

SHORT-LIVED CLIMATE POLLUTANT RESEARCH DIGEST

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CLIMATE POLLUTANTS

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Short-Lived Climate Pollutants (SLCPs)

Description: This is a cross-cutting section which includes articles which specifically focus on SLCPs as a category of emissions and/or measures

Laser absorption spectroscopy applied to monitoring of short-lived climate pollutants (SLCPs)

Enhanced mitigation of short-lived climate pollutants (SLCPs) has been recently paid more attention in order to provide more sizeable short-term reductions of global warming effects over the next several decades. We overview in this article our recent progress in the development of spectroscopic instruments for optical monitoring of major SLCPs based on laser absorption spectroscopy. Methane (CH₄) and black carbon (BC) are the most important SLCPs contributing to the human enhancement of the global greenhouse effect after CO₂. We present optical sensing of these two climate-change related atmospheric species to illustrate how “classical” spectroscopy can help to address today’s challenging issues: (1) Photoacoustic measurements of BC optical absorption coefficient in order to determine its radiative-forcing related optical parameters (such as mass absorption coefficient, absorption Ångström coefficient) with higher precision (~7.4% compared to 12–30% for filter-based methods routinely used nowadays). The 1 σ (SNR = 1) minimum measurable volumetric mass density of 21 ng/m³ (in 60 s) for black carbon. (2) Direct absorption spectroscopy-based monitoring of methane (CH₄) in field campaign to identify pollution source in conjunction with air mass back-trajectory modeling. Using a White-type multipass cell (an effective path-length of 175 m), a 1 σ detection limit of 33.3 ppb in 218 s was achieved with a relative measurement precision of 1.1% and an overall measurement uncertainty of about 5.1%. Performance of the custom, lab-based instruments (in terms of detection limits, measurement precision, temporal response, etc.), spectroscopic measurement aspects, experimental details, spectral data processing, analysis and modeling of the observed environmental episode will be presented and discussed.

Wang, G., Shen, F., Yi, H., Hubert, P., Deguine, A., Petitprez, D., Maamary, R., Augustin, P., Fourmentin, M., Fertein, E. and Sigrist, M.W., 2018. Laser absorption spectroscopy applied to monitoring of short-lived climate pollutants (SLCPs). Journal of Molecular Spectroscopy, 348, pp.142-151.

Effective Radiative Forcing and Climate Response to Short-Lived Climate Pollutants Under Different Scenarios

We used an online aerosol-climate model (BCC_AGCM2.0_CUACE/Aero) to simulate effective radiative forcing and climate response to changes in the concentrations of short-lived climatic pollutants (SLCPs), including methane, tropospheric ozone, and black carbon, for the period 2010–2050 under Representative Concentration Pathway scenarios (RCPs) 8.5, 4.5, and 2.6. Under these three scenarios, the global annual mean effective radiative forcing were 0.1, -0.3, and -0.5 W m⁻², respectively. Under RCP 8.5, the change in SLCPs caused significant increases in surface air temperature (SAT) in middle and high latitudes of the Northern Hemisphere and significant decreases in precipitation in the Indian Peninsula and equatorial Pacific. Global mean SAT and precipitation increased by 0.13 K and 0.02 mm d⁻¹, respectively. The reduction in SLCPs from 2010 to 2050 under RCPs 4.5 and 2.6 led to significant decreases in SAT at high latitudes in the Northern Hemisphere. Precipitation increased slightly in most continental regions, and the Intertropical Convergence Zone moved southward under both of these mitigation scenarios. Global mean SAT decreased by 0.20 and 0.44 K, and global averaged precipitation decreased by 0.02 and 0.03 mm d⁻¹ under RCPs 4.5 and 2.6, respectively.

Zhang, H., Xie, B. and Wang, Z., 2018. Effective radiative forcing and climate response to short-lived climate pollutants under different scenarios. Earth's Future, 6(6), pp.857-866.

