Short-lived Climate Pollutant Research Digest

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TO REDUCE SHORT-LIVED CLIMATE POLLUTANTS

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Multiple Benefits/Impacts & Crosscutting

Description: This section includes articles addressing the multiple benefits of action to address SLCPs and implement SLCP measures.

Health and climate impacts of future United States land freight modelled with global-to-urban models

Driven by economic growth, globalization and e-commerce, freight per capita in the United States has been consistently increasing in recent decades. Projecting to 2050, we explore the emissions, and health and climate impacts of US freight truck and rail transport under various policy scenarios. We predict that, overall, air pollutant emissions and health impacts from the freight-truck-rail system will be greatly reduced from 2010 to 2030, while long-term climate forcing will continue to increase if petroleum is the fuel source. A carbon tax could shift freight shipments from trucking to energy-efficient rail, providing the greatest reduction in long-term forcing among all policies (24%), whereas a policy enforcing truck fleet maintenance would cause the largest reduction in air pollutant emissions, offering the largest reduction in mortalities (36%). Increasing urban compactness could reduce freight activity but increase population exposure per unit emission, offering slight health benefits over the current urban sprawl trend (13%).

Liu, Liang, et al. "Health and climate impacts of future United States land freight modelled with global-to-urban models." NATURE SUSTAINABILITY 2.2 (2019): 105-112.

Methane

Description: This section includes articles addressing methane source apportionment, emissions factors, impacts and emissions trends.

Measuring methane emissions from abandoned and active oil and gas wells in West Virginia

Recent studies have reported methane (CH4) emissions from abandoned and active oil and gas infrastructure across the United States, where measured emissions show regional variability. To investigate similar phenomena in West Virginia, we measure and characterize emissions from abandoned and active conventional oil and gas wells. In addition, we reconcile divergent regional CH4 emissions estimates by comparing our West Virginia emissions estimates with those from other states in the United States. We find the CH4 emission factors from 112 plugged and 147 unplugged wells in West Virginia are 0.1 g CH4 h−1 and 3.2 g CH4 h−1, respectively. The highest emitting unplugged abandoned wells in WV are those most recently abandoned, with the mean emission of wells abandoned between 1993 and 2015 of 16 g CH4 h−1 compared to the mean of those abandoned before 1993 of 3 × 10−3 g CH4 h−1. Using field observations at a historic mining area as a proxy for state-wide drilling activity in the late 19th/early 20th century, we estimate the number of abandoned wells in WV at between 60,000 and 760,000 wells. Methane emission factors from active conventional wells were estimated at 138 g CH4 h−1. We did not find an emission pattern relating to age of wells or operator for active wells, however, the CH4 emission factor for active conventional wells was 7.5 times larger than the emission factor used by the EPA for conventional oil and gas wells. Our results suggest that well emission factors for active and abandoned wells can vary within the same geologic formation and may be affected by differences in state regulations. Therefore, accounting for state-level variations is critical for accuracy in greenhouse gas emissions inventories, which are used to guide emissions reduction strategies.

Riddick, Stuart N., et al. "Measuring methane emissions from abandoned and active oil and gas wells in West Virginia." Science of The Total Environment 651 (2019): 1849-1856.

Very strong atmospheric methane growth in the four years 2014–2017: Implications for the Paris Agreement

Atmospheric methane grew very rapidly in 2014 (12.7 ± 0.5 ppb/year), 2015 (10.1 ± 0.7 ppb/year), 2016 (7.0 ± 0.7 ppb/year), and 2017 (7.7 ± 0.7 ppb/year), at rates not observed since the 1980s. The increase in the methane

burden began in 2007, with the mean global mole fraction in remote surface background air rising from about 1,775 ppb in 2006 to 1,850 ppb in 2017. Simultaneously the 13C/12C isotopic ratio (expressed as δ13CCH4) has shifted, has shifted, now trending negative for more than a decade. The causes of methane's recent mole fraction increase are therefore either a change in the relative proportions (and totals) of emissions from biogenic and thermogenic and pyrogenic sources, especially in the tropics and subtropics, or a decline in the atmospheric sink of methane, or both. Unfortunately, with limited measurement data sets, it is not currently possible to be more definitive. The climate warming impact of the observed methane increase over the past decade, if continued at >5 ppb/year in the coming decades, is sufficient to challenge the Paris Agreement, which requires sharp cuts in the atmospheric methane burden. However, anthropogenic methane emissions are relatively very large and thus offer attractive targets for rapid reduction, which are essential if the Paris Agreement aims are to be attained.

Nisbet, E. G., et al. "Very Strong Atmospheric Methane Growth in the 4 Years 2014–2017: Implications for the Paris Agreement." Global Biogeochemical Cycles (2019).

Tracing the climate signal: mitigation of anthropogenic methane emissions can outweigh a large Arctic natural emission increase

Natural methane emissions are noticeably influenced by warming of cold arctic ecosystems and permafrost. An evaluation specifically of Arctic natural methane emissions in relation to our ability to mitigate anthropogenic methane emissions is needed. Here we use empirical scenarios of increases in natural emissions together with maximum technically feasible reductions in anthropogenic emissions to evaluate their potential influence on future atmospheric methane concentrations and associated radiative forcing (RF). The largest amplification of natural emissions yields up to 42% higher atmospheric methane concentrations by the year 2100 compared with no change in natural emissions. The most likely scenarios are lower than this, while anthropogenic emission reductions may have a much greater yielding effect, with the potential of halving atmospheric methane concentrations by 2100 compared to when anthropogenic emissions continue to increase as in a business-as-usual case. In a broader perspective, it is shown that man-made emissions can be reduced sufficiently to limit methane-caused climate warming by 2100 even in the case of an uncontrolled natural Arctic methane emission feedback, but this requires a committed, global effort towards maximum feasible reductions.

Christensen, Torben Røjle, et al. "Tracing the climate signal: mitigation of anthropogenic methane emissions can outweigh a large Arctic natural emission increase." Scientific reports 9.1 (2019): 1146.

Black Carbon

Description: This section includes articles addressing black carbon source apportionment, emissions factors, impacts and emissions trends.

Emission of black carbon from rural households kitchens and assessment of lifetime excess cancer risk in villages of North India

The use of biomass solid fuels (BSFs) for cooking, contribute significantly to the household air pollution (HAP) in developing countries. Emissions resulting from a variety of BSFs (cow dung cakes, wood, and agriculture residues) contain a significant amount of air pollutants, which are now recognized for their role in climatic change and adverse human health impacts. In the current study, daily variations in black carbon (BC) or Short-Lived Climate Forcer concentrations were studied from rural household kitchens using portable aethalometer. The hourly average concentration of BC ranges from 5.4 μg·m−3 to 34.9 μg·m−3 for various types of household kitchens. The peak levels of BC were found to be significantly higher, when compared to World Health Organization PM2.5 limits for ambient air and hence pose a threat to the health of the vulnerable population, i.e., women, children, older adults and those who have health problems. The study also highlights the variation of BC concentration in different kitchen type. The average BC concentration in indoor, outdoor and semi-open kitchen was observed to be 14.54, 14.28 and 24.69 μg·m−3, respectively. The excess lifetime carcinogenic risk for cooking 4 h/day in these kitchens in the North Indian villages was estimated to be 1.25 × 10−7, 1.22 × 10−7, and 2.12 × 10−7 respectively.

Age-specific excess cancer deaths due to BC exposure were measured highest in children below four years of age in Chandigarh, India. Hence, there is a need to shift the BSF users to clean fuel alternatives to reduce the exposure to HAP. This can be achieved by generating local/regional evidences of BSFs associated health risks to support policy interventions. Further, more research is required to improve the air quality in indoor micro-environments and specifically in kitchens.

Ravindra, Khaiwal. "Emission of black carbon from rural households kitchens and assessment of lifetime excess cancer risk in villages of North India." Environment international 122 (2019): 201-212.

