### Prospectus: A Community Emissions Data System (CEDS)

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### Summary

Historical estimates for emissions of greenhouse gases, anthropogenic aerosol (BC, OC) and aerosol and ozone precursor compounds (SO2, NOx, NH3, CH4, CO, NMVOC) are key data needed for Earth System Models, Integrated Assessment Models and research more generally on aerosols, air pollution, and atmospheric chemistry. Global emissions data sets have a number of shortcomings, including timeliness and transparency. We propose to construct a data system, building on current global efforts, to produce annually updated estimates of global emissions using a data-driven, open source framework.

### Emissions Data Needs

Historical emissions estimates of anthropogenic aerosol and chemically active compounds are key data needed for Earth system models, climate models, and atmospheric chemistry and transport models; both for general analysis and for model validation through comparisons with observations. Such data are also used for calibration of future projections from integrated assessment models. While detailed historical data exist for GHG concentrations and (to a lesser extent) solar and volcanic forcings, data on aerosol and chemically reactive species is relatively crude. Because of the short atmospheric lifetime of many of these species spatial location matters, as does the large changes in emissions that have occurred in many regions over decadal or shorter timescales.

The current historical global dataset used by the community (Lamarque et al. 2010) was a major advance in terms of consistency and completeness. This data, however, has a number of shortcomings including limited temporal resolution, different methodologies between gases, lack of comprehensive uncertainty analysis, and a most recent data point of 2000.

Satellite and other earth-system data are increasingly available in near real-time, but global emission estimates lag by 5-10 years. While satellite data products, including inversion analysis, show promise for variety of uses, these products cannot currently replace bottom-up emission inventories. Indeed, inversion studies have found that the default emission dataset has one of the largest influences on inversion results. Improved inventory estimates will, therefore, enhance the use of satellite data.

We propose a system for extending and analyzing emissions data that will produce estimates that are policy-relevant (e.g. using country-level inventories where these are complete), consistent over time, include uncertainty, and are as up to date as possible. The goal is to produce annual emission estimates by country, sector, and fuel (+spatial emission grids), with uncertainty analysis, as diagramed in below.



Figure 1

### Proposed Emissions Data System

We will implement an open-source data system that will allow the production of global and regional emission datasets that have improved temporal and spatial resolution. Seasonality will be included, and we ultimately aim to include sub-country resolution for countries with large geographical extent (e.g., USA, China, etc.), and other characteristics as deemed important by the user community. These data will enable improved validation and assessment of aerosol and cloud model components, the emissions data needed for both historical attribution and near-term climate predictions, provide uncertainty assessments needed for uncertainty quantification (UQ) research, and allow enhanced use of satellite data products.

The basic methodologies to be used for this system have been documented in recent journal papers (Smith et al. 2011, Klimont, Smith and Cofala 2013, see Figure 2 below), and are designed to complement and extend existing emission inventory efforts. For example, the emission estimates will use country-level emission inventories (e.g., US EPA, Environment Canada, etc.) where these are judged complete. Where data are not available, emissions factors or alternative default data (e.g. EDGAR, GAINS, etc.) can be used to derive estimates, with extrapolation and gap-filling using aggregate sectoral emissions factors. Because energy and other driver data will be incorporated as part of the emissions data system, consistency over time and space can be examined (for example by examining the implied sectoral emissions factors). Emissions estimates can be extended to one year before present, albeit with additional uncertainty (see Figure 1), using, for example, preliminary BP energy statistics, as is done for CO2 emissions under the Global Carbon Project.

A central component of the proposed system is the estimation of uncertainty. Current global emission estimates are generally not provided with uncertainty values. While uncertainty is challenging to calculate for these emissions, simplified methodologies can provide transparent, time, and country-specific estimates (Smith et al. 2011) that can be easily applied in the new data system to produce uncertainty estimates that are consistent across species. The development of the proposed emission data system will also enable the development and implementation of more sophisticated approaches.

The data system will be constructed using the R open source platform. The development of this system builds on experience at the PI’s institution with both global data processing and historical emission estimates. The use of an open source platform will enable the system to be released to researchers to perform their own research or develop alternative scenarios. The data system release will allow researchers, analysts, and policy-makers to access data by sector, fuel, and country that will allow an unprecedented community involvement in emissions research and data development (Frost et al. 2012). Emissions data and results will also be documented in journal papers.

### References

Frost GJ, S Falke, C Granier, T Keating, JF Lamarque, M Melamed, P Middleton, G Petron, and SJ Smith (2012) New Directions: Toward a community emissions approach *Atmospheric Environment* **51** 333–334.

Klimont, Z, S J Smith and J Cofala (2013) The last decade of global anthropogenic sulfur dioxide: 2000-2011 emissions *Environmental Research Letters* **8** 014003. doi:10.1088/1748-9326/8/1/014003.

Lamarque, J. F; Bond, Tami C; Eyring, Veronika; Granier, Claire; Heil, Angelika; Klimont, Z; Lee, David S; Liousse, Catherine; Mieville, Aude; Owen, Bethan; Schultz, Martin; Shindell, Drew; Smith, Steven J; Stehfest, Eike; van Aardenne, John; Cooper, Owen; Kainuma, M; Mahowald, Natalie; McConnell, J.R.; Riahi, Keywan; Van Vuuren, Detlef (2010) Historical (1850-2000) gridded anthropogenic and biomass burning emissions of reactive gases and aerosols: methodology and application *Atmospheric Chemistry and Physics* **10** pp. 7017–7039. doi:10.5194/acp-10-7017-2010

Smith, SJ, J van Aardenne, Z Klimont, R Andres, AC Volke, and S Delgado Arias (2011) Anthropogenic Sulfur Dioxide Emissions: 1850-2005 *Atmos. Chem. Phys*., **11**, 1101–1116.



Figure 2 – Schematic diagram of the emissions data system.