Multiple Benefits

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

Potential health and economic benefits of banning diesel traffic in Dublin, Ireland

Air pollution has been linked to 491,000 deaths in Europe annually and diesel vehicles are one of the major sources of two deadly air pollutants, PM_{2.5} (Particulate Matter) and NO_x (Oxides of Nitrogen). Ireland has the highest number of newly registered diesel vehicles in Europe with a share of 43.57% in the overall fleet which is expected to increase to 73.9% by 2025. This will have significant health and financial impacts, especially in the urban areas. The present study quantifies the environmental, financial and health burdens from cars, Light Commercial Vehicles (LCVs) and buses in Dublin under the existing conditions and estimates the potential impact of the increasing numbers of diesel cars, LCVs and buses following the current trend projected over the next decade. As a preventative measure, the present study examines the impact of banning diesel vehicles older than 20 years from 2018 through the initiation of a phase-out policy. Furthermore, the impacts of a policy to ban new diesel vehicle sales from the year 2025 is also estimated. In both future scenarios, the preventative measures show significant savings in terms of reductions in NO_x and PM_{2.5} emissions which were found to be 47% and 52% respectively in the year 2030 compared to the year 2015 levels. Additionally, this reduction will amount to savings of 300 DALYs and €43.8 million. Consequently, the results of this study make a strong case for policies and investments aimed at reducing the environmental impact caused by urban transportation and improving public health.

Dey, S., Caulfield, B. and Ghosh, B., 2018. Potential health and economic benefits of banning diesel traffic in Dublin, Ireland. Journal of Transport & Health.

Estimating health and economic benefits of reductions in air pollution from agriculture

Agricultural ammonia emissions strongly contribute to fine particulate air pollution (PM_{2.5}) with significant impacts on human health, contributing to mortality. We used model calculated emission scenarios to examine the health and economic benefits accrued by reducing agricultural emissions. We applied the “value of statistical life” metric to monetize the associated health outcomes. Our analysis indicates that a 50% reduction in agricultural emissions could prevent > 200 thousand deaths per year in the 59 countries included in our study, notably in Europe, Russia, Turkey, the US, Canada and China, accompanied with economic benefits of many billions US\$. In the European Union (EU) mortality could be reduced by 18% with an annual economic benefit of 89 billion US\$. A theoretical complete phase-out of agricultural emissions could lead to a reduction in PM_{2.5} related mortality of > 50% plus associated economic costs in 42 out of the 59 countries studied. Within the EU, 140 thousand deaths could be prevented per year with an associated economic benefit of about 407 billion US\$/year. A cost-benefit assessment of ammonia emission abatement options for the EU indicates that the reduction of agricultural emissions generates net financial and social benefits. The monetization of the health benefits of air pollution abatement policies and the costs of implementation can help devise cost-effective air quality management strategies.

Giannadaki, D., Giannakis, E., Pozzer, A. and Lelieveld, J., 2018. Estimating health and economic benefits of reductions in air pollution from agriculture. Science of the Total Environment, 622, pp.1304-1316.

Health and economic benefits of building ventilation interventions for reducing indoor PM_{2.5} exposure from both indoor and outdoor origins in urban Beijing, China

China is confronted with serious PM_{2.5} pollution, especially in the capital city of Beijing. Exposure to PM_{2.5} could lead to various negative health impacts including premature mortality. As people spend most of their time indoors, the indoor exposure to PM_{2.5} from both indoor and outdoor origins constitutes the majority of personal exposure to PM_{2.5} pollution. Different building interventions have been introduced to mitigate indoor PM_{2.5} exposure, but always at the cost of energy expenditure. In this study, the health and economic benefits

of different ventilation intervention strategies for reducing indoor PM_{2.5} exposure are modeled using a representative urban residence in Beijing, with consideration of different indoor PM_{2.5} emission strengths and outdoor pollution. Our modeling results show that the increase of envelope air-tightness can achieve significant economic benefits when indoor PM_{2.5} emissions are absent; however, if an indoor PM_{2.5} source is present, the benefits only increase slightly in mechanically ventilated buildings, but may show negative benefit without mechanical ventilation. Installing mechanical ventilation in Beijing can achieve annual economic benefits ranging from 200yuan/capita to 800yuan/capita if indoor PM_{2.5} sources exist. If there is no indoor emission, the annual benefits above 200yuan/capita can be achieved only when the PM_{2.5} filtration efficiency is no <90% and the envelope air-tightness is above Chinese National Standard Level 7. Introducing mechanical ventilation with low PM_{2.5} filtration efficiency to current residences in urban Beijing will increase the indoor PM_{2.5} exposure and result in excess costs to the residents.

