A Presentation in Two Parts

1) Emissions from biomass burning

2) Anthropogenic Emissions

Historical missions from biomass burning for CMIP6

By a large group of collaborators

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Emissions from biomass burning

- **Goal:** provide gridded estimates of trace gas emissions and aerosols from fires for the 1750 – 2014 period.

- **Approach:** Scale back in time emissions from the Global Fire Emissions Database (GFED4s) using proxy data where available and fire models / assumptions to fill gaps.

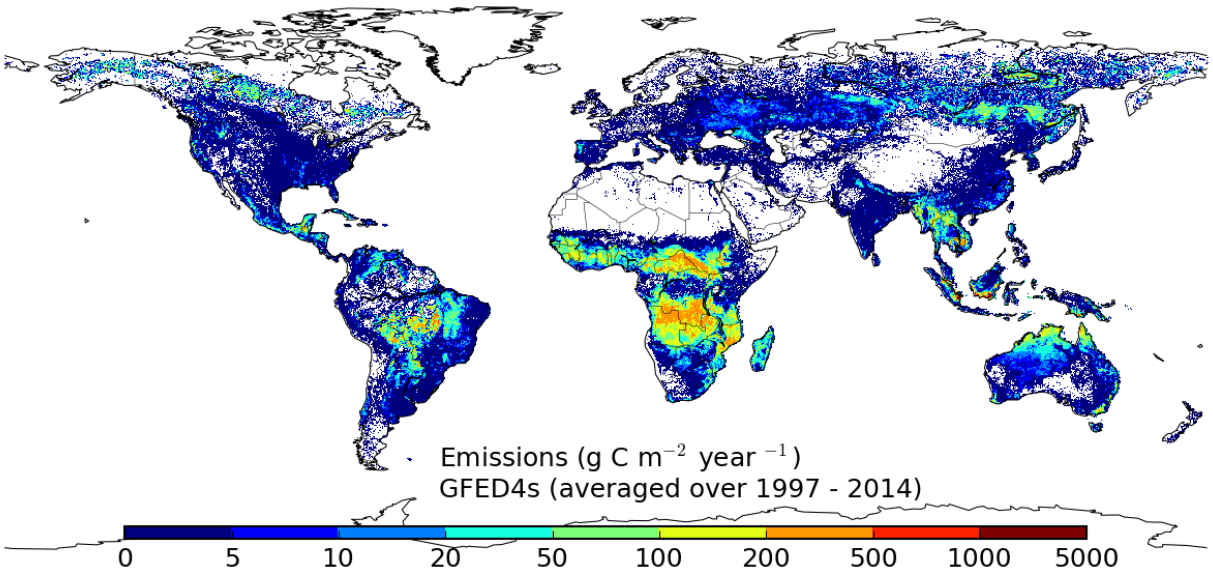
- **Who**: community effort with contribution of the GFED, *charcoal, fire modeling, ice core, visibility, historic reconstructions, and near-real-time fire emission* communities.

Spatial and temporal resolution

- GFED-era (1997-2014):
  - Monthly, for 2003 onwards daily
  - 0.25°×0.25°
- Pre-GFED era (1750-1996):
  - Monthly but based on GFED climatology (so assuming no change over time)
  - Annual values scaled where possible, for example when using visibility data starting from 1950 and high-resolution ice core or firn records
  - For other regions or time periods decadal estimates
  - 1°×1°
- Source categories: savanna, forest, deforestation, agricultural, peat
- Species: all that are available in GFED. Others can be calculated based on emission factors

Approach

1. Use GFED4s for 1997-2014 and calculate for each grid cell emissions for various categories and fire frequencies
2. On a regional level: scale current emissions back in time using proxy data indicating emission levels (charcoal, ice core, visibility) or using changes in land use or cover with changing fire frequencies
3. Use DGVM's with fire models as well as statistical fire models or assumptions to fill gaps and provide uncertainty range