Variation, sources and historical trend of black carbon in Beijing, China based on ground observation and MERRA-2 reanalysis data

Based on the ground-measurements and MERRA-2 (Modern-Era Retrospective Analysis for Research and Applications, Version 2) reanalysis data, the temporal-spatial variation of black carbon (BC) in Beijing and the affecting factors were investigated. According to the ground-measured BC concentration in November months of 2014, 2015 and 2016, the before-heating period in November 2014 showed the lowest BC concentration as a result of the efficient emission controls for the Asia-Pacific Economic Cooperation (APEC) meeting. Except for November 2014, the BC mass concentration during the heating periods was notably lower than the before-heating periods in November 2015 and 2016. Wind speed and relative humidity appeared to be two important meteorological parameters affecting BC pollution. The MERRA-2 BC concentration was validated through comparison with the continuous ground BC measurements in 2015 and 2016, affirming its reliability in demonstrating the large scale and long term variations of the ground BC concentration. The MERRA-2 BC spatial distribution, the potential source regions determined by concentration weighted trajectory (CWT) analysis, and the regional emission inventories were combined to reveal the potential source regions and source types of BC in Beijing. Transportation emission in Beijing and residential emissions in the neighboring regions such as Hebei appeared to be important sources of BC in Beijing. According to the historical trends of MERRA-2 BC concentration and typical fossil fuel consumption (1980–2017), local coal and coke are no longer the major factor affecting the BC concentration, instead, liquid fuels such as gasoline, kerosene, and diesel may highly contribute to the BC pollution in Beijing in recent years. Regional transport of BC may have also contributed to the loading of BC in Beijing. Open biomass burning may be a non-negligible factor for the short-term variation of BC in the atmosphere.

Qin, Weihua, et al. "Variation, sources and historical trend of black carbon in Beijing, China based on ground observation and MERRA-2 reanalysis data." Environmental Pollution 245 (2019): 853-863.

Quantifying the contributions of various emission sources to black carbon and assessment of control strategies in western China

In this study, an air quality model WRF-Chem (Weather Research and Forecasting Chemistry) was used to simulate meteorological conditions and surface black carbon (BC) concentrations in the western China from June 2016 to May 2017, given emissions from various sources in Asia. Comparison between simulations and measurements in western China showed that the model can capture the key spatial and temporal features of meteorological elements and surface BC concentrations. The modeling framework was then used to quantify the relative contributions of different emission sectors to BC concentrations via sensitivity experiments. Our results show that the residential emission sector presented the largest contribution in western China. The second largest contributor for the highly populated mega-cities (HM) region including Sichuan and Guanzhong basins, and for the remote background (RB) region covering the central part of the Tibetan Plateau (TP), was the industrial sector and the transportation sector, respectively. Power plants and open biomass burning sources played minor roles in the regional BC concentration. The seasonality of BC concentrations showed higher values in winter, mainly due to the residential winter heating under conditions of lower precipitation scavenging and poor boundary layer mixing. A further evaluation of emission control strategies shows that a 50% reduction of residential emissions caused annual mean surface BC concentrations in the RB and HM regions to decrease by 36.2% and 36.7%, respectively. In contrast, a 50% reduction in industrial emissions or transportation emissions led to less than 12% decreases in both regions. The 50% reduction of transportation emissions caused BC concentrations to decrease by 9.2% in the RB region, larger than the 5.9% decrease caused by a 50% reduction

of industrial emissions. Transportation emissions were responsible for more BC pollution than industrial emissions for the RB region, in contrast to the highly-industrialized HM region. Therefore, more attention should be paid to transportation emissions when designing control strategies for air pollution over the TP. The results from this work provide useful information for local governments to prepare and implement air pollution guidelines in western China.

Yang, Junhua, et al. "Quantifying the contributions of various emission sources to black carbon and assessment of control strategies in western China." Atmospheric research 215 (2019): 178-192.

A number-based inventory of size-resolved black carbon particle emissions by global civil aviation

With the rapidly growing global air traffic, the impacts of the black carbon (BC) in the aviation exhaust on climate, environment and public health are likely rising. The particle number and size distribution are crucial metrics for toxicological analysis and aerosol-cloud interactions. Here, a size-resolved BC particle number emission inventory was developed for the global civil aviation. The BC particle number emission is approximately (10.9 ± 2.1) × 1025 per year with an average emission index of (6.06 ± 1.18) × 1014 per kg of burned fuel, which is about 1.3% of the total ground anthropogenic emissions, and 3.6% of the road transport emission. The global aviation emitted BC particles follow a lognormal distribution with a geometric mean diameter (GMD) of 31.99 ± 0.8 nm and a geometric standard deviation (GSD) of 1.85 ± 0.016. The variabilities of GMDs and GSDs for all flights are about 4.8 and 0.08 nm, respectively. The inventory provides new data for assessing the aviation impacts.

Zhang, Xiaole, Xi Chen, and Jing Wang. "A number-based inventory of size-resolved black carbon particle emissions by global civil aviation." Nature communications 10.1 (2019): 534.

Tropospheric Ozone

Description: This section includes articles addressing tropospheric ozone impacts and important trends in precursor emissions.

Episode analysis of regional contributions to tropospheric ozone in Beijing using a regional air quality model

Tropospheric ozone (O3) is a major photochemical pollutant during the summer in Beijing and an analysis of its sources and their regional contributions is important in the formulation of O3 control strategies. A typical heavy O3 pollution event occurred in Beijing from July 1 to July 10, 2015. The first two days were defined as clean days with a prevailing northerly wind and low O3 concentrations. The following period from July 3 to July 10 was regarded as polluted days with a prevailing southerly wind and high O3 concentrations. The Integrated Source Apportionment Method (ISAM) implemented in the Regional Atmospheric Modeling System Community Multiscale Air Quality (RAMS-CMAQ) model was applied to quantify the regional contributions to O3 concentrations in Beijing during this pollution episode. The model evaluation shows that the model reproduced the spatiotemporal variations of meteorological conditions (temperature, relative humidity and wind vector) and concentration field (O3 and NO2) well. The diurnal variations of O3 and NOx in both urban and suburban areas are unimodal. The concentration of O3 decreased rapidly in the urban areas after reaching a peak value, but only slowly in the suburbs. The peaks of NOx concentration in suburban areas appear around 05:00 a.m., while those in urban areas appear at 08:00 a.m. With the change in wind direction and enhanced local emissions, the O3 in Beijing was mainly affected by the boundary conditions on clean days and increased by contributions from Tianjin, Hebei, Shandong, and local emissions on polluted days. By contrast, the O3 precursor NO2 was mostly sourced from local and nearby emissions and was only slightly influenced by the meteorological conditions.

Liu, Hailing, et al. "Episode analysis of regional contributions to tropospheric ozone in Beijing using a regional air quality model." Atmospheric Environment 199 (2019): 299-312.

Socio-Economic impacts

Description: This section includes articles addressing the socio-economic impacts due to air pollutions and SLCP related climate changes

Environmental regulation, economic growth and air pollution: Panel threshold analysis for OECD countries

Particles with a diameter of <2.5 μm (PM2.5) have serious adverse-effects on human health, which have caused widespread public concern in recent decades. Currently, most of the existing research on PM2.5 have used linear regression analysis; very few studies on the subject have been conducted using non-linear models. This study adopts a panel threshold model, which is seldom used in environmental studies, to examine the non-linear effects of environmental regulation and economic growth on PM2.5 in 30 OECD countries, and we also explore the key driving socio-economic factors for PM2.5 emissions. The results of our analysis show that, along with an increase in environmental policy stringency, PM2.5 emissions first rise and then show no significant correlations, and thus a reduction in emissions can be expected if current trends continue. As for GDP per capita, significant and negative correlations are found across the three phases divided by the panel threshold model, indicating a promoting effect for PM2.5 mitigation. In addition, public expenditure on the air sector correlated positively with PM2.5 concentrations, expanding the share of service economy reward to reduce air pollution, and urban population ratio exhibits an inverted U-shaped pattern. Future studies may shed more light on the regulation-PM2.5 nexus, and more studies are needed to confirm the existence of bi-directional correlations between economic development and air pollution.