Yuan, Y., Luo, Z., Liu, J., Wang, Y. and Lin, Y., 2018. Health and economic benefits of building ventilation interventions for reducing indoor PM 2.5 exposure from both indoor and outdoor origins in urban Beijing, China. Science of the Total Environment, 626, pp.546-554.

PM_{2.5} mitigation in China: Socioeconomic determinants of concentrations and differential control policies

Elucidating the key impact factors on PM_{2.5} concentrations is crucial to formulate effective mitigation policies. In this study, we employed an extended Stochastic Impacts by Regression on Population Affluence and Technology (STIRPAT) model to identify the socioeconomic determinants of PM_{2.5} concentrations for 12 different regions and across China. The evaluation was based on a balanced panel dataset integrating long-term satellite-derived PM_{2.5} concentrations and socio-economic data in China from 1999 to 2011. Empirical results indicate that the influencing factors can be ranked in descending order of importance as: proportion of secondary sector of the economy, GDP per capita, urbanization, population, energy intensity, and proportion of tertiary sector. Proportion of secondary sector is the greatest contribution to increasing PM_{2.5} concentrations, especially for heavily polluted regions. GDP per capita is secondary in importance, and its impact is weakened by the existence of an EKC relationship between GDP per capita and PM_{2.5} concentrations. Therefore, PM_{2.5} pollution is an economic development mode problem, rather than a general economic development problem. The impact of urbanization varies across regions; while promoting urbanization will be conducive to decreased PM_{2.5} concentrations in Northwest China and Northeast China, it will contribute to increased PM_{2.5} concentrations in other regions. Population and energy intensity are significant in most regions, but neither are decisive factors because of the small absolute value of their coefficients. Finally, different combinations of mitigation policies are proposed for different regions in this study to meet the mitigation targets.

Luo, K., Li, G., Fang, C. and Sun, S., 2018. PM 2.5 mitigation in China: Socioeconomic determinants of concentrations and differential control policies. Journal of environmental management, 213, pp.47-55.

Spatiotemporal Assessment of PM_{2.5}-Related Economic Losses from Health Impacts during 2014–2016 in China

Background: Particulate air pollution, especially PM_{2.5}, is highly correlated with various adverse health impacts and, ultimately, economic losses for society, however, few studies have undertaken a spatiotemporal assessment of PM_{2.5}-related economic losses from health impacts covering all of the main cities in China. Methods: PM_{2.5} concentration data were retrieved for 190 Chinese cities for the period 2014–2016. We used a log-linear exposure–response model and monetary valuation methods, such as value of a statistical life (VSL), amended human capital (AHC), and cost of illness to evaluate PM_{2.5}-related economic losses from health impacts at the city level. In addition, Monte Carlo simulation was used to analyze uncertainty. Results: The average economic loss was 0.3% (AHC) to 1% (VSL) of the total gross domestic product (GDP) of 190 Chinese cities from 2014 to 2016. Overall, China experienced a downward trend in total economic losses over the three-year period, but the Beijing–Tianjin–Hebei, Shandong Peninsula, Yangtze River Delta, and Chengdu–Chongqing regions experienced greater annual economic losses. Conclusions: Exploration of spatiotemporal variations in PM_{2.5}-related economic losses from long-term health impacts could provide new information for policymakers regarding

priority areas for PM_{2.5} pollution prevention and control in China.

Yang, Y., Luo, L., Song, C., Yin, H. and Yang, J., 2018. Spatiotemporal Assessment of PM_{2.5}-Related Economic Losses from Health Impacts during 2014–2016 in China. *International journal of environmental research and public health*, 15(6).