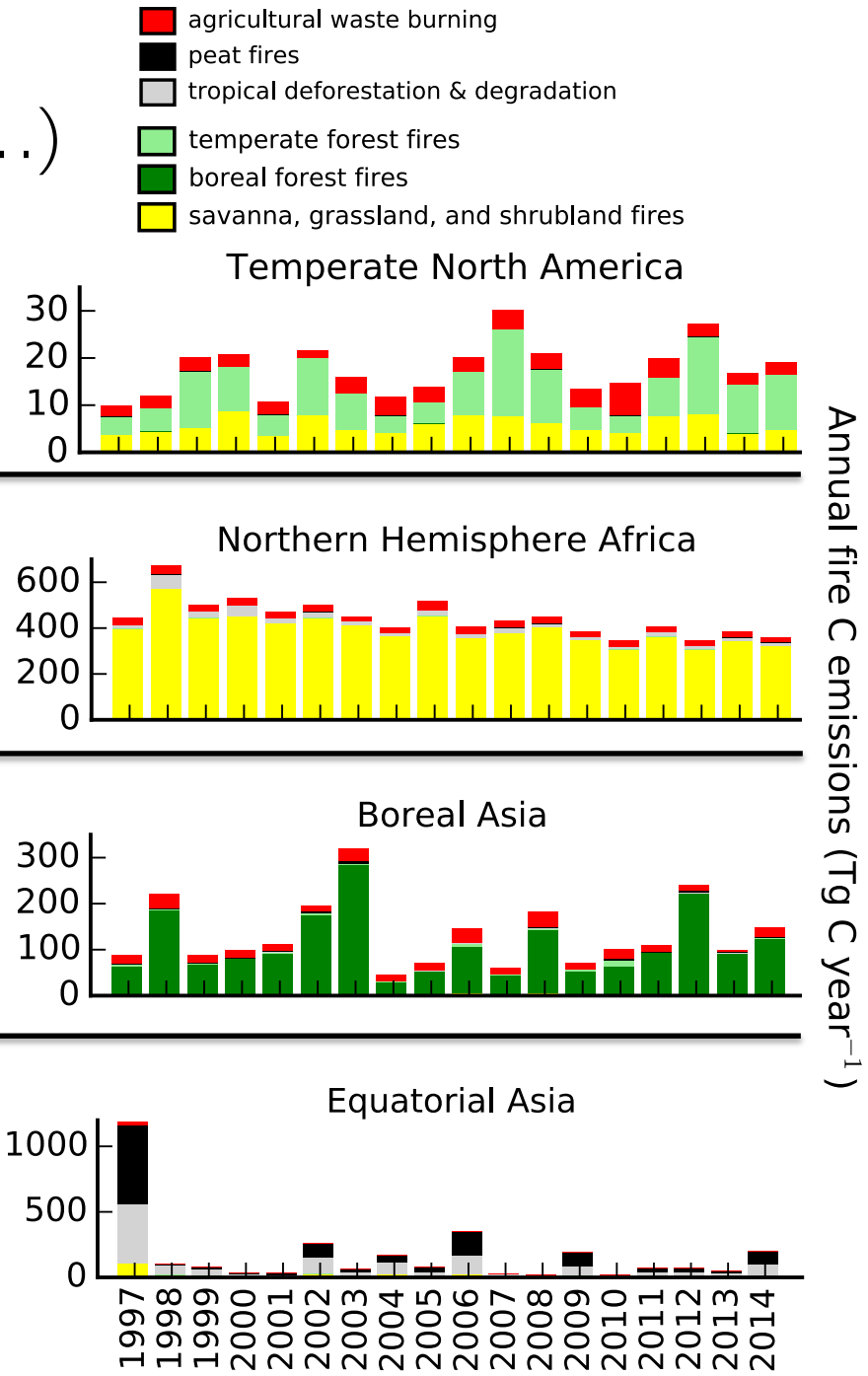
Examples (work in progress…)

US: extensive and reliable historic and charcoal records will be used as proxies

Africa: decline in emissions due to cropland expansion, use land cover data for pre-1997

Boreal region: peaks and trends overlap with records from ice and firn

Indonesia: excellent correlation between GFED and visibility records (starting 1950)



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Community Emissions Data System (CEDS)

Community Emissions Data System (CEDS) - New Historical Emissions for Aerosol and Chemistry Research

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PNNL-SA-112479

Outline

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

Steering Committee

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Claire Granier (LATMOS, NOAA)
Jean-Francois Lamarque (NCAR)
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Collaborators

Liu Liang, Tami Bond (U Illinois), Bob Andres (ORNL), Others

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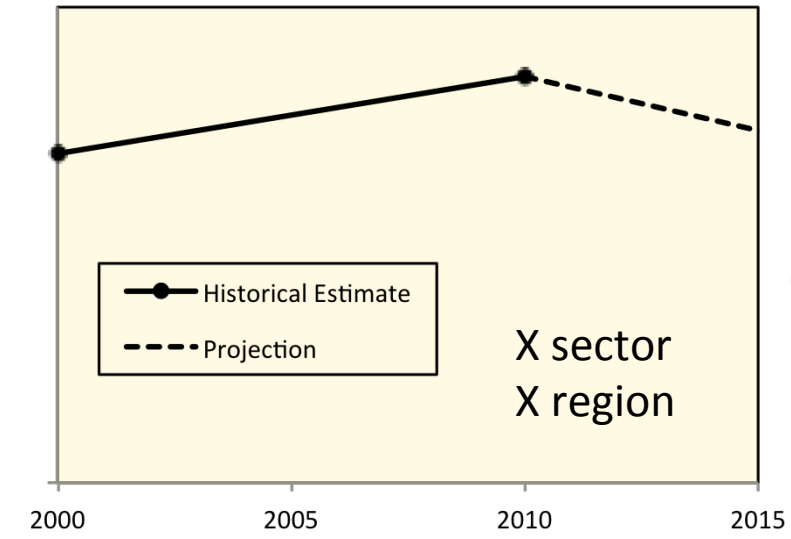
Timely "research" estimates for emissions of aerosol (BC, OC) and aerosol precursor compounds (SO_2, NO_x, NH_3, CH_4, CO, NMVOC) are key inputs for aerosol research and Earth System Models

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

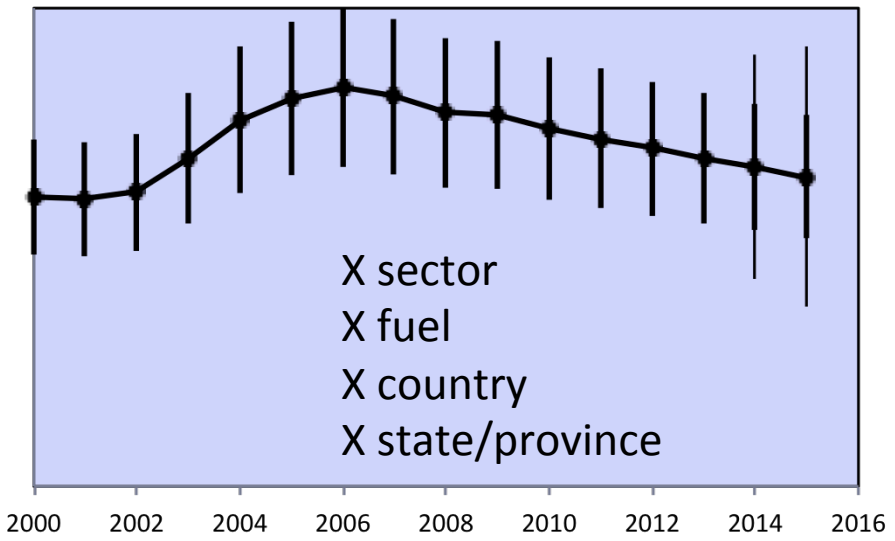
Instead of this



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

Uncertainty essential for estimates of more recent years.

Produce



Methodology

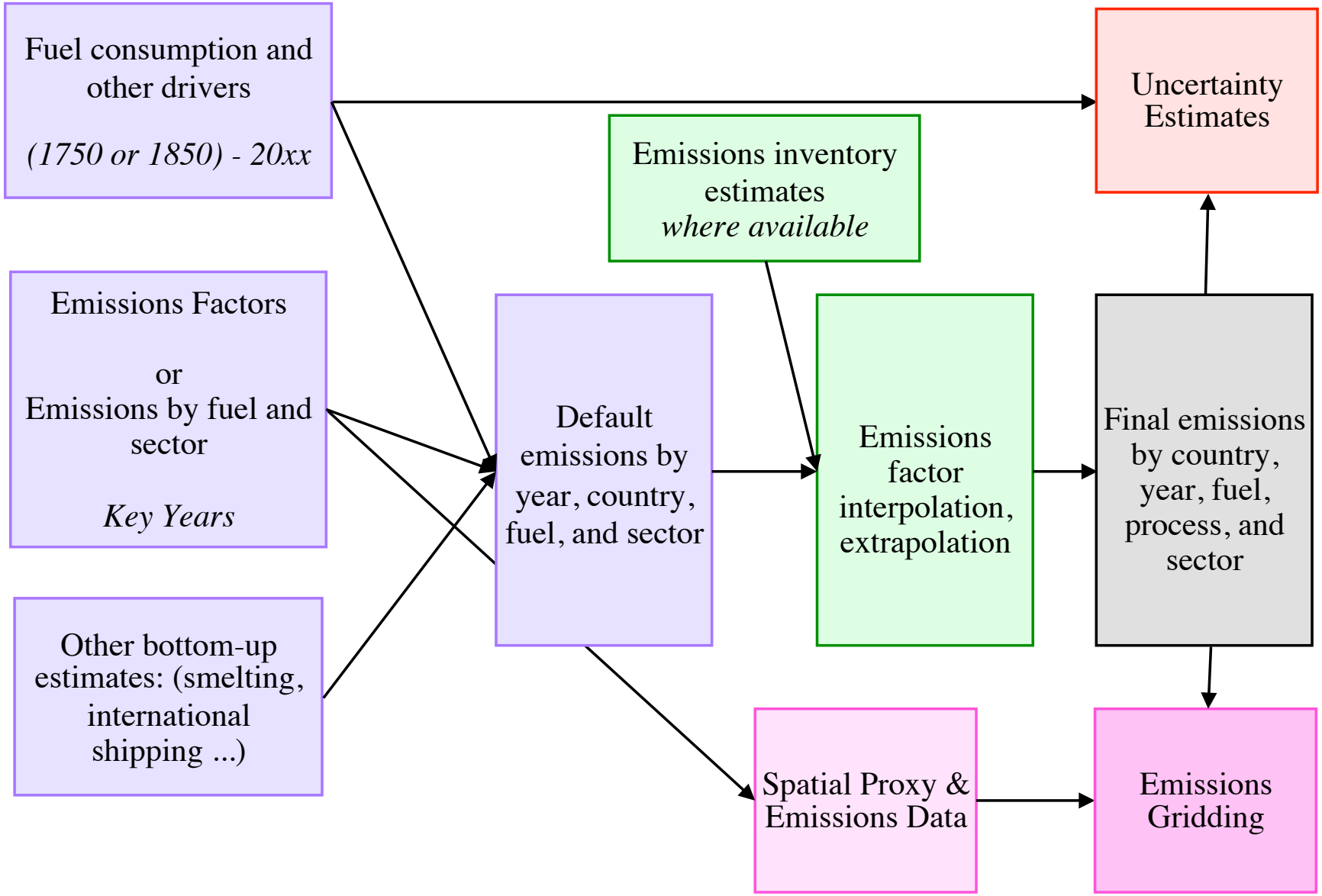
Approach: Hybrid of bottom-up emissions & inventory

- Develop a default dataset (GAINS emission factors, EDGAR, etc.)
- Calibrate to country-level inventories at the sectoral level where available and reliable (e.g., most policy-relevant). Similar to approach for RCP/CMIP5 data 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.

System Diagram



Overall Project Timeline

Phase I: 2015

Community input and review in both phases.

- Build emissions data system
- Updated dataset for CMIP6 focusing on recent decades (Fall 2015)

Phase II: 2016 – 2017

- Consistently estimate uncertainty over time and region
- Expand sub-regional detail for large countries and extend emissions estimates over entire industrial era
- Improve gridding, add seasonality and other characteristics

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Implementation

- Modular, data-driven system, in the **R open-source platform**
- Flexible, automated system
- Consistent with country-level inventories (where desired/appropriate)
- Open source code and input data (where possible)
- Tool for emissions research more broadly

I. Interim CEDS Emissions Dataset for CMIP6

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Interim emissions data product that updates the Lamarque et al. (2010) dataset in time for CMIP6.

- Recent emissions consistent with country inventory data over approximately ~1970 – 2014
- Early Winter 2015 Data: SO_2, NO_x, CO, NMVOC, NH_3, CH_4, BC, OC, CO_2
- EDGAR 4.3 (0.1°) basis for gridding and default emissions
- Extrapolate to earlier years using RCP data (e.g. HYDE)
- Future scenario will be harmonized to depart from this starting point
- Additional features will be added in Phase II

Calculation Status (Oct 1, 2015)

Emission Data Used
Gains (Default EF)
US Emission Trends
Canada Emission Trends
UNFCCC Reporting
EDGAR, REAS, Adl Results Asia, US NEI, EMEP

Emissions of SO2 by Country, Sector, Fuel
(1960/1971 – 2014)

Uncertainty Estimates

Uncertainty For Most Recent Years (Phase I)

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"

Comprehensive Uncertainty Estimates (Phase II)

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

- Guide assumptions with literature, comparisons between inventories, and comparisons between within CEDS
- Reduce dimensionality by a "tiered" approach to group assumptions

  Otherwise: ~40 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

Additional Uncertainty For Recent Years

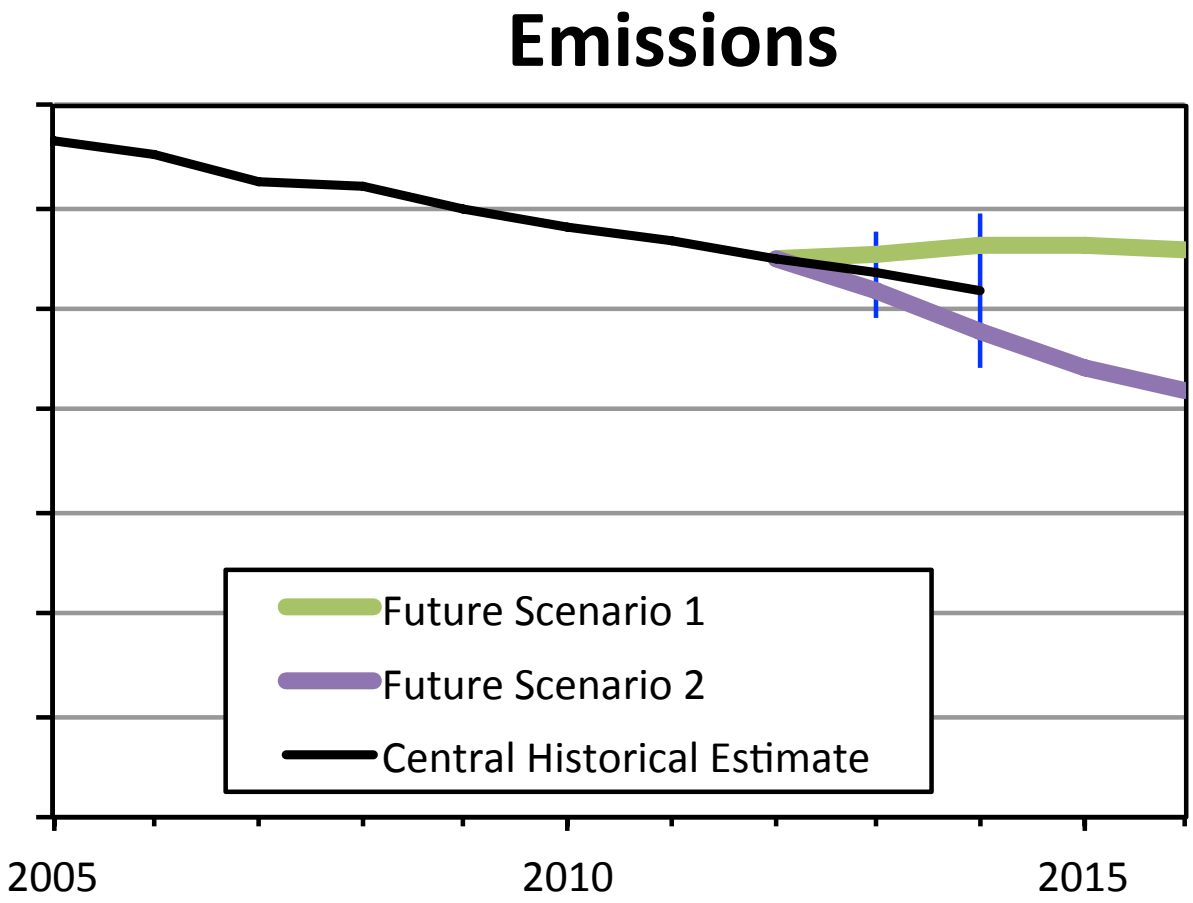
- Emissions inventory data, even for well-developed systems, have additional uncertainty for recent years.

