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A Community Emissions Data System (CEDS) For Anthropogenic Emissions

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Outline

This effort grew out of experience producing historical emissions for the RCP/CMIP5 process several years ago.

Overview

Data Products

Methodology

- **Uncertainty Estimates**
- **Sub-regional estimate and evaluation**

Summary

Funding for this project Provided by the US Department of Energy Office of Science and the National Aeronautics and Space Administration

CEDS Goals:

Emissions with the same standards of timeliness, openness, and uncertainty quantification as other key model inputs.

Motivation

Emissions estimates (aggregate & gridded) for aerosol (BC, OC) and aerosol precursor compounds (SO_2, NO_x, NH_3, CH_4, CO, NMVOC) are key inputs for aerosol and air pollution research and Earth System Models

- Needed for historical and future simulations, validation/comparisons with observations, historical attribution, and uncertainty quantification

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The current historical dataset used by GCMs/ESMs (Lamarque et al. 2010) was a major advance in terms of consistency and completeness. This data, however, has a number of shortcomings.

- Only extends to 2000 with coarse temporal resolution (10-years)
- Time series for many of the species formed by combining different data sets leading to inconsistencies
- No comprehensive uncertainty analysis provided (available only for SO_2 – Smith et al. 2011 and earlier BC/OC datasets – Bond et al. 2007)
- Underlying driver data not made available with emissions data set
- Methodology not consistent across emission species
- Process was not designed to be repeatable and easily updated

Community Emissions Data System

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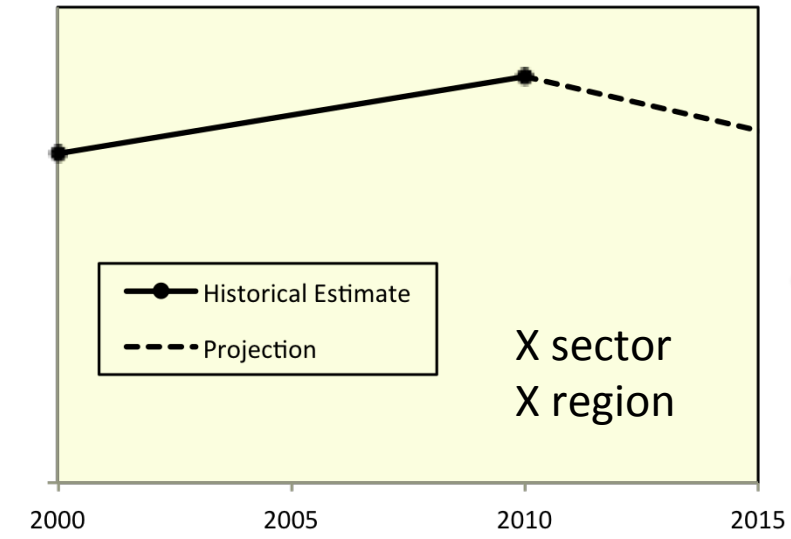
Timely "research" estimates for emissions of aerosol (BC, OC) and aerosol precursor compounds (SO_2, NO_x, NH_3, CH_4, CO, NMVOC) are key inputs for aerosol research and Earth System Models

Needed for historical and future simulations, validation/comparisons with observations, historical attribution, uncertainty quantification, IAM calibration and validation, and economic/policy analysis.

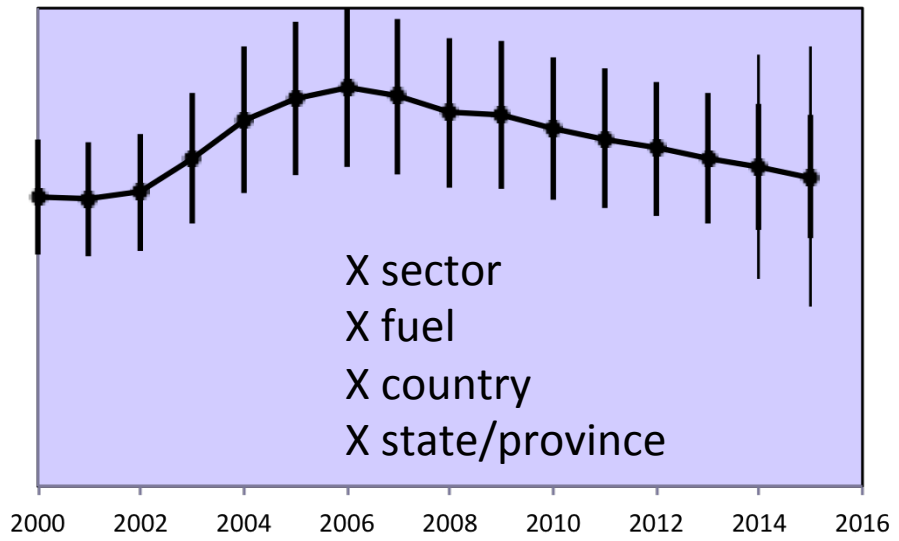
Instead of this



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

Produce

Uncertainty essential for estimates of more recent years.



Project Outcomes

Global Emissions by Country, Sector, and Fuel

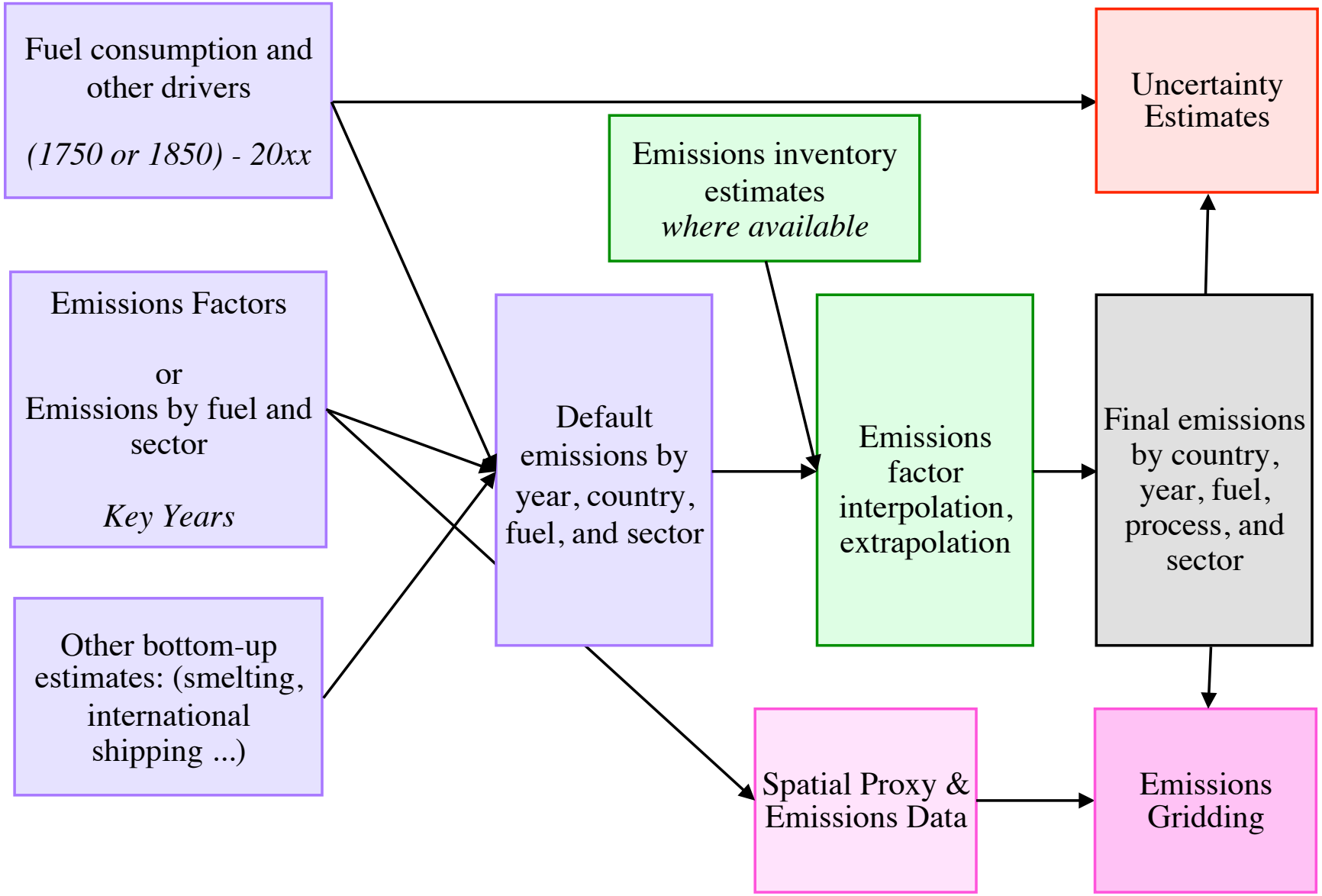
- Annual estimates of anthropogenic emissions (not open burning) to latest full calendar year of chemically reactive species and CO_2 (as reference) over the entire industrial era. Readily updated every year.
  - With greater spatial detail (state/province) for large countries
- Uncertainty estimated at the same level (Country, fuel, sector)
- Seasonal cycle (monthly), aggregate NMVOCs by sector/sub-sector
- Gridded emissions (0.1°) w/ sub-national resolution for large countries

Goals

- Consistent extrapolation at the aggregate level over time (prevent spurious discontinuities)
- Community data review: aggregate (country, sector, ...) & gridded
- Facilitate cross-country comparison (EF consistency, trends)
- Transparent emission results (assumptions -> emissions)
- Tool for more general use

Complementary project coordinated with existing, more detailed work

System Diagram



Methodology

General approach

- Develop a default dataset (GAINS emission factors, EDGAR, etc.)
- Calibrate to country-level inventories at the broad sectoral level (at least) where available and reliable (e.g., most policy-relevant). Similar to approach in RCP and EDGAR-HTAP
- Most of the effort is in gathering input data
  - Driver data (historical energy, agricultural output, other sectors)
  - Default emissions factors. Sectoral emissions for calibration.
- Methodologies similar to Smith et al. (2011) & Klimont et al. (2013)

Produce “a” best estimate, not a fully independent estimate

- In most OECD countries much effort goes into estimating emissions, so use those. Important when control levels are changing over time.
- Emissions factors are changing less rapidly in many developing countries (but are less well known in many cases).
- Some countries (e.g. China, SE Asia) – changes are also rapid –are also more uncertain. Challenging. Wider community involvement can improve results.

Implementation Details

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Implementation

- Modular, data-driven system, in the **R open-source platform**
- Consistent with country-level inventories (where desired/appropriate)
- Open source code and input data
  - IEA energy statistics not open source (but can be "plugged in" by users)
  - Public release of emissions data to as high level of detail as practical
- Tool for emissions research more broadly

Timeline

2014 & Winter 2015	Spring – Summer 2015	Fall 2015	2016-2018	Future On-Going
Initial code design and prototyping	Data collection and processing focused on recent decades	*Community review* **Updated global data for CMIP6**	*Com. review* **Uncertainty** & adl history	*Com. review* **Annual Updates**
		State & other Sub-Regional data	Satellite eval: recent trends	

Uncertainty Estimates

Overall Approach

All bottom-up emission uncertainty estimates contain a substantial element of expert judgment

- Guide assumptions with literature & comparisons between inventories
- Reduce dimensionality by a "tiered" approach to group assumptions

  Otherwise: ~10 sectors X 200+ countries X 5 fuels X ~10 emissions
- Consider correlations across sectors and countries (spatially)
- Result: consistent uncertainty estimates across species and regions

Uncertainty For Most Recent Years

It is critical that emissions for recent years are coupled with uncertainty estimates

- The additional uncertainty in the most recent years can be rigorously assessed by applying the extension methodologies to past data

  Although "past uncertainty does not guarantee future uncertainty"

Sub-Regional Emissions Trends

Previous global emission datasets have often use one spatial distribution for each country. For large countries such as the United States, this can lead to in accuracies in regional emission trends over time.

In this portion of the project we will produce an estimates of sub-regional emissions for large countries (e.g., USA, China, Canada, etc.).

- Collect emissions estimates where available (e.g. US NEI)
- Process state/province level historical energy consumption data
- Will likely need to eventually use some spatial defaults for earlier time periods where statistics are not available

Implement a methodology for data processing so that sub-regional detail can be expanded as data becomes available

Evaluation with Satellite Data

- Compare modeled aerosol optical depth trends (using CAM5) over recent years with satellite data
- Use to better constrain emission trends where particularly uncertain (e.g. China).

Issues: Producing a community inventory

- Discrepancies w/ different versions of country inventories (e.g. Janssens-Maenhout, EDGAR-HTAP 2012)

CO	2000	2001	2002	2003	2004	2005
AUT	0.84	0.85	0.84	0.85	0.86	0.88
BEL	1.04	1.01	1.06	1.28	1.32	1.78
BGR	0.00	1.06	1.03	1.09	1.11	1.14
BLR	0.00	2.40	0.40	2.59	2.40	1.72
CAN	0.00	0.00	0.00	0.00	0.00	0.00
CHE	0.92	0.94	0.95	0.95	0.95	0.95
CYP	0.00	0.00	0.00	0.00	0.00	0.00
CZE	0.00	0.95	0.94	0.93	0.93	0.93
DEU	0.98	0.98	0.97	0.98	1.00	0.96
DNK	1.03	1.04	1.05	1.06	1.05	1.02
ESP	0.91	0.89	0.92	0.87	0.89	0.92
EST	0.92	0.87	0.89	0.84	0.79	0.75
FIN	0.00	1.04	1.05	1.01	1.01	1.02
FRA	0.93	0.96	0.95	0.93	0.93	0.92
GBR	1.01	1.01	1.01	1.01	1.01	1.02
GRC	0.00	0.00	0.93	0.98	0.56	1.02

Table 3 (portion: Ratio of the global emissions for CO reported to UNFCCC to those reported to EMEP.

Zero indicates no reported emission inventory for EMEP was available. Green colors are ratios between 0.98 and 1.02, red colors indicate larger deviations.

How much of this is uncertainty (estimates changing year-to-year) and how much reporting issues? (Sectoral definitions, etc.)

Project Summary

We are building an open-source emissions data system to produce up-to-date anthropogenic aerosol and aerosol precursor emissions estimates.

Emissions Data

- Estimates out to most recent full calendar year
- Annual (& monthly) emission estimates in order to 1) capture timing of regional trends and 2) to provide as up-to-date estimates as possible
- Consistent uncertainty estimates
- Build on existing efforts (GAINS, EDGAR, REAS, country-level inventories) to provide data products and analysis needed for: modeling & climate/air quality work, and advance emissions estimation science.

Data System and Process

- Open data processes for community buy-in and verification
- Publish methodology and results in peer-reviewed literature
- As an open source system, other groups can add/modify code and data
- International steering committee

END