Methane

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

Developing emission factors for dairy cow enteric fermentation in Korea

We developed emission factors for dairy cow enteric fermentation in Korea, along with their uncertainties. A total of 30 dairy cow farms were randomly chosen from the 3500 possible farms, then data on the number of heads, their body weights, the amount of feed intake, and the feed composition were collected. Statistical analysis of the methane conversion factor (Y_m) and gross energy (GE) data showed that the emission factor for the enteric fermentation of a cow should be estimated using three different body weight classes (equivalent to the growth phases). The EF values for the three classes, A, B, and C in this study were greater than those recommended by the 2006 IPCC guideline by 2.3%, 78.5%, and 7.6%, respectively. The Monte Carlo simulation (MCS) and bootstrap method were used to estimate emission factor uncertainty, and the results showed that the bootstrap method gave smaller confidence interval (CI) width and a smaller percentage uncertainty (U). Treating Y_m as constant leads to underestimation of the uncertainty of the emission factors, compared to treating Y_m as a random variable. Thus, estimation of the emission factors and their uncertainties should be based on an emission factor calculation model where both Y_m and GE are treated as random variables.

Lee, J.Y., Lee, M.H., Lee, J.S., Chun, Y.Y., Kim, K.H., Kim, M.S. and Lee, K.M., 2018. Developing emission factors for dairy cow enteric fermentation in Korea. *Journal of Cleaner Production*, 198, pp.754-762.

On the systematic underestimation of methane conversion factors in IPCC guidance

This paper documents a systematic underestimation in how the Tier 2 methane conversion factors (MCF) are calculated in IPCC (2006) guidelines for liquid manure management. The first issue is the use of annual average temperature as an input to a non-linear function describing methane production. As expected based on Jensen's inequality, the MCF calculated based on annual average temperature is always an underestimate. In regions with large intra-annual temperature ranges, such as temperate climates, the underestimation can exceed 30%. A second issue is the lack of consideration for volatile solids retention time. Future updates to the IPCC methodology should therefore account for intra-annual temperature regime and retention time—not simply annual average temperature.

VanderZaag, A.C., 2018. On the systematic underestimation of methane conversion factors in IPCC guidance. *Waste Management*, 75, pp.499-502.

The combustion mitigation of methane as a non-CO₂ greenhouse gas

Anthropogenic emissions of non-CO₂ greenhouse gases such as fugitive methane contribute significantly to global warming. A review of fugitive methane combustion mitigation and utilisation technologies, which are primarily aimed at methane emissions from coal mining activities, with a focus on modelling and simulation of ultra-lean methane oxidation/combustion is presented. The challenges associated with ultra-lean methane oxidation are on the ignition of the ultra-lean mixture and sustainability of the combustion process. There is a lack of fundamental studies on chemical kinetics of ultra-lean methane combustion and reliable kinetic schemes

that can be used together with computational fluid dynamics studies to design and develop advanced mitigation systems. Mitigation of methane as a greenhouse gas calls for more efforts on understanding ultra-lean combustion. Recuperative combustion provides a promising means for mitigating ultra-lean methane emissions. Progress is needed on effective methods to ignite and to recuperate and retain heat for oxidation/combustion of the ultra-lean mixtures. Catalysts can be very effective in reducing the temperatures required for oxidation while plasmas may be utilised to assist the ignition, but thermodynamic/aerodynamic limits of burning ultra-lean methane remain unexplored. Further technological developments may be focussed on developing innovative capturing technology as well as technological innovations to achieve effective ignition and sustainable oxidation/combustion.

Jiang, X., Mira, D. and Cluff, D.L., 2018. The combustion mitigation of methane as a non-CO2 greenhouse gas. Progress in Energy and Combustion Science, 66, pp.176-199.

Evaluating year-to-year anomalies in tropical wetland methane emissions using satellite CH₄ observations

Natural wetlands are the largest source of methane emissions, contributing 20–40% of global emissions and dominating the inter-annual variability. Large uncertainties remain on their variability and response to climate change.

This study uses atmospheric methane observations from the GOSAT satellite to evaluate methane wetland emission estimates. We assess how well simulations reproduce the observed methane inter-annual variability by evaluating the detrended seasonal cycle. The latitudinal means agree well but maximum differences in the tropics of 28.1–34.8 ppb suggest that all simulations fail to capture the extent of the tropical wetland seasonal cycle.

We focus further analysis on the major natural wetlands in South America: the seasonally flooded savannah of the Pantanal (Brazil) and Llanos de Moxos (Bolivia) regions; and the riverine wetlands formed by the Paraná River (Argentina). We see large discrepancies between simulation and observation over the Pantanal and Llanos de Moxos region in 2010, 2011 and 2014 and over the Paraná River region in 2010 and 2014. We find highly consistent behaviour between the time and location of these methane anomalies and the change in wetland extent, driven by precipitation related to El Niño Southern Oscillation activity.

