granier ([claire.granier@noaa.gov](mailto:claire.granier@noaa.gov))

*Community historic inventory*: Claire Granier ([claire.granier@noaa.gov](mailto:claire.granier@noaa.gov))

*Community emissions data systems*: Steve Smith ([ssmith@pnnl.gov](mailto:ssmith@pnnl.gov)), Cathy Lioussse ([Cathy.Liousse@aero.obs-mip.fr](mailto:Cathy.Liousse@aero.obs-mip.fr))

*GEIA*: Greg Frost ([gregory.j.frost@noaa.gov](mailto:gregory.j.frost@noaa.gov))

*ECCAD*: Claire Granier ([claire.granier@noaa.gov](mailto:claire.granier@noaa.gov))