c.f. Janssens-Maenhout, EDGAR-HTAP 2012

CO Emissions - Comparison with US EPA Trends 2008 Data

Inventory	1996	1997	1999	2000	2002	2003	2004	2005	2006
Highway									
Trends 1998	**-32%**	**-32%**							
Trends 2000	**-31%**	**-30%**	**-28%**	**-29%**					
Trends 2003	0%	0%	0%	0%	3%	4%			
Trends 2006	0%	0%	0%	0%	4%	7%	**11%**	**16%**	**19%**
Off-Highway									
Trends 1998	**-17%**	**-14%**							
Trends 2000	**16%**	**18%**	**20%**	**16%**					
Trends 2003	0%	0%	0%	0%	8%	**11%**			
Trends 2006	0%	0%	0%	0%	-1%	4%	9%	**14%**	**21%**
Total (All Sectors)									
Trends 1998	**-26%**	**-20%**							
Trends 2000	**-19%**	**-11%**	**-11%**	-4%					
Trends 2003	0%	0%	0%	0%	1%	2%			
Trends 2006	0%	0%	0%	0%	-2%	2%	6%	**10%**	**14%**

Uncertainty Illustration



The last data point in such a time series does not quite have the same meaning as the previous data points.

Engagement

Your input is encouraged

- ssmith@pnnl.gov
- We have a web site
  - http://www.globalchange.umd.edu/CEDS/
- And a listserv for updates
  - Send an email to listserv@listserv.umd.edu with the email body: “subscribe cedsinfo”. (You will get a return e-mail asking you to verify your subscription.)

The data system and input data will be released as open source software

- *(You will have to purchase a license for the IEA energy data.)*
- Including capability of producing gridded emission datasets

Questions for the Community

CMIP6 Emissions Data (Fall 2015)

- At what uncertainty does a more recent data point become less useful?
  - 20% more uncertain than data from 2 years prior? 30%?
- What are important issues for data validation?
  - NH_3 emissions over Mongolia.
  - …..

What emission data features are ultimately important?

- Seasonality (Monthly)
- Stack height (how important is this? What resolution?)
  - An inventory could potentially provide an indication of injection height – "effective height" would need to be estimated through assessment of modeling, and field measurements.
- Emission ensembles to assess uncertainty
  - Aerosol speciation alternatives. VOC speciation alternatives.
- Other?

END