We conclude that the inability of land surface models to increase wetland extent through overbank inundation is the primary cause of these observed discrepancies and can lead to under-estimation of methane fluxes by as much as 50% (5.3–11.8 Tg yr⁻¹) of the observed emissions for the combined Pantanal and Paraná regions. As the hydrology of these regions is heavily linked to ENSO variability, being able to reproduce changes in wetland behaviour is important for successfully predicting their methane emissions.

Parker, R.J., Boesch, H., McNorton, J., Comyn-Platt, E., Gloor, M., Wilson, C., Chipperfield, M.P., Hayman, G.D. and Bloom, A.A., 2018. Evaluating year-to-year anomalies in tropical wetland methane emissions using satellite CH₄ observations. Remote Sensing of Environment, 211, pp.261-275.

Street-level emissions of methane and nitrous oxide from the wastewater collection system in Cincinnati, Ohio

Recent studies have indicated that urban streets can be hotspots for emissions of methane (CH₄) from leaky natural gas lines, particularly in cities with older natural gas distribution systems. The objective of the current study was to determine whether leaking sewer pipes could also be a source of street-level CH₄ as well as nitrous oxide (N₂O) in Cincinnati, Ohio, a city with a relatively new gas pipeline network. To do this, we measured the carbon ($\delta^{13}\text{C}$) and hydrogen ($\delta^2\text{H}$) stable isotopic composition of CH₄ to distinguish between biogenic CH₄ from sewer gas and thermogenic CH₄ from leaking natural gas pipelines and measured CH₄ and N₂O flux rates and concentrations at sites from a previous study of street-level CH₄ enhancements (77 out of 104 sites) as well as additional sites found through surveying sewer grates and utility manholes (27 out of 104 sites). The average isotopic signatures for $\delta^{13}\text{C}\text{-CH}_4$ and $\delta^2\text{H}\text{-CH}_4$ were $-48.5\text{‰} \pm 6.0\text{‰}$ and $-302\text{‰} \pm 142\text{‰}$. The measured flux rates ranged from 0.0 to 282.5 mg CH₄ day⁻¹ and 0.0–14.1 mg N₂O day⁻¹ (n = 43). The average CH₄ and N₂O concentrations measured in our study were 4.0 ± 7.6 ppm and 392 ± 158 ppb, respectively (n = 104). 72% of

sites where fluxes were measured were a source of biogenic CH₄. Overall, 47% of the sampled sites had biogenic CH₄, while only 13% of our sites had solely thermogenic CH₄. The other sites were either a source of both biogenic and thermogenic CH₄ (13%), and a relatively large portion of sites had an unresolved source (29%). Overall, this survey of emissions across a large urban area indicates that production and emission of biogenic CH₄ and N₂O is considerable, although CH₄ fluxes are lower than those reported for cities with leaky natural gas distribution systems.

Fries, A.E., Schiffman, L.A., Shuster, W.D. and Townsend-Small, A., 2018. Street-level emissions of methane and nitrous oxide from the wastewater collection system in Cincinnati, Ohio. Environmental Pollution, 236, pp.247-256.

On methane emissions from shale gas development

Environmental and economic impacts of methane escaping from the natural gas supply chain remain uncertain. Flowback emissions from hydraulically fractured natural gas wells are a key component of emissions from unconventional gas wells. While reduced emission completions in the United States are required by regulation, Canada's proposed regulation will only be implemented in 2020 with the two highest producing provinces under exemption. To understand potential benefits of regulations, we use predictive modelling of well-level production data of 1633 hydraulically fractured shale gas wells in five plays to estimate pre-production emissions. The mean estimate for flowback emissions (2346 ± 95% confidence interval of 91 Mg CO₂e/completion) fall within the 95% confidence limits of measured potential emissions (2566 ± 777 Mg CO₂e/completion). Our results indicate that in 2015, the average emissions per shale gas well undergoing flowback was 2347 Mg CO₂e/completion in the U.S. and 1859 Mg CO₂e/completion in Canada. Mean potential profits from controlling methane emissions using reduced emission completions were US\$17,200/well in the U.S. and US\$11,200/well in Canada.

Umeozor, E.C., Jordaan, S.M. and Gates, I.D., 2018. On methane emissions from shale gas development. Energy, 152, pp.594-600.

Black Carbon

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

Brown and Black Carbon Emitted by a Marine Engine Operated on Heavy Fuel Oil and Distillate Fuels: Optical Properties, Size Distributions, and Emission Factors

We characterized the chemical composition and optical properties of particulate matter (PM) emitted by a marine diesel engine operated on heavy fuel oil (HFO), marine gas oil (MGO), and diesel fuel (DF). For all three fuels, ~80% of submicron PM was organic (and sulfate, for HFO at higher engine loads). Emission factors varied only slightly with engine load. Refractory black carbon (rBC) particles were not thickly coated for any fuel; rBC was therefore externally mixed from organic and sulfate PM. For MGO and DF PM, rBC particles were lognormally distributed in size (mode at drBC ≈ 120 nm). For HFO, much larger rBC particles were present. Combining the rBC mass concentrations with in situ absorption measurements yielded an rBC mass absorption coefficient MAC_{BC,780nm} of 7.8 ± 1.8 m²/g at 780 nm for all three fuels. Using positive deviations of the absorption Ångström exponent (AAE) from unity to define brown carbon (brC), we found that brC absorption was negligible for MGO or DF PM (AAE(370,880 nm) ≈ 1.0 ± 0.1) but typically 50% of total 370-nm absorption for HFO PM. Even at 590 nm, ~20% of the total absorption was due to brC. Using absorption at 880 nm as a reference for BC absorption and normalizing to organic PM mass, we obtained a MAC_{OM,370nm} of 0.4 m²/g at typical operating conditions. Furthermore, we calculated an imaginary refractive index of (0.045 ± 0.025)(λ/370nm)⁻³ for HFO PM at 370 nm > λ > 660 nm, more than twofold greater than previous

recommendations. Climate models should account for this substantial brC absorption in HFO PM.

Corbin, J.C., Pieber, S.M., Czech, H., Zanatta, M., Jakobi, G., Massabo, D., Orasche, J., El Haddad, I., Mensah, A.A., Stengel, B. and Drinovec, L., 2018. Brown and black carbon emitted by a marine engine operated on heavy fuel oil and distillate fuels: optical properties, size distributions, emission factors. Journal of Geophysical Research: Atmospheres.

Long-term black carbon variation in the South-Eastern Baltic Region in 2008–2015

Long-term continuous measurement data of equivalent black carbon (eBC) concentration over a period of 8 years (2008–2015) from the coastal – background site in Preila, Lithuania, have been analysed. The analysis performed with Preila data has shown that the average mean of eBC concentration was 750 ng/m³. A seasonal pattern was also observed with the highest eBC values (1170 ng/m³) in winter gradually declining to the minimum concentration (380 ng/m³) in summer. The frequency distribution of the data was fitted with lognormal modes. Cold and warm seasons were parameterised with three and two modes, respectively. Both the parametric and non-parametric trend analysis methods were applied in this research. A positive annual linear trend for the whole period was estimated to range from +1.97% to +5.35% per year. However, the second order trend had a maximum in 2013 and was declining during the last years of the analysed period, or, according to the t-test, had any statistically significant trend. Regional and long-range emissions of coal and biomass combustion are the main sources of the observed eBC in the Preila station during the cold seasons. This study presents the current situation of black carbon trends in the Baltic Sea region and will be helpful for assessing the policies of black carbon emissions in Europe.

Davulienė, L., Sakalys, J., Dudoitis, V., Reklaitė, A. and Ulevičius, V., 2018. Long-term black carbon variation in the South-Eastern Baltic Region in 2008–2015. Atmospheric Pollution Research.

An observational study on the variation of black carbon aerosol and source identification over a tropical station in south India

Continuous and high temporal resolution surface based measurements of Black Carbon (BC) concentrations have been carried out during 1st September 2014 to 30th April 2017 at Thiruvananthapuram (8.5°N, 76.9°E), a near equatorial tropical coastal station, in South India. High diurnal and seasonal variations of BC aerosols in relation to changes in the regional meteorological conditions are examined. The BC exhibited well defined diurnal cycle with a bimodal peak one in the morning (07.00–08.00 LST) and other in evening (21.00–23.00 LST). Relative humidity of 60–90% and 70–90% favours the BC mass concentration in daytime and nighttime respectively. BC mass concentration is considerably less for the relative humidity category of 90–100%. BC greater than 10 µg m⁻³ are mostly associated with low wind speed (less than 2 ms⁻¹). Hence the local BC emissions are not well mixed or transported to a larger distance in calm or low wind speed. In high wind speed local emissions are quickly and well mixed in the air. Coherence wavelet analysis between BC and rainfall shows periodicities in the synoptic scale of less than 10 days and in the between 16–32 days. This shows the importance of intra seasonal rainfall scavenging on BC concentration over the tropical region. Synoptic systems over the monsoon region shows high scavenging relation. The bivariate analysis pointed that the local emission from northeast sector contributes the black carbon aerosol to the observational site. HYSPLIT trajectory model reveals that the long range transport of air mass is through northwest India and Bay of Bengal in winter season.

Rajeevan, K., Sumesh, R.K., Resmi, E.A. and Unnikrishnan, C.K., 2018. An observational study on the variation of black carbon aerosol and source identification over a tropical station in south India. Atmospheric Pollution Research.

Local and remote black carbon sources in the Metropolitan Area of Buenos Aires

Equivalent black carbon (EBC) mass concentrations in the fine inhalable fraction of airborne particles (PM_{2.5}) were determined using a 7-wavelength Aethalometer for 17 months, between November 2014 and March 2016, for a suburban location of the Metropolitan Area of Buenos Aires (MABA), Argentina. In addition to describing seasonal and diurnal black carbon (BC) cycles for the first time in this region, the relative contributions of fossil

fuel and remote and local biomass burning were determined by distinguishing different carbonaceous components based on their effect on light attenuation for different wavelengths. Trajectory analyses and satellite-based fire products were used to illustrate the impact of long-range transport of particles emitted by non-local sources. EBC data showed a marked diurnal cycle, largely modulated by traffic variations and the height of the boundary layer, and a seasonal cycle with monthly median EBC concentrations (in) ranging from 1.5 (February) to 3.4 (June). Maximum values were found during winter due to the combination of prevailingly stable atmospheric conditions and the increase of fossil fuel emissions, derived primarily from traffic and biomass burning from the domestic use of wood for heating. The use of charcoal grills was also detected and concentrated during weekends. The average contribution of fossil fuel combustion sources to EBC concentrations was 96%, with the remaining 4% corresponding to local and regional biomass burning. During the entire study period, only two events were identified during which EBC concentrations attributed to regional biomass burning accounted for over 50% of total EBC; these events demonstrate the relevance of agricultural and forestry activities that take place far from the city yet whose emissions can affect the urban atmosphere of the MABA.

Resquin, M.D., Santágata, D., Gallardo, L., Gómez, D., Rössler, C. and Dawidowski, L., 2018. Local and remote black carbon sources in the Metropolitan Area of Buenos Aires. Atmospheric Environment, 182, pp.105-114.

Enhanced light absorption due to the mixing state of black carbon in fresh biomass burning emissions

A lack of information on the radiative effects of refractory black carbon (rBC) emitted from biomass burning is a significant gap in our understanding of climate change. A custom-made combustion chamber was used to simulate the open burning of crop residues and investigate the impacts of rBC size and mixing state on the particles' optical properties. Average rBC mass median diameters ranged from 141 to 162 nm for the rBC produced from different types of crop residues. The number fraction of thickly-coated rBC varied from 53 to 64%, suggesting that a majority of the freshly emitted rBC were internally mixed. By comparing the result of observed mass absorption cross-section to that calculated with Mie theory, large light absorption enhancement factors (1.7–1.9) were found for coated particles relative to uncoated cores. These effects were strongly positively correlated with the percentage of coated particles but independent of rBC core size. We suggest that rBC from open biomass burning may have strong impact on air pollution and radiative forcing immediately after their production.

Wang, Q., J. Cao, Y. Han, J. Tian, Y. Zhang, S. Pongpiachan, Y. Zhang, L. Li, X. Niu, Z. Shen, Z. Zhao, D. Tipmanee, S. Bunsomboonsakul, Y. