Pacific Northwest
NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Links between global-scale emission estimates and national emission inventories

STEVEN J. SMITH

Joint Global Change Research Institute
College Park, MD

Expert Meeting on Short-Lived Climate Forcers

Geneva, Switzerland

May 28, 2018

Pacific Northwest
NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

UNIVERSITY OF MARYLAND

Background

Global emission inventories are necessary for global Earth-system models, Human-Earth System models, and comparative analysis across countries.

National inventories are a key component of efforts to limit pollution and its impacts on human health and the environment.

Inventories are particularly important for short-lived species that have high spatial heterogeneity.

- Aerosol Emissions: BC, OC, (other PM2.5), (dust)
- Aerosol and ozone precursors: SO_2, NO_X, CO, NH_3, NMVOC

Inventories of CO_2, CH_4 are also used for carbon-cycle and atmospheric chemistry studies.

The substantial amount of work that goes into developing and updating national inventories makes these useful for the development of global inventories.

A Variety of Approaches to using of national inventory information in global estimates

Independent Estimates

- *e.g.*, EDGAR. (Sources: EMEP/EEA 2013 guidebook, literature, IEA energy data)

Pros: Independent estimate with consistent methodology across countries

Cons: May not have most up to date regional information or location-specific details. Must use global proxy databases for gridding.

Mosaic Emissions Grids

- *e.g.*, HTAPv2. (regional gridded air pollution inventories "stitched" together with EDGAR gridded data as default where other information not available), MIX

Pros: Detailed regional information consistent with air quality studies.

Cons: Gridded data not always available for the same year, nor for most recent or earlier years. No detailed sector info (and maybe not consistent)

Mosaic Aggregate Regional/Country Emissions by Sector

- *e.g.*, HTAPv1, CEDS, RCP (also GAINS-extensive country consultations)

Pros: Can use most up to date regional emissions information

Cons: Inconsistent methods, generally global grid proxies (e.g., EDGAR)

Community Emissions Data System (CEDS)

Advertisement

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

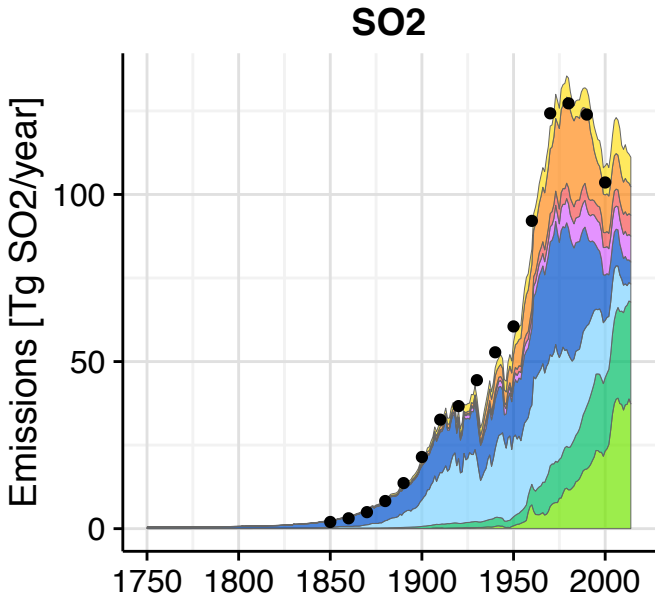
Timely, reproducible, consistent, "research" estimates for emissions of aerosol (BC, OC), precursor compounds (SO_2, NO_x, NH_3, CH_4, CO, NMVOC), and CO_2.

Methodology

- Hybrid of bottom-up emission estimates & calibration to inventories (e.g. EPA, EMEP, etc.)
- Mapped to spatial grids for CMIP6 and other research
- **Calibrated to country-level inventories** (most species but not BC/OC)
- Drawing heavily on existing work (EDGAR, GAINS, country inventories)
- Seasonality and VOC speciation

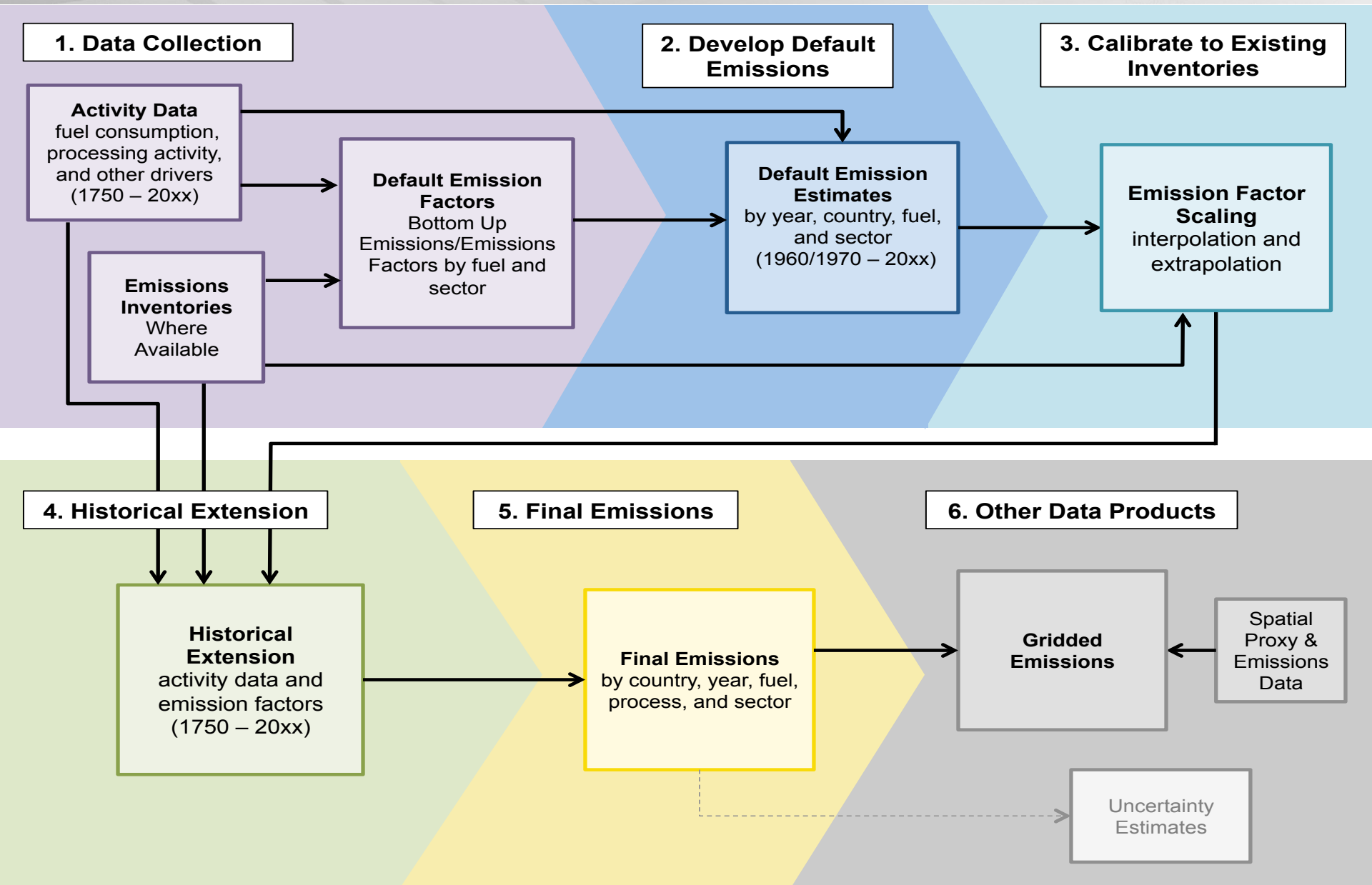
CMIP6 Anthropogenic Emissions (1750 – 2014)

- Aggregate data (country/sector) : in Journal Article supplement https://www.geosci-model-dev.net/11/369/2018/gmd-11-369-2018.html
- Gridded data: https://esgf-node.llnl.gov/search/input4mips/
- GitHub: https://github.com/JGCRI/CEDS/
- Project Web Site: http://www.globalchange.umd.edu/CEDS/



CEDS System Diagram

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965



Issues With Connecting Country Inventories to Global Datasets

- **Heterogeneous data formats**
  - There is no common format for either aggregate or gridded emissions data
  - Custom data processing needed for each dataset
- **Inconsistent sector definitions**
  - Definitions of sectors are sometime unclear
  - Not all inventories include all sectors – important to know where to gap fill
  - Some air pollutant sectors (e.g. off road) have incomplete global driver data
- **General lack of fuel-specific data**
  - Emissions by fuel and sector would enable analysis and allow better calibration
    - (Thank you U.K. for providing both!)
- **Lack of activity data**
  - Activity data is not always publicly available, making consistency difficult to check
  - While global inventories use fuel consumption as driver data, some sectors in country inventories may use other types of activity data (e.g. vehicle-km, etc.).
  - It would be very valuable for global inventories if country inventories could report combustion emission factors and process emissions intensities (physical units).
- **Limited or no uncertainty analysis**
  - Not traditionally a priority for country em inventories used for regulatory purposes.
  - For scientific purposes, uncertainty is highly desired.

Issues: Inventory Errors, Gaps and Biases

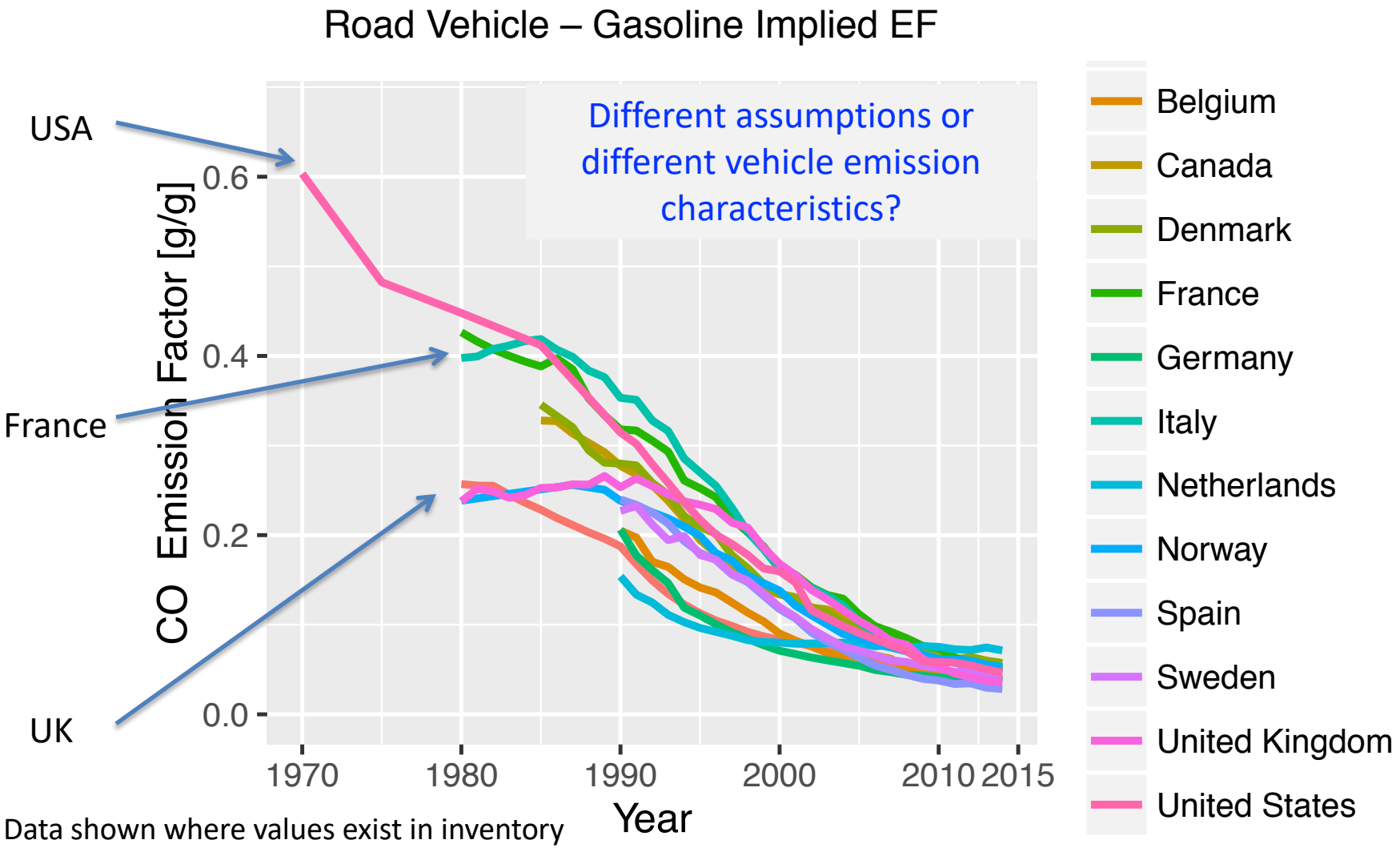
Regulatory air pollutant inventories are generally based on extensive guidance and processes, including, for example, testing regimes for road vehicles and reporting requirements

- Given their regulatory purposes, adherence to a well-defined, publicly accessible, and approved process is important.

- **For many scientific purposes, the most accurate dataset is desired, not necessarily the dataset most well aligned with a country inventory**
  - There are a number of documented cases where observational (+model) evidence indicates that current processes have lead to biases in regulatory inventories both in USA and Europe (and likely elsewhere).
  - How much evidence is required to depart from the “official” inventory data?
- **There are known issues and gaps in some country data**
  - Thus, for example, leading to the EMEP data “as used by models”
  - Alternative approach is GAINS, where extensive consultations and expert judgment are used in the process of emissions estimation
  - Shipping emissions consistency (”international” vs ”domestic”) are a significant issue (in and between country inventories, and between country and global inventories)
  - Fugitive emissions are difficult to quantify in all cases
  - Different goals/hierarchies for air quality vs climate emissions at the country level

Consistency in Country Inventories: What is going on here?

Because CEDS consistently processed inventory and driver data, we can examine implied emission factors in country-level inventories.



Data shown where values exist in inventory

Issues: Primary Aerosol Emissions

There are some specific issues related to primary aerosol emissions.

- Climate modeling is primarily focused on sub-micron primary BC and OC emissions (e.g. BC1, OC1)
- Air quality inventories primarily quantify PM2.5

- **Composition of PM2.5 is not detailed in most existing inventories**
  - Current regulatory regimes focus on total PM2.5, regardless of composition
  - The anthropogenic BC and OC portion of PM2.5 is particularly important for climate change studies
  - The best way to use country estimates of PM2.5 to improve BC and OC are not clear
  - Need to better determine: PM2.5 -> PM1.0 = BC + OM + ? (+ Brown Carbon?)
- **Biomass Consumption**
  - A major source of aerosol particles is solid biomass consumption, particularly traditional biomass (but also wood fuels in higher income countries)
  - Biomass consumption statistics range widely in quality
  - Data sources are not always well documented on an international scale
  - Annual trends in international statistics can be incomplete or inconsistent over time (some trends are likely per-capita extrapolations)
- **Be careful about use of defaults**
  - Need to be cautious when using default emission factors (illusion of certainty)

Summary - Future Directions *(Initial thoughts)*

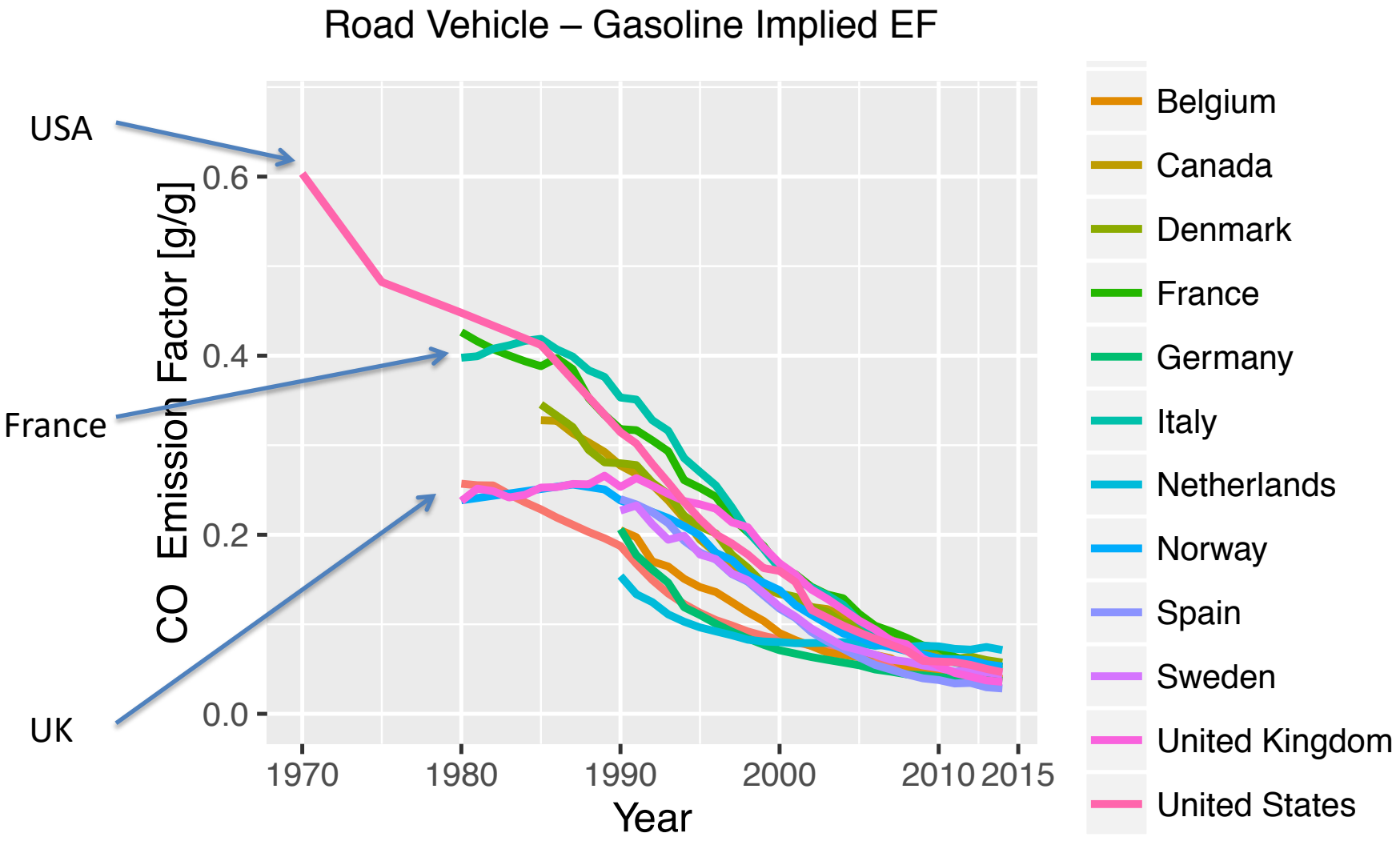
- **Develop common data formats and definitions for country-level inventory data**
  - This would greatly advance analysis, use, and comparison
  - Should be coupled with API (Application Programing Interface) data access
- **Better document sectoral definitions**
  - Is a particular issue for research inventories
  - Issue: fuel comb and process (e.g. IPCC guidelines) vs facility emissions (country level)
- **Improved methods for inclusion of high quality country/regional gridded emissions data/proxies into global inventories**
  - This would improve the quality of global inventory data for recent years
  - Need to develop methods to smoothly merge the higher quality gridded data for recent years with the less available proxy data for earlier years for time series model analysis
- **Confront inventories with observations**
  - Observations are critical for many species, particularly BC/OC!
  - Particularly where real-world emissions conditions vary widely (**fugitive emissions**, **carbonaceous aerosols** in nearly all cases, **biologic sources** (NO_X, NH_3)), in-situ and remote observations will be necessary to better constrain emissions
- **Document/research methods to harmonize estimates of PM2.5 and BC/OC**
  - Kudos to Klimont et al. (2017) for providing PM10, PM2.5, PM1, BC1, OC1, OM1

END

ADDITIONAL SLIDES ON CEDS

Consistency in Country Inventories: What is going on here?

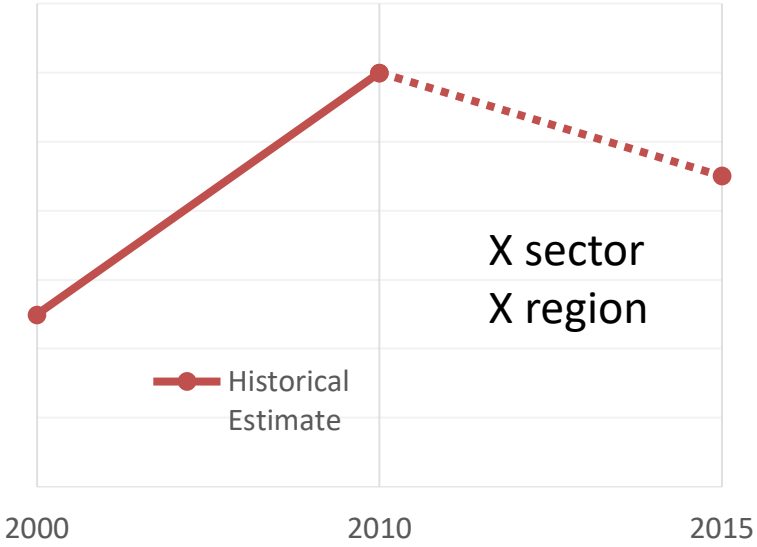
Because CEDS consistently processed inventory and driver data, we can examine implied emission factors in country-level inventories.



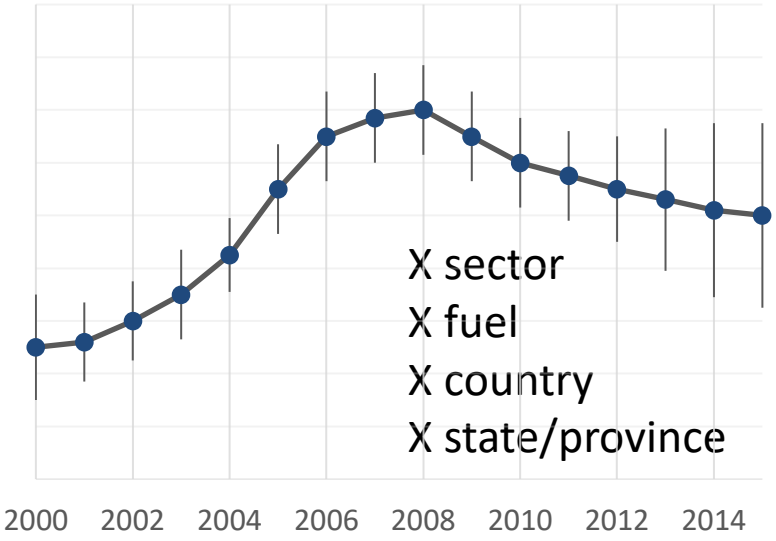
CEDS goals

Timely, reproducible, consistent, "research" 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 this



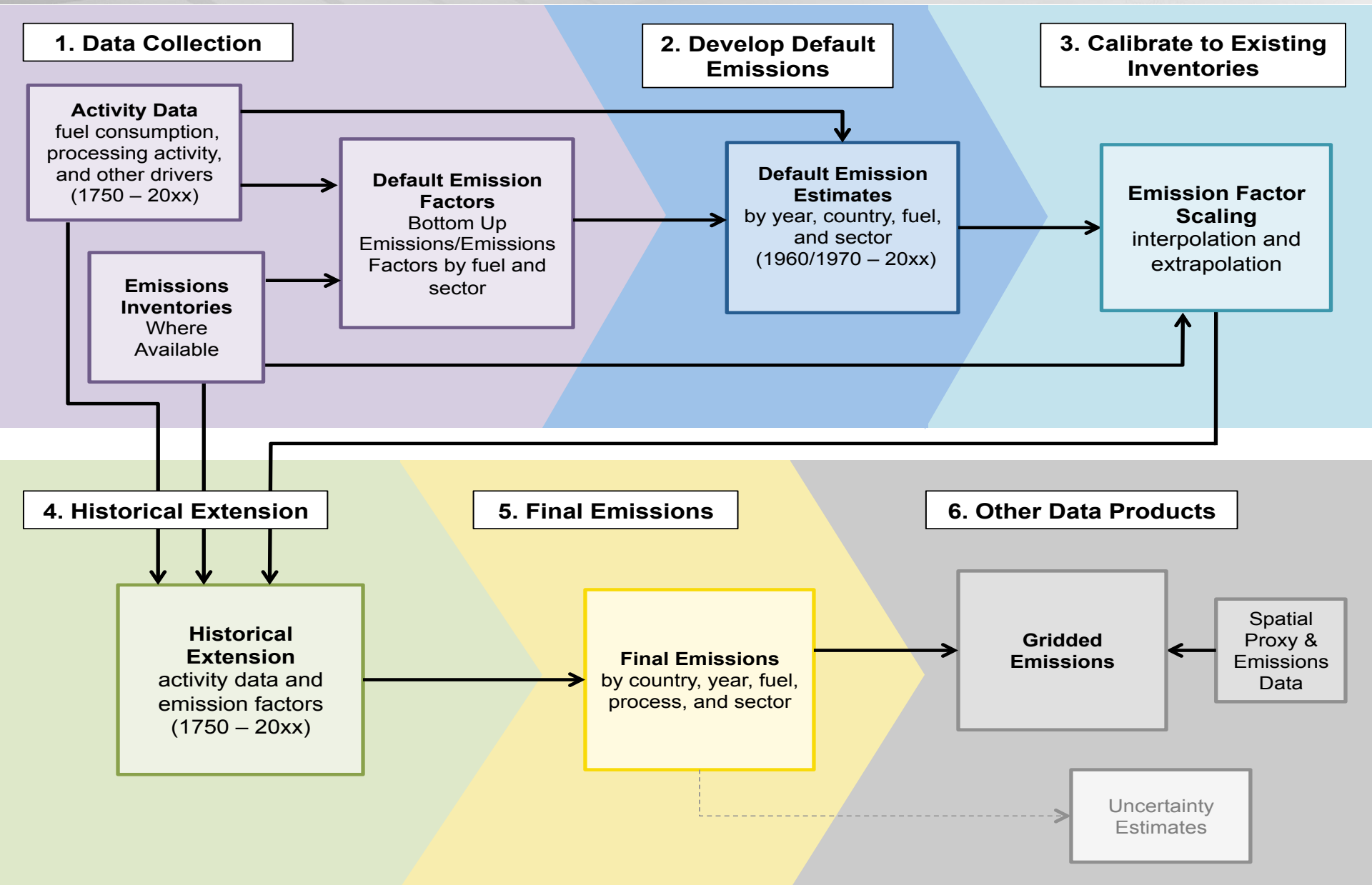
CEDS produces:

- SO_2, NO_x, CO, OC, BC, NH_3, NMVOC, CO_2, CH_4
- 1750 – 2014
- Aggregate annual estimates (221 regions/countries, 8 fuels, 55 sectors)
- Gridded data (0.5° x 0.5° , monthly seasonality, 9 sectors)

Uncertainty essential for estimates of more recent years.

System Diagram

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965



Methodology

1) Estimates by Country, Sector, Fuel

- Hybrid of bottom-up emission estimates & calibration to inventories (e.g. EPA, EMEP, etc.)

2) Map to spatial grid

- Country values mapped to spatial grids for 14 “intermediate” gridding sectors. (Chosen where we have EDGAR, and other global grids.)
- Other than population, we lack spatial information for earlier years.
  - Mostly use time-changing EDGAR grids over 1970 – 2008, then constant
  - Residential emissions distribution merges to population grid by 1900

3) Add Seasonality

- Global gridded monthly profiles (mostly from ECLIPSE) applied by gridding sector

4) Aggregate for gridded data release

- Aggregated to 9 final gridding sectors, month (including aircraft)

CEDS CMIP6 – Improvements Relative To CMIP5

- **More robust emission trends**
  - Consistent methodology across all years
  - All emission species use same driver data
  - Consistently calibrated to country-level inventories where available
- Annual data resolves important socio-economic events
- **Emissions estimates out to 2014 to capture recent trends** as best as possible
  - *Albeit with additional uncertainty (which is now being estimated)*
- 1850 Emissions – CO higher and NO_X lower, due to explicit representation of biomass and coal emissions for all species.
- New sectors included
  - Residential waste burning
  - Flaring (from ECLIPSE project)
  - Fossil-fuel Fires (from EDGAR)
- **Reproducible emissions generation process**
  - CEDS data system and most input data will be released as open source software
  - Updated data such as new country inventories and energy driver data can be readily incorporated to allow annual updates
  - Modular system facilitates data updates (e.g., “drag and drop” capability)

GitHub Wiki - https://github.com/JGCRI/CEDS/wiki

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

JGCRI / CEDS

Watch 4 | Star 0 | Fork 0

Code | Issues 3 | Pull requests 0 | Projects 0 | Wiki | Settings | Insights

Home

Steve Smith edited this page 19 hours ago · 2 revisions

Edit | New Page

Extensive Wiki Documentation

Welcome to the Community Emissions Data System (CEDS) wiki.

Introduction

The CEDS project is building a data-driven, open source framework that will produce annually updated emission estimates for research and analysis.

CEDS System Documentation

The CEDS User Guide page provides information on using the CEDS data system, including some programing hints.

CEDS Data and Assumptions

The Data and Assumptions section documents data sources and assumptions.

Pages 3

- Home
- Data_and_Assumptions
- User_Guide

+ Add a custom sidebar

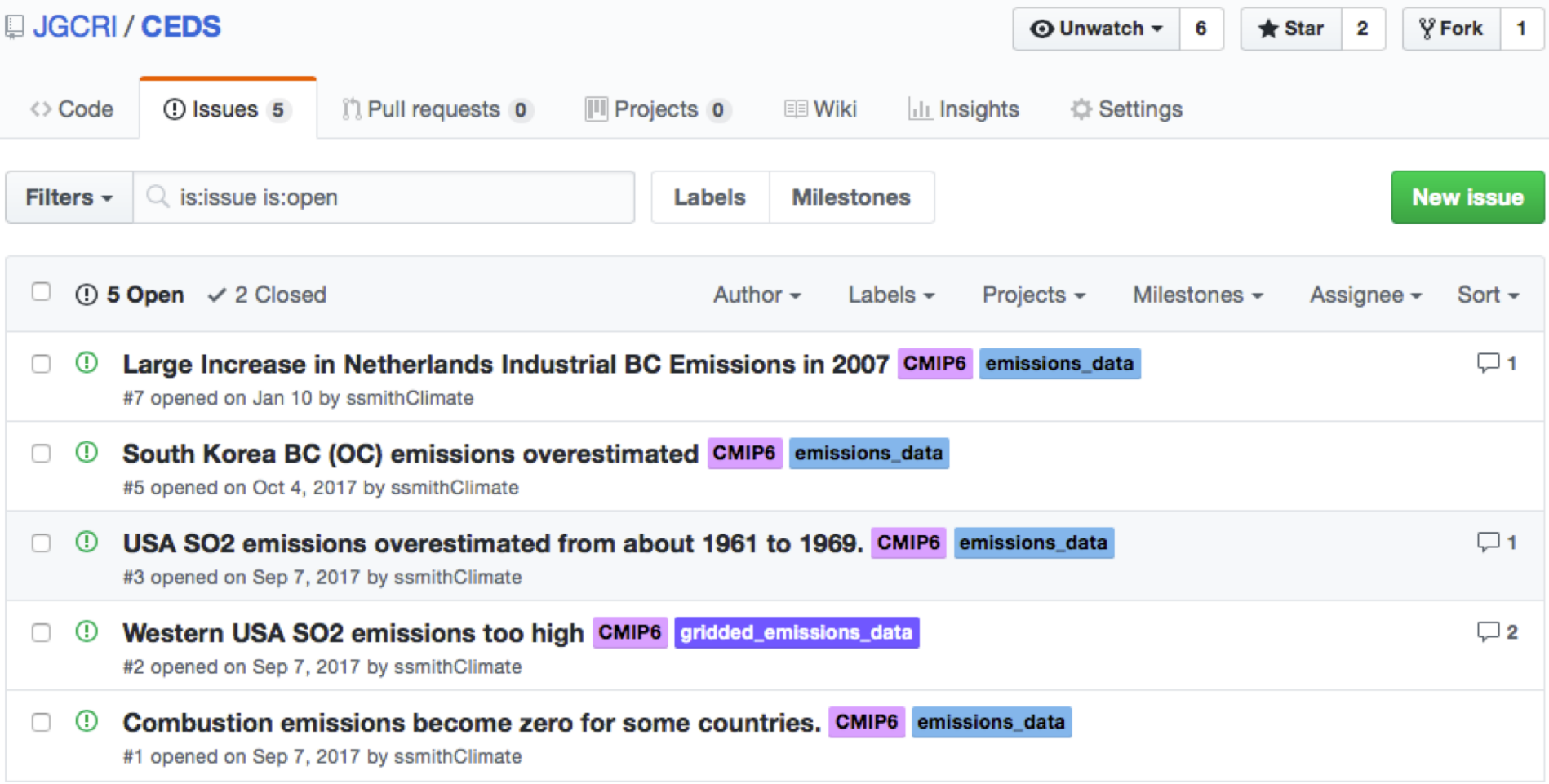
Clone this wiki locally

https://github.com/JGCRI/

Clone in Desktop

GitHub – Tracking Issues

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965



https://github.com/JGCRI/CEDS/issues