Ouyang, Xiao, et al. "Environmental regulation, economic growth and air pollution: Panel threshold analysis for OECD countries." Science of The Total Environment 657 (2019): 234-241.

Has China's war on pollution slowed the growth of its manufacturing and by how much? Evidence from the Clean Air Action

We provide the first causal estimate of the aggregate effect of the 2013–2017 Clean Air Action, one of the largest and most recent environmental programs in China, on the growth of the manufacturing industry. Using a quasi-experimental approach, we find that the Clean Air Action significantly reduced the manufacturing output in the Beijing-Tianjin-Hebei region, which was subject to the most stringent air pollution regulation, by 6.7% during its first two years of implementation. The losses add up to 408.7 billion yuan (2013 price level), equal to 6.5% of the regional GDP in 2013. The action slowed the growth of manufacturing in Hebei and Tianjin by 9.6% and 5.9%, respectively. We find no evidence that it caused a significant reduction of manufacturing output in Beijing. The heterogeneous treatment effects can be explained by the difference in industrial structure between Beijing, Tianjin, and Hebei. Our analysis empirically suggests that the Clean Air Action helped drive the structural change of the Chinese economy by substantially suppressing “dirty” manufacturing sectors.

Li, Xiao, Yuanbo Qiao, and Lei Shi. "Has China's war on pollution slowed the growth of its manufacturing and by how much? Evidence from the Clean Air Action." China Economic Review 53 (2019): 271-289.

Biomass Burning & Household Energy

Description: This section includes articles primarily addressing SLCP measures and innovations related to the household energy initiative, open burning of agricultural residue, and SLCP emissions in relevant sectors. Solid waste burning is covered in the waste section.

The Impact of Future Fuel Consumption on Regional Air Quality in Southeast Asia

Aerosols emitted from fossil fuel burning can cause air quality and human health issues. In this sensitivity study, we examine the impact of fossil fuel aerosols on air quality in Southeast Asia under five different hypothetical fuel consumption scenarios. These scenarios reflect air pollutant outcomes of implementations of certain

idealized policies in the power generation, industry, and residential sectors. Analyses based on comparison among the modeling results from these scenarios reveal the sectors that should be targeted by air pollution mitigation policy. The results reveal that in Southeast Asia, sulfate could be decreased by 25% if coal were to be replaced by natural gas in the power generation and industry sectors. Black carbon concentration would reduce 42% overall if biofuel were replaced by natural gas in the residential sector. Shipping emissions are especially critical for the urban air quality in Singapore: fine particular matters (PM2.5) could be dramatically cut by 69% in Singapore by merely eliminating shipping emissions.

Lee, Hsiang-He, Oussama Iraqui, and Chien Wang. "The Impact of Future Fuel Consumption on Regional Air Quality in Southeast Asia." Scientific reports 9.1 (2019): 2648.

Air quality in megacity Delhi affected by countryside biomass burning

South Asian megacities are strong sources of regional air pollution. Delhi is a key hotspot of health- and climate-impacting black carbon (BC) emissions, affecting environmental sustainability in densely populated northern India. Effective mitigation of BC impact is hampered by highly uncertain emission source estimates. Here, we use dual-carbon isotope fingerprints (δ13C/Δ14C) of BC to constrain the seasonal source variability in Delhi. These measurements show that lower BC concentrations in summer are predominantly from fossil fuel sources (~83%). However, large-scale open burning of post-harvest crop residue/wood in nearby rural regions is contributing to severe haze pollution in Delhi during winter and autumn (~42 ± 17%). Hence, the common conception that megacities affect their surroundings is here amended or seasonally reversed. Therefore, to combat the severe air pollution problems in Delhi and the environmental quality of northern India, current urban efforts need to be complemented with countryside regional mitigation.

Bikkina, Srinivas, et al. "Air quality in megacity Delhi affected by countryside biomass burning." Nature Sustainability (2019): 1.

Current fossil fuel infrastructure does not yet commit us to 1.5 °C warming

Committed warming describes how much future warming can be expected from historical emissions due to inertia in the climate system. It is usually defined in terms of the level of warming above the present for an abrupt halt of emissions. Owing to socioeconomic constraints, this situation is unlikely, so we focus on the committed warming from present-day fossil fuel assets. Here we show that if carbon-intensive infrastructure is phased out at the end of its design lifetime from the end of 2018, there is a 64% chance that peak global mean temperature rise remains below 1.5 °C. Delaying mitigation until 2030 considerably reduces the likelihood that 1.5 °C would be attainable even if the rate of fossil fuel retirement was accelerated. Although the challenges laid out by the Paris Agreement are daunting, we indicate 1.5 °C remains possible and is attainable with ambitious and immediate emission reduction across all sectors.

Smith, Christopher J., et al. "Current fossil fuel infrastructure does not yet commit us to 1.5 C warming." Nature communications 10.1 (2019): 101.

Cook Stoves & Other Stoves

Description: This section includes articles primarily addressing SLCP measures and innovations related to cook stoves and other stoves

Wood stove use and other determinants of personal and indoor exposures to particulate air pollution and ozone among elderly persons in a Northern Suburb

A six-month winter-spring study was conducted in a suburb of the northern European city of Kuopio, Finland, to identify and quantify factors determining daily personal exposure and home indoor levels of fine particulate matter (PM2.5, diameter <2.5 μm) and its light absorption coefficient (PM2.5abs), a proxy for combustion-derived black carbon. Moreover, determinants of home indoor ozone (O3) concentration were examined. Local central site outdoor, home indoor, and personal daily levels of pollutants were monitored in this suburb among 37 elderly residents. Outdoor concentrations of the pollutants were significant determinants of their levels in

home indoor air and personal exposures. Natural ventilation in the detached and row houses increased personal exposure to PM2.5, but not to PM2.5abs, when compared with mechanical ventilation. Only cooking out of the recorded household activities increased indoor PM2.5. The use of a wood stove room heater or wood-fired sauna stove was associated with elevated concentrations of personal PM2.5 and PM2.5abs, and indoor PM2.5abs. Candle burning increased daily indoor and personal PM2.5abs, and it was also a determinant of indoor ozone level. In conclusion, relatively short-lasting wood and candle burning of a few hours increased residents' daily exposure to potentially hazardous, combustion-derived carbonaceous particulate matter.

Siponen, Taina, et al. "Wood stove use and other determinants of personal and indoor exposures to particulate air pollution and ozone among elderly persons in a Northern Suburb." Indoor air (2019).

Impact of intervention of biomass cookstove technologies and kitchen characteristics on indoor air quality and human exposure in rural settings of India

This study investigates the impact of increased levels of indoor air pollution (IAP) caused due to biomass burning in the rural households of Northern India. A comparative assessment of the impact of traditional cookstoves (TCS) and improved cookstoves (ICS) coupled with the characteristics of kitchen was conducted to estimate the PM (PM10, PM2.5, PM1), CO/CO2 concentrations in the micro-environments of kitchen and living area of the households. The study incorporated both extensive and intensive real-time indoor air quality (IAQ) monitoring during the two cooking sessions of the day. The pollutant concentrations were reported in terms of 24-h as well as 8-h (cooking hours including morning and evening meal) averages. Influence of the three types of kitchen characteristics, i.e., enclosed, semi-enclosed and open was also comprehensively analyzed to measure its impact on the IAQ. In addition to this, the IAQ was further used to evaluate the particle size distribution (PSD), respiratory tract deposition and exposure index to assess its impact on health status of the exposed group including women involved in cooking practices. The results of the study highlighted that deployment of ICS would help in improving the IAQ of the kitchen area by resulting in reducing the concentrations of PM10, PM2.5, PM1 and CO by 21–62%, 20–80%, 24–87% and 19–93%, respectively. It was also highlighted that the kitchen characteristics significantly influence the accumulation of air pollutants, demonstrated by the results that the IAQ being worst in the case of enclosed kitchen, resulted in the highest exposure index values. Multivariate regression models to predict PM1 concentration were also developed for three kitchen categories for both TCS and ICS. Thus, the current study concludes that usage of ICS coupled with efficient designing of the kitchen can improve the overall IAQ of the household along with immense health benefits. Overall, the study emphasized the need of more comprehensive studies to fully assess the association of household air pollution (HAP) and health of individual in the rural settings by considering the toxicity of PM.

Sharma, Deepti, and Suresh Jain. "Impact of intervention of biomass cookstove technologies and kitchen characteristics on indoor air quality and human exposure in rural settings of India." Environment international 123 (2019): 240-255.

Significant reduction in air pollutant emissions from household cooking stoves by replacing raw solid fuels with their carbonized products

Residential solid fuel combustion contributes significantly to ambient and indoor air pollutions. An appropriate clean solid fuel to reduce residential emissions is urgently needed. This study evaluates the reduction in pollutant emissions achieved by carbonized solid fuels in residential cooking practice. Four biochar samples, three semi-coke briquette samples and their raw materials were tested in a typical cooking stove. These carbonized samples showed higher thermal efficiencies and lower particulate matter (PM) emission factors (EFs) than their raw material samples. Owing to distilled volatile matter during carbonization treatment, average energy delivered-based PM2.5 EFs were 10 ± 5 mg/kJ (carbonized) and 50 ± 28 mg/kJ (raw) for the biomass and 0.33 ± 0.04 mg/kJ (carbonized) and 3.0 ± 1.3 mg/kJ (raw) for the coal samples. The energy delivered-based EFs of organic carbon, elemental carbon, and 16 priority polycyclic aromatic hydrocarbons extracted from PM2.5 samples from carbonized fuels were reduced by 97 ± 1%, 93 ± 3%, and 97 ± 2%, respectively, for the tested biomass samples, and those for the tested coal samples were 96 ± 1%, 90 ± 6%, and 98 ± 2%, respectively. Average EFs of benzo[a]pyrene equivalent carcinogenic potency for individual polycyclic aromatic hydrocarbons were reduced 95 ± 3% to ~0.51 μg/kJ (carbonized) from ~19.6 μg/kJ (raw). Furthermore, the average ratio of volatile organic

compounds contained in PM2.5 samples was also reduced from 38.8 ± 5.4% to 7.1 ± 3.9%. These results suggest that carbonized solid fuels exhibit better performance in reducing carcinogenic potency and pollutants, most of which are highly correlated with the volatile matter content of the fuel. Switching from raw solid fuel to carbonized solid fuel will help to reduce pollutant emissions from household combustion and achieve both environmental benefits and health benefits for household residents.

Li, Qing, et al. "Significant reduction in air pollutant emissions from household cooking stoves by replacing raw solid fuels with their carbonized products." Science of the Total Environment 650 (2019): 653-660.

Indoor levels of black carbon and particulate matters in relation to cooking activities using different cook stove-fuels in rural Nepal

In Nepal, majority of households still burn solid fuels in inefficient cook stoves inside poorly ventilated kitchens, which results in very high levels of indoor pollutants, including black carbon (BC). Previous studies have not yet reported BC concentrations in typical kitchen configurations in rural Nepal. In this study, fine particulate matter (PM) and BC concentrations were monitored continuously inside two types of kitchens (separated from and attached to the main house) under actual cooking practices. Prior to monitoring of pollutants, a field survey was conducted to gain insight into the types of kitchens, cook stoves and fuels used. Indoor PM and BC concentrations were monitored using biomass fuels in traditional cook stoves (TC) and improved cook stoves (ICS). Clear diurnal variations of the pollutants were observed in both kitchens, with the highest concentrations during cooking times. BC and PM concentrations during cooking and non-cooking periods demonstrated clear reductions in the concentrations during non-cooking periods. It was observed that the concentrations rose steeply during the first half hour of cooking, then decreased slightly and finally leveled off to the non-cooking period concentrations. 24-hour average indoor PM concentrations in both kitchens frequently exceeded Nepal's indoor air quality standards and the WHO PM2.5 guidelines, by a factor of ~8 to ~28. We found that the specific type of ICS used in this study, a commonly used ICS in Nepal and other developing countries might help in PM emission reductions but not necessarily BC emission reduction.

Rupakheti, Dipesh, et al. "Indoor levels of black carbon and particulate matters in relation to cooking activities using different cook stove-fuels in rural Nepal." Energy for Sustainable Development 48 (2019): 25-33.

Agriculture and Livestock

Description: This section includes articles primarily addressing SLCP measures and innovations related to the Agriculture initiative and SLCP emissions in relevant sectors

A new Tier 3 method to calculate methane emission inventory for ruminants

Livestock is the main source of methane (CH4) emissions. It is important to accurately determine emissions from ruminants that meet standardized international guidelines for national greenhouse gas inventories. A new method to improve the accuracy of CH4 emissions that complies with IPCC rules for a Tier 3 method is described and evaluated. This method, developed by INRA (French Institute for Agricultural Research), was applied to the French inventory of CH4 emissions by ruminants and compared with the IPCC Tier 2 method. For enteric CH4, depending on the animal category, the INRA CH4 emission estimates lay between 88% and 114% of IPCC's. The INRA/IPCC ratio for enteric emission was close to unity and did not differ between methods ($P = 0.43$) for adult cows (i.e. most cattle). In France, feedlot manure is stored in aerobic conditions, and so the INRA/IPCC fit for manure emission was poorer ($P < 0.05$). The INRA/IPCC fit for enteric CH4 was very close between methods to that for total CH4 ($P = 0.39$), enteric CH4 representing 93% of total emissions. The main improvement is the use of a robust equation (from numerous data and diets), based on digestible organic matter intake (DOMI) corrected for the digestive interactions, to predict CH4 consistently from enteric and manure sources. It was developed for the French livestock inventory but is customizable for other countries. This new improved CH4 estimation method, based on equations from a large literature database, complies with IPCC rules for a Tier 3 method.

Eugène, M., et al. "A new Tier 3 method to calculate methane emission inventory for ruminants." Journal of environmental management 231 (2019): 982-988.

Evaluating the GHG mitigation-potential of alternate wetting and drying in rice through life cycle assessment

Alternate wetting and drying (AWD), has gained increasing attention as a promising strategy for mitigating greenhouse gas emissions (GHG) in flooded rice systems. AWD involves periodic drainage of rice paddies in order to inhibit methane (CH4) emissions. To date, studies evaluating this practice have been limited in their scope and resolution. Our study evaluates the mitigation potential of AWD from a life cycle perspective using high-resolution CH4 modeling to more accurately estimate the mitigation potential of this practice. We simulated California rice production under continuous flooding and under five AWD schedules ranging in the severity and frequency of dry-downs. Production models were coupled with the Peatland Ecosystem Photosynthesis Respiration and Methane Transport (PEPRMT) model to simulate CH4 fluxes at daily intervals. We then evaluated the GHG mitigation potential of AWD using life cycle assessment models. Frequent or severe dry-downs reduced simulated grain yields, which negated some of the benefits of AWD when assessed on a yield-scaled basis. We also found AWD-induced mitigation of CH4 emissions modeled with PEPRMT to be roughly half the magnitude reported from up-scaling of chamber measurements, highlighting the importance of high resolution field data to better characterize GHGs in rice systems. Reduced yields and conservative CH4 mitigation in our model lessened the overall mitigation potential of AWD. When the entire rice life cycle was considered, mitigation of overall global warming potential (GWP) was further reduced by the presence of additional GHG sources, which comprised roughly half of life cycle GWP. Our simulations resulted in ⩽12% reductions in GWP kg−1 across all AWD scenarios and saw an increase in GWP when yields were severely reduced. Our results highlight the importance of constraining uncertainties in CH4 emissions and considering a life cycle perspective expressed on a yield-scaled basis in characterizing the mitigation potential of AWD.

Fertitta-Roberts, Cara, Patricia Y. Oikawa, and G. Darrel Jenerette. "Evaluating the GHG mitigation-potential of alternate wetting and drying in rice through life cycle assessment." Science of The Total Environment 653 (2019): 1343-1353.

Agricultural CH4 and N2O emissions of major economies: Consumption-vs. production-based perspectives

Agriculture is one of the most important sectors for global anthropogenic methane (CH4) and nitrous oxide (N2O) emissions. While much attention has been paid to production-side agricultural non-CO2 greenhouse gas (ANGHG) emissions, less is known about the emissions from the consumption-based perspective. This paper aims to explore the characteristics of agricultural CH4 and N2O emissions of global major economies by using the latest emission data from the Food and Agriculture Organization Corporate Statistical Database (FAOSTAT) and the recently available global multi-regional input-output model from the World Input-Output Database (WIOD). The results show that in 2014, the 42 major economies together accounted for 60.7% and 65.0% of global total direct and embodied ANGHG emissions, respectively. The consumption-based ANGHG emissions in the US, Japan, and the EU were much higher than their production-based emissions, while the converse was true for Brazil, Australia, and India. The global-average embodied ANGHG emissions per capita was 0.7 t CO2-eq, but major developing countries such as China, India, Indonesia and Mexico were all below this average value. We find that the total transfer of embodied ANGHG emissions via international trade was 622.4 Mt CO2-eq, 11.9% of the global total. China was the largest exporter of embodied ANGHG emissions, while the US was the largest importer. Most developed economies were net importers of embodied emissions. Mexico-US, China-US, China-EU, China-Japan, China-Russia, Brazil-EU, India-EU and India-US formed the main bilateral trading pairs of embodied emission flows. Examining consumption-based inventories can be useful for understanding the impacts of final demand and international trade on agricultural GHG emissions and identifying appropriate mitigation potentials along global supply chains.

Han, Mengyao, et al. "Agricultural CH4 and N2O emissions of major economies: Consumption-vs. production-based perspectives." Journal of Cleaner Production 210 (2019): 276-286.

Reducing enteric methane emissions from dairy cattle: Two ways to supplement 3-nitrooxypropanol

The aim of this work was to determine the effect of 3-nitrooxypropanol (3-NOP) on the enteric methane (CH4) emissions and performance of lactating dairy cows when mixed in with roughage or incorporated into a concentrate pellet. After 2 pretreatment weeks without 3-NOP supplementation, 30 Holstein Friesian cows were divided into 3 homogeneous treatment groups: no additive, 3-NOP mixed in with the basal diet (roughage; NOPbas), and 3-NOP incorporated into a concentrate pellet (NOPconc). The pretreatment period was followed by a 10-wk treatment period in which the NOPbas and NOPconc cows were fed 1.6 g of 3-NOP/cow per day. After the treatment period, a 2-wk washout period followed without 3-NOP supplementation. The CH4 emissions were measured using a GreenFeed unit (C-Lock Inc., Rapid City, SD) installed in a freestall with cubicles during the entire experimental period. On average for the total treatment period and compared with the no-additive group, CH4 production (g/d) was 28 and 23% lower for NOPbas and NOPconc, respectively. Methane yield (g/kg of dry matter intake) and methane intensity (g/kg of milk) were 23 and 24% lower for NOPbas, respectively, and 21 and 22% lower for NOPconc, respectively. No differences were found between NOPbas and NOPconc. Moreover, supplying 3-NOP did not affect total dry matter intake, milk production, or milk composition. The results of this experiment show that 3-NOP can reduce enteric CH4 emissions of dairy cattle when incorporated into a concentrate pellet and that this reduction is not different from the effect of mixing in 3-NOP with the basal diet (roughage). This broadens the possibilities for using 3-NOP in the dairy sector worldwide, as it is not always feasible to provide an additive mixed in with the basal diet.

Van Wesemael, D., et al. "Reducing enteric methane emissions from dairy cattle: Two ways to supplement 3-nitrooxypropanol." Journal of Dairy Science 102.2 (2019): 1780-1787.

The effect of integrative crop management on root growth and methane emission of paddy rice

In previous studies, integrative crop management (ICM) improved shoot growth and grain yield of rice (Oryza sativa L.). However, little is known about the effect of ICM on root growth and methane (CH4) emission of paddy rice. In this study, two rice varieties, Wuyunjing 24 and Yongyou 2640, were grown. A field experiment was conducted with three crop management treatments including zero nitrogen fertilization (0N), local farmer practice (LFP), and ICM. Root morphophysiological traits and CH4 emission from the paddy field were investigated. ICM significantly increased mean grain yield by 29.9%, with the effect attributed mainly to an increase in mean total number of spikelets by 26.4% compared to LFP. ICM increased root and shoot biomass, root length, number of roots, root oxidation activity (ROA), root bleeding rate, and root total and active absorbing surface area by respectively 24.4%, 25.7%, 17.1%, 9.3%, 18.7%, 29.5%, 12.1%, and 24.7%. The concentrations of malic, succinic, and acetic acids in root exudates were respectively 5.8%, 6.0%, and 10.5% higher in ICM than in LFP. Compared to LFP, ICM significantly decreased the rate of CH4 emission during emission peak stages and reduced total CH4 emission by 17.1%. The root morphophysiological traits were positively and significantly correlated with grain yield, whereas root length, specific root length, ROA, and root total and active absorbing surface area were negatively and significantly correlated with total CH4 emission. These results suggest that ICM could achieve the dual goals of increasing grain yield and reducing the greenhouse gas effect by improving the root morphology and physiological traits of paddy rice.

Zhang, Hao, et al. "The effect of integrative crop management on root growth and methane emission of paddy rice." The Crop Journal (2019).

Equine Contribution in Methane Emission and Its Mitigation Strategies

Greenhouses gas emission mitigation is a very important aspect of earth sustainability with greenhouse gasses reduction, a focus of agricultural and petrochemical industries. Methane is produced in nonruminant herbivores such as horses because they undergo hindgut fermentation. Although equine produce less methane than ruminant, increasing population of horses might increase their contribution to the present 1.2 to 1.7 Tg, estimate. Diet, feeding frequency, season, genome, and protozoa population influence methane production equine. In population, Methanomicrobiales, Methanosarcinales, Methanobacteriales, and Methanoplasmatales are the clade identified in equine. Methanocorpusculum labreanum is common among hindgut fermenters like horses and termite. Naturally, acetogenesis and interrelationship between the host and the immune-anatomical interaction are responsible for the reduced methane output in horses. However, to reduce methane output in equine, and increase energy derived from feed intake, the use of biochar, increase in acetogens, inclusion of

fibre enzymes and plant extract, and recycling of fecal energy through anaerobic gas fermentation. These might be feasible ways to reducing methane contribution from horse and could be applied to ruminants too.

Elghandour, Mona MMY, et al. "Equine contribution in methane emission and its mitigation strategies." Journal of equine veterinary science (2018).

Coal-Fired Power

Description: This section includes articles primarily addressing SLCP measures and innovations related to the power sector

China's coal mine methane regulations have not curbed growing emissions

Anthropogenic methane emissions from China are likely greater than in any other country in the world. The largest fraction of China's anthropogenic emissions is attributable to coal mining, but these emissions may be changing; China enacted a suite of regulations for coal mine methane (CMM) drainage and utilization that came into full effect in 2010. Here, we use methane observations from the GOSAT satellite to evaluate recent trends in total anthropogenic and natural emissions from Asia with a particular focus on China. We find that emissions from China rose by 1.1 ± 0.4 Tg CH4 yr−1 from 2010 to 2015, culminating in total anthropogenic and natural emissions of 61.5 ± 2.7 Tg CH4 in 2015. The observed trend is consistent with pre-2010 trends and is largely attributable to coal mining. These results indicate that China's CMM regulations have had no discernible impact on the continued increase in Chinese methane emissions.

Miller, Scot M., et al. "China's coal mine methane regulations have not curbed growing emissions." Nature communications 10.1 (2019): 303.

Global emission hotspots of coal power generation

Coal power generation is a primary cause of greenhouse gas (GHG) and toxic airborne emissions globally. We present a uniquely comprehensive inventory of CO2, methane, particulate matter, sulfur dioxide, nitrogen oxides and mercury emissions for 7,861 coal-generating units including their supply chains. Total GHG and toxic substance emissions are largest from China, the United States, India, Germany and Russia (together >64% per pollutant). Overall supply chain contributions are below 19%, but exceed 75% for individual units and pollutants. Methane emissions from underground coal mining offset Chinese coal power plant efficiency advantages in comparison to India. Health impacts, as quantified by regionalized life cycle assessment, are highest in India and parts of eastern and southeastern Europe due to lack of modern flue gas treatment, and in China due to widespread coal power generation. Deployment of state-of-the-art flue gas treatment, driven by local emission limits, can mitigate health impacts in India and parts of Europe while it is already largely used in China and the United States. Phase-out of the 10% most polluting coal power plants (by capacity) would reduce coal power GHG emissions by 16% or human health impacts by 64%, respectively.

Oberschelp, Christopher, et al. "Global emission hotspots of coal power generation." Nature Sustainability 2.2 (2019): 113.

Underreported coal in statistics: A survey-based solid fuel consumption and emission inventory for the rural residential sector in China

Solid fuel consumption and associated emissions from residential use are highly uncertain due to a lack of reliable statistics. In this study, we estimate solid fuel consumption and emissions from the rural residential sector in China by using data collected from a new nationwide field survey. We conducted a field survey in 2010 which covered ~17,000 rural residential households in 183 counties in China, to obtain data for solid fuel consumption and use patterns. We then developed a Generalized Additive Model (GAM) to establish the relationship between solid fuel consumption and heating degree days (HDD), income, coal production, coal price, and vegetation coverage, respectively. The GAM was used to estimate solid fuel consumption in rural households

in China at the county level. We estimated that, in 2010, 179.8Tg of coal were consumed in Chinese rural households for heating and cooking, which is 62% higher than that reported in official energy statistics. We found that large quantities of rural residential coal consumption in the North China Plain were underreported in energy statistics. For instance, estimated coal consumption in rural households in Hebei (one of most polluted provinces in China) was 20.8Tg in 2010, which is twice as high as government statistics indicate. In contrast, modeled national total consumption of crop residues (used as fuels) we found to be ~50% lower than reported data. Combining the underlying data from the survey, the GAM and emission factors from literature, we estimate emissions from China's rural residential sector in 2010 to be: 3.3Tg PM2.5, 0.6Tg BC, 1.2Tg OC, 2.1Tg VOC, 2.3Tg SO2, 0.4Tg NOx, 43.6Tg CO and 727.2Tg CO2, contributing to 29%, 35%, 38% and 26% of national total PM2.5, BC, OC, and CO emissions respectively. This work reveals that current emission inventories in China likely underestimate emissions from coal combustion in rural residential households due to missing coal consumption in official statistics, especially for the heavily polluted North China Plain (NCP) region. Per capita income appears to be the driving factor that results in the difference between surveyed data and official data. Residents with high income prefer commercial energy and have a higher per capita fuel consumption than lower income residents. Therefore, rural residential coal combustion may contribute even more to regional air pollution than the large contributions previously identified.

Peng, Liqun, et al. "Underreported coal in statistics: A survey-based solid fuel consumption and emission inventory for the rural residential sector in China." Applied energy 235 (2019): 1169-1182.

Transportation

Description: This section includes articles primarily addressing SLCP measures and innovations related to the Diesel initiative and SLCP emissions in relevant sectors

Atmospheric emission inventory of multiple pollutants from civil aviation in China: Temporal trend, spatial distribution characteristics and emission features analysis

A detailed comprehensive emission inventory of multiple air pollutants from civil aviation in China for the historical period of 1980–2015 is developed by using an approach of combining bottom-up with top-down for the first time. Annual emissions of various pollutants present a rapidly ascending trend along with the increase of economic volume and population, which are estimated at approximately 4.77 kt HC, 59.63 kt CO, 304.77 kt NOx, 59,961 kt CO2, 19.04 kt SO2, 3.32 kt PM2.5, 1.59 kt BC, 1.06 kt OC and 5.44 t heavy metals (HMs), respectively, by the year 2015. We estimate the local emissions in 208 domestic civil airports and allocate the total cruise emissions onto 299 main domestic flight segments with surrogate indexes, such as route distance, cargo and passenger turnover. The results demonstrate that emission intensities in central and eastern China are much higher than those in northeastern and western China, and these regions are characterized with high population density, huge economy volume, as well as transit convenience. Furthermore, we have explored emission characteristics of multiple pollutants under different operation modes in 2015. For PM2.5, SO2/CO2/HMs and NOx, the emissions from cruise process constitute the dominant contributor with a share of 89%, 92% and 81%, of the associated total emissions, respectively, comparing with 76% and 71% of the total CO and HC emissions release from Landing and Take-off (LTO) process. Consequently, there are notably different emission characteristics from different flight processes due to various combustion status of aviation fuel. In addition, we predict the future trends of multi-pollutants emissions from China's civil aviation industry through 2050 under three scenarios, and the results indicate that the reduction from the improvement of new technology or new national standards would be largely offset by the rise in multi-pollutants emissions from rapidly aviation fuel growth.

Liu, Huanjia, et al. "Atmospheric emission inventory of multiple pollutants from civil aviation in China: Temporal trend, spatial distribution characteristics and emission features analysis." Science of the total environment 648 (2019): 871-879.

Comparison of the cost-effectiveness of eliminating high-polluting old vehicles and imposing driving

restrictions to reduce vehicle emissions in Beijing

Motor vehicle emissions contribute significantly to air pollution in Beijing. Therefore, a number of measures have been taken to control emissions from motor vehicles, including the elimination of high-polluting old vehicles and driving restrictions. We compared the pollution reduction effects and implementation costs of these two policies. The results showed that an average annual investment of about 1.7 billion RMB was invested in a policy of eliminating old vehicles in Beijing, resulting in annual emissions reductions of about 22,600 tons of CO, 1330.2 tons of NOx, 2197 tons of HC, 78.6 tons of PM2.5, and 81.3 tons of PM10. Meanwhile, a driving restrictions policy resulted in an annual loss by consumers of more than 17.84 billion RMB and annual emissions reductions of just 12,000 tons of CO, 845 tons of NOx, 1356 tons of hydrocarbons HC, 53 tons of PM2.5, and 57 tons of PM10. A policy of eliminating old cars is more cost-effective than a driving restrictions policy, policy formulation should take into account the cost-effectiveness of policies.

Xiao, Cuicui, et al. "Comparison of the cost-effectiveness of eliminating high-polluting old vehicles and imposing driving restrictions to reduce vehicle emissions in Beijing." Transportation Research Part D: Transport and Environment 67 (2019): 291-302.

Air pollution & Health Impacts

Description: This section includes articles primarily addressing linkages between air pollution exposure and health impacts

Estimation of PM2·5-associated disease burden in China in 2020 and 2030 using population and air quality scenarios: a modelling study

Air pollution and its adverse effects on public health remain a considerable problem in China, where policies have been implemented to improve the situation. We aimed to estimate the disease burden associated with particulate matter (PM)2·5 across China for 2020 and 2030 to identify the populations and regions most at risk, quantify the health benefits of air quality improvement targets, and determine the effect of population growth and ageing on this disease burden. In this modelling study, we investigated premature deaths associated with PM2·5 across China on the basis of air quality scenarios proposed by the expert group involved in the formulation of the 13th Five-Year Plan for Eco-Environmental Protection and population scenarios based on the Shared Socioeconomic Pathways of the Intergovernmental Panel on Climate Change. We used the integrated exposure–response model used for the Global Burden of Disease Study to estimate the number of PM2·5-related premature deaths under each scenario. The projected health benefits of the air-quality-improving targets are substantial, and could reduce the number of PM2.5-related premature deaths in China by approximately 129 278 by 2020 and 217 988 by 2030, compared with 2010. However, since China's population is increasing and ageing, the number of PM2.5-related premature deaths was estimated to increase by 84 102 by 2020 and by 244 191 by 2030, indicating that the health benefits induced by air quality improvements could be offset by the effect of the population increasing in size and ageing. To reduce the future disease burden in China, targets that are stricter than the interim target and stringent policies to improve air quality and protect public health are needed, especially for at-risk population groups, such as older individuals (aged >55 years) and patients with cardiovascular diseases, particularly in regions with a high disease burden.

Wang, Qing, et al. "Estimation of PM2· 5-associated disease burden in China in 2020 and 2030 using population and air quality scenarios: a modelling study." The Lancet Planetary Health 3.2 (2019): e71-e80.

Analysis of the adverse health effects of PM2.5 from 2001 to 2017 in China and the role of urbanization in aggravating the health burden

In this study, the trend of PM2.5 concentrations and its adverse health effects in China from 2001 to 2017 are estimated utilizing 1-km high-resolution annual satellite-retrieved PM2.5 data. PM2.5 concentrations for most of the provinces/cities remained stable from 2001 to 2012; however, following the issue of the Air Pollution Prevention and Control Action Plan (APPCAP) by the central government of China, a dramatic decrease in PM2.5

concentrations from 2013 to 2017 occurred. Premature mortality caused by PM2.5 dropped from 1,078,800 in 2014 to 962,900 in 2017. The PM2.5 caused 17-year average mortality ranges from 3800 in Hainan Province to 124,800 in Henan Province. The health cost benefits gained by the reduction of PM2.5 pollution amounted to US $193,800 in 2017 (compared to the costs due to PM2.5 concentrations in 2013), amounting to 1.58% of the total national GDP. The impacts of urbanization on PM2.5 concentration and mortality are analyzed. The PM2.5 concentration and its induced mortality density in dense urban areas are much higher than those in rural areas. The aggravation of PM2.5 associated premature mortality in urban areas is mainly due to the larger amount of emissions and to urban migration, and 6500 deaths in 2014 could have been avoided were the population ratios in dense-urban/normal-urban/rural areas to be reversed to the ones in 2001. It is recommended that people with respiratory-related diseases live in rural areas, where the pollutant concentration is relatively low.

Lu, Xingcheng, et al. "Analysis of the adverse health effects of PM2. 5 from 2001 to 2017 in China and the role of urbanization in aggravating the health burden." Science of The Total Environment 652 (2019): 683-695.

Potential reductions in premature mortality attributable to PM2.5 by reducing indoor pollution: A model analysis for Beijing-Tianjin-Hebei of China

China has one of the highest PM2.5 (particulate matter with an aerodynamic diameter smaller than 2.5 μm) pollution levels in the world. It might still be long before air quality reaches the National Class II standard of 35 μg/m3. We aim to estimate the potential reduction in premature mortality by reducing indoor PM2.5 levels in the Beijing-Tianjin-Hebei (BTH) region and compare it with reducing outdoor levels. We combined PM2.5 transport model and the Global Burden of Disease (2016) methodology to estimate potential reductions in premature mortality attributable to PM2.5 by reducing indoor PM2.5 to National Class I standard of 15 μg/m3, and compared with reducing outdoor PM2.5 to Government 2020 Interim target of 64 μg/m3 or National Class II standard of 35 μg/m3. A total of 74,000 (95% confidence interval (CI): 43,000–111,000) premature deaths were attributable to PM2.5 exposure in 2013. Thirty percent, or 22,000 (95% CI: 17,000–32,000) deaths, would have been averted if indoor PM2.5 had reached the National Class I standard. The benefit is greater than that from reaching the Government 2020 Interim target for outdoor PM2.5 [22%, or 16,000 (95% CI: 12,000–23,000), deaths], although still smaller than that from reaching the National Class II standard [42%, or 31,000 (95% CI: 24,000–45,000), deaths]. Reaching the National Class I level of indoor PM2.5 at current outdoor pollution levels could bring considerable health benefits, which are comparable to those from reaching the Government 2020 Interim target for outdoor PM2.5.

Ji, Wenjing, Bin Zhou, and Bin Zhao. "Potential reductions in premature mortality attributable to PM2. 5 by reducing indoor pollution: A model analysis for Beijing-Tianjin-Hebei of China." Environmental Pollution 245 (2019): 260-271.

PM2.5 and Air Pollution

Description: This section includes articles addressing PM2.5 and air pollution source apportionment, impacts and emissions trends.

Effects of meteorology and emission reduction measures on air pollution in Beijing during heating seasons

Beijing implemented five-year clean air plan during 2013–2017, and realized the continuous improvement of air quality in the whole city year by year. In this study, the MK (Mann-Kendall) test and KZ (Kolmogorov-Zurbenko) filtering analysis method were applied to evaluate the variations of PM2.5 concentration at different sites in Beijing before and after the filtering meteorological conditions. The results showed that the averaged PM2.5 concentrations in five sites decreased by 29.82% after filtering weather conditions, which was significantly lower than the average decrease rate (33.61%) of the original data. The emissions by human activities contributed about 69–94% to the decreased PM2.5 concentrations during 2013–2017 at different sites in Beijing while the meteorological conditions contributed not more than 31% indicating the leading role of the emission reduction measures in the air quality improvement in Beijing. Contrary to the monthly averaged trends, the original PM2.5

concentrations in heating seasons during 2013–2016 did not decrease obviously and not passed the significant test (= 0.1) due to the unfavor weather conditions which always aggravated degree and duration of air pollution. In order to further improve air quality, emission reduction measures such as reducing coal combustion, reducing oil consumption, controlling vehicles, emissions reduction, and cleaning dust should be continuously promoted.

Cheng, Nianliang, et al. "Effects of meteorology and emission reduction measures on air pollution in Beijing during heating seasons." Atmospheric Pollution Research (2019).

Long-term trends (2005–2016) of source apportioned PM2.5 across New York State

The United States has experienced substantial air pollutant emissions reductions in the last two decades. Among others, emissions produced by electricity generation plants and industries were significantly lowered. Ultralow (<15 ppm) sulfur fuels were introduced for road vehicles, nonroad, rail, and maritime transport. New heavy-duty diesel trucks have been equipped with particle traps and NOx controls. Residual oil (No. 6) for space heating and for any other purpose was replaced with cleaner No. 2 and No. 4 oils. Chemical speciation of PM2.5 has been measured since 2005 at eight sites across the New York State. A prior study has identified and apportioned the major sources of PM2.5 across the State using receptor modelling (positive matrix factorization). This present study aims to investigate the long-term trends of those source-apportioned PM2.5 mass contributions from 2005 to 2016 at the eight sites: two rural sites (Pinnacle and Whiteface), three medium sized cities (Buffalo, Albany, Rochester), and three sites in the New York City metropolitan area (Bronx, Manhattan and Queens). Negative trends from 2005 to 2016 were detected across the state for secondary sulfate (from −0.19 μg/m3/y in Rochester to −0.36 μg/m3/y at BRO and QUE) and secondary nitrate (from −0.02 μg/m3/y at the rural sites to approximately −0.2 μg/m3/y at BRO and MAN). Spark-ignition vehicles were the only source type experiencing upward annual trends at all urban sites with slopes ranging from 0.02 μg/m3/y (ROC, not statistically significant) to ~0.2 μg/m3/y (Albany, Bronx, Manhattan). Other sources exhibited different trends among the sites. The relationships of source contributions with emissions inventories were explored with regression analysis. A new trajectory model, differential concentration-weighted trajectories (DCWT), was used to examine spatial changes in sources of secondary aerosol affecting the rural sites.

Masiol, Mauro, et al. "Long-term trends (2005–2016) of source apportioned PM2. 5 across New York State." Atmospheric Environment 201 (2019): 110-120.

PM2.5 source apportionment for the port city of Thessaloniki, Greece

This paper aims to identify the chemical fingerprints of potential PM2.5 sources and estimate their contribution to Thessaloniki port-city's air quality. For this scope, Positive Matrix Factorization model was applied on a comprehensive PM2.5 dataset collected over a one-year period, at two sampling sites: the port and the city center. The model indicated six and five (groups of) sources contributing to particle concentration at the two sites, respectively. Traffic and biomass burning (winter months) comprise the major local PM sources for Thessaloniki (their combined contribution can exceed 70%), revealing two of the major control-demanding problems of the city. Shipping and in-port emissions have a non-negligible impact (average contribution to PM2.5: 9–13%) on both primary and secondary particles. Road dust factor presents different profile and contribution at the two sites (19.7% at the port; 7.4% at the city center). The secondary-particle factor represents not only the aerosol transportation over relatively long distances, but also a part of traffic-related pollution (14% at the port; 34% at the city center). The study aims to contribute to the principal role of quantitative information on emission sources (source apportionment) in port-cities for the implementation of the air quality directives and guidelines for public health.

Saraga, Dikaia E., et al. "PM2. 5 source apportionment for the port city of Thessaloniki, Greece." Science of The Total Environment 650 (2019): 2337-2354.

The contribution of the Beijing, Tianjin and Hebei region's iron and steel industry to local air pollution in winter

The Beijing, Tianjin and Hebei region (BTH) in China is a highly populated area that has recently experienced frequent haze episodes in winter. With high production capacities, the iron and steel industry (ISI) has long been

a key source of air pollutants in BTH and is thus considered responsible for the degradation of local air quality. Here, we conducted a cross-disciplinary research combining the Weather Research and Forecasting with Chemistry (WRF/Chem) model, the multiregional input-output model (MRIO) and the health assessment model to explore the impacts of the ISI on air pollution in the BTH region in January 2012. Our results show large increases in air pollution due to direct ISI emissions, with up to a 90 μg/m3 monthly average of fine particulate matter (PM2.5) and sulfur dioxide (SO2) in eastern Tangshan and western Handan. In addition to direct emissions, the ISI has induced large quantities of indirect emissions from upstream sectors (e.g., the electricity and transportation sectors), leading to PM2.5, SO2 and NOx increases of 2–10 μg/m3 in BTH. Considering the direct and indirect emissions, we estimated that 275 (233–313) PM2.5-related mortalities occurred in January, and approximately 42% of these premature deaths occurred in Tangshan. A high rate of premature deaths also occurred in urban Beijing due to its high population density. Revealing the great health burden caused by the ISI, our results underscore the necessity for the Chinese government to reduce air pollutant emissions from the ISI and its upstream industries in BTH.

Yang, Haozhe, et al. "The contribution of the Beijing, Tianjinand Hebeiregion's iron and steel industry to local air pollution in winter." Environmental Pollution 245 (2019): 1095-1106.

Air pollution reduction in China: Recent success but great challenge for the future

China's rapid economic growth has caused severe air pollution, raising serious concerns about the growing evidence of its negative health, environmental, and economic impacts. Consequently, the Chinese government has implemented a number of policies and measures to reduce air pollution. Relying on published information over the last three decades in China, we analyzed trends in air pollutant emissions (SO2 and NOx) and concentrations of particulate matter (PM) and ozone (O3). During the past decade, SO2 and NOx emissions had declined throughout China and concentrations of PM2.5 and PM10 had considerably decreased in most cities, but average reported 90th MDA8 O3, M7, and AOT40 O3 for 31 capital cities showed an increasing trend between 2013 and 2017. Despite progress in air pollution reduction and an increasing number of “clear sky” days, PM concentrations throughout China remain higher than the World Health Organization guidelines, and urban smog and haze remain a major threat to human health and the environment. Thus far, significant emission reductions have occurred largely through robust administrative power, especially when emission reductions were tied to the performance evaluations and promotion of government officials. Similar to most already-industrialized nations, China is now shifting away from SO2-dominated to NOx- and O3-dominated air pollution. Existing technologies and improved operations of existing control equipment appear unlikely to achieve sufficient reductions in NOx and O3 pollution. Considering the complex relationship between O3, NOx, VOCs, weather, and socio-economic changes in China, it is necessary to increase research on impacts of increasing ozone on plants and to adopt novel technologies and implemented to further reduce air pollution to levels that will protect human health and the environment.

Zeng, Yingying, et al. "Air pollution reduction in China: Recent success but great challenge for the future." Science of The Total Environment 663 (2019): 329-337.

SLCPs & Vulnerable Regions

Description: This section includes articles addressing SLCP impacts on vulnerable regions or studies discussing the specific vulnerabilities of regions to SLCPs.

Warming Effects of Spring Rainfall Increase Methane Emissions From Thawing Permafrost

Methane emissions regulate the near-term global warming potential of permafrost thaw, particularly where loss of ice-rich permafrost converts forest and tundra into wetlands. Northern latitudes are expected to get warmer and wetter, and while there is consensus that warming will increase thaw and methane emissions, effects of increased precipitation are uncertain. At a thawing wetland complex in Interior Alaska, we found that interactions between rain and deep soil temperatures controlled methane emissions. In rainy years, recharge from the watershed rapidly altered wetland soil temperatures, warming the top ~80 cm of soil in spring and

summer and cooling it in autumn. When soils were warmed by spring rainfall, methane emissions increased by ~30%. The warm, deep soils early in the growing season likely supported both microbial and plant processes that enhanced emissions. Our study identifies an important and unconsidered role of rain in governing the radiative forcing of thawing permafrost landscapes.

Neumann, Rebecca B., et al. "Warming effects of spring rainfall increase methane emissions from thawing permafrost." Geophysical Research Letters 46.3 (2019): 1393-1401.

Factors controlling the long-term (2009–2015) trend of PM2.5 and black carbon aerosols at eastern Himalaya, India

A first-ever long-term (2009–2015) study on the fine particulate matter (PM2.5) and black carbon (BC) aerosol were conducted over Himalaya in order to investigate the characteristics, temporal variations and the important factors regulating the long-term trend. The study was conducted over a high altitude station, Darjeeling (27°01′ N, 88°15′E, 2200 m asl) representing a typical high altitude urban atmosphere at eastern Himalaya in India. The average concentrations of PM2.5 and BC over a period of seven years were 25.2 ± 5.6 μg m−3 (ranging between 2.2 and 220.4 μg m−3) and 3.4 ± 0.7 μg m−3 (0.4 to 15.6 μg m−3) respectively. We observed decreasing trends in both PM2.5 (49% at a rate of 170 ng m−3 month−1) and BC (34% at the rate of 20 ng m−3 month−1) mass concentration over this region from 2009 to 2015. We extensively studied the impact of micrometeorological parameters on the long-term trend in PM2.5 and BC through the correlation analysis. The significant changes in boundary layer dynamics over this region played a major role in the decreasing trend of aerosols. The concentration weighted trajectory analysis revealed that the important contributory long-distant source regions for PM2.5 and BC over eastern Himalaya were Indo Gangetic Plane and Nepal. The contributions from these regions were found to be decreased significantly from 2009 to 2015. Investigations on the fire counts associated with the forest fire, and open burning activities through the satellite observations revealed that the decreasing trend in PM2.5 and BC over eastern Himalaya is well correlated to the decreasing trend in the fire counts over IGP and Nepal. We also explored that the changes and up gradation of the domestic fuel at the Indo Gangetic Plane regions in recent years not only improved the regional air quality but also affected the atmospheric environment over the eastern part of Himalaya.

Sarkar, Chirantan, et al. "Factors controlling the long-term (2009–2015) trend of PM2. 5 and black carbon aerosols at eastern Himalaya, India." Science of The Total Environment 656 (2019): 280-296.

Evaluating Recent Updated Black Carbon Emissions and Revisiting the Direct Radiative Forcing in Arctic

There is significant uncertainty in the global inventory of black carbon (BC). Several recent studies have reported BC emission updates, including the Fire Emission Inventory‐northern Eurasia, anthropogenic emission in Russia, and global natural gas flaring. Compared with the inventory used by Intergovernmental Panel on Climate Change, these updates are only 10% higher on a global scale but are 3 times greater than previous estimations in Arctic (60–90°N). We applied GEOS‐Chem to examine these emission updates and evaluate their impacts on direct forcing. We found that Fire Emission Inventory‐northern Eurasia may be substantially overestimated, Russia shows no prominent influence on simulation, and natural gas flaring noticeably improves simulation performance in the Arctic. Model estimated direct forcing of BC is increased by 30% on the global scale and is 2 times higher in the Arctic through application of these emission updates. This study reveals the urgent need to improve the reliability of emission inventories in the high latitudes, especially over Eurasia.

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