HISTORICAL ESTIMATES OF ATMOSPHERIC REACTIVE GASES AND AEROSOLS BY THE COMMUNITY EMISSIONS DATA SYSTEM (CEDS)

The Community Emissions Data System (CEDS) produces gridded estimates of atmospheric emissions by country and sector from 1750 to the present. These emissions result in increased concentrations of aerosols - small particles in the atmosphere that have a net cooling effect and also influence human health and ecosystems. Emissions data are used by models such as DOE's Energy Exascale Earth System Model (E3SM, e3sm.org) to examine how atmospheric concentrations of aerosols and gases have changed over time and to evaluate whether models are accurately representing atmospheric chemistry and transport processes.

The long-term global coverage provided by the CEDS system allows models to capture important changes over time in the size and location of emissions. For example, the major sources of sulfur dioxide (SO_2) emissions (the precursor gas for sulfate aerosols) in the mid- to late 20th century were North America and Europe. Emissions in these areas declined substantially following the implementation of air pollution controls in the late 20th century. In south and east Asia, emissions of sulfur dioxide increased making these areas the dominant source regions by the early 21st century (see Fig. 1).

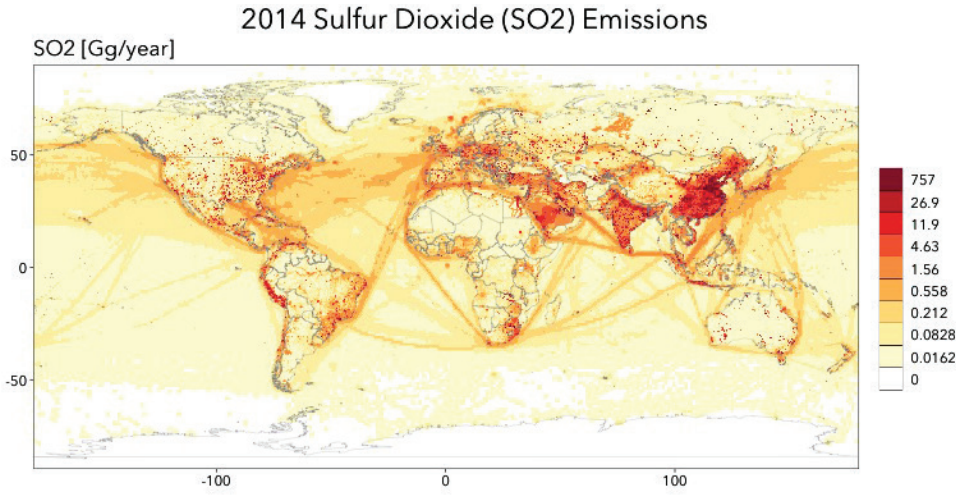

Figure 1. CEDS global sulfur dioxide (SO_2) emissions in gigagrams per year (Gg/year) for 2014. Sulfur dioxide is the primary anthropogenic precursor of sulfate aerosol, which cools the Earth by reflecting sunlight into space. Emissions over the oceans are due to sea navigation routes.

CONSISTENT TIME SERIES

Country-to-country differences in compiling emissions data make it difficult to construct consistent time series of past emissions across the globe. While progress has been made in prior emissions data sets, none satisfy the growing needs of the modeling community for reproducibility, high temporal resolution, and uniform methods across emissions species. CEDS meets these needs by bringing together information on energy consumption by sector, default emission factors, population, and country-level emission inventory data to generate annual estimates over time for the following emissions species: carbon monoxide (CO), methane (CH_4), ammonia (NH_3), oxides of nitrogen (NO_x), sulfur dioxide (SO_2), non-methane volatile organic compounds (NMVOCs), carbonaceous aerosols (black carbon – BC, and organic carbon – OC), and carbon dioxide (CO_2). A unique feature of the CEDS system is that results match detailed emission inventories where available (such as for the United States, Canada, China, Europe, and South Korea) to create time series

Get CEDS

- Code – **https://github.com/JGCRI/CEDS/**
- Docs – **https://github.com/JGCRI/CEDS/wiki**
- Emissions Data – **http://www.globalchange.umd.edu/ceds/ceds-cmip6-data/**

consistent with these country-level data (see Fig. 2).

CMIP6 EMISSIONS DATA

The fundamental output of CEDS are emissions by emission species, country, sector (including 50+ sectors covering industry, energy transformation, transportation, buildings, agriculture, and waste) and fuel (including hard coal, brown coal, coal coke, light oil, diesel oil, heavy oil, natural gas, and biomass). These country-level data are then mapped to a spatial grid for use in Earth system models. This system was used to create the 1750-2014 historical emissions data set used in the Coupled Model Intercomparison Project Phase 6 (CMIP6).

FLEXIBLE SOFTWARE

The CEDS system has now been released as open source software to facilitate community use, involvement, and improvement of global emission inventory data. All the code and data files needed to run CEDS are available on-line except for global energy statistics from the International Energy Agency (IEA), which the user needs to purchase. Users can modify the system to use different assumptions or obtain different outputs, such as gridded emissions for a specific fuel or sector. Key assumptions, such as default emission factors, can be changed without altering code. New inventories can also be added by following the format of existing inventory scaling routines. Users can also supply historical energy data for a specific country, overriding default historical values. The system is also readily extendable to new emission species.

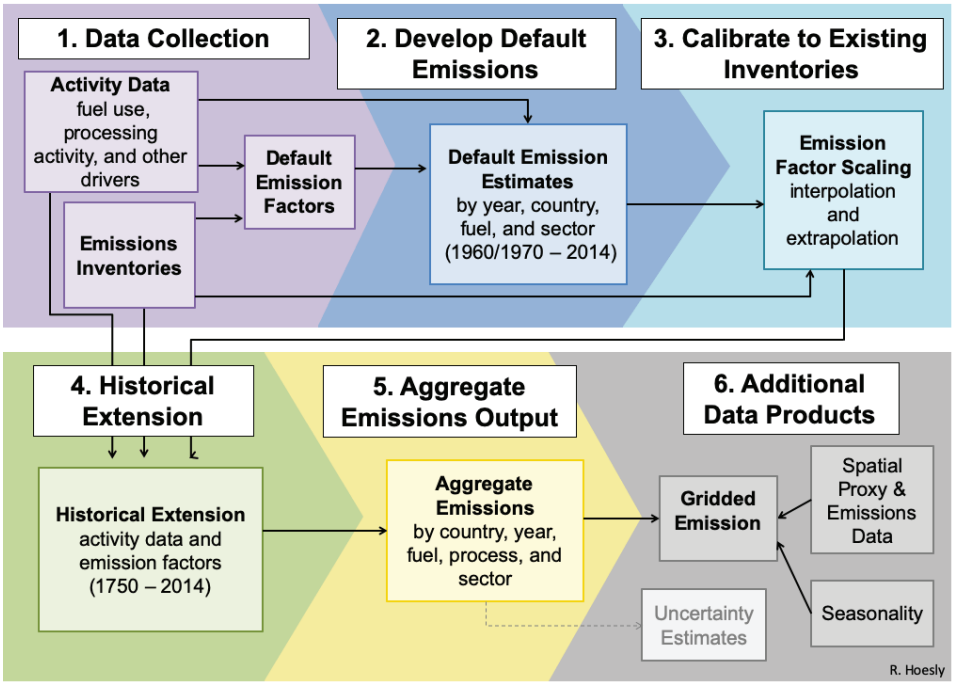

Figure 2. CEDS system summary. The key steps in calculation are to (1) collect and process activity, emission factors, and emission data; (2) develop default emission estimates; (3) calibrate default estimates to existing inventories; (4) extend emissions back to historical time periods; (5) summarize emission outputs; and (6) produce data products including gridded emissions and, in ongoing work, uncertainty estimates.

The CEDS software and data are publicly available through an open-source repository. This approach facilitates transparency, regular updates, and community involvement and improvement. Development and use of the CEDS system is ongoing, and collaborations are welcome.

LOOKING AHEAD

CEDS provides a reproducible approach applied to all emissions types, uses updated emissions factors and more recent estimates, and documents data sources. In addition to regular updates to the data, future work includes producing uncertainty ensembles to ultimately help scientists better understand the potential range of aerosol sources and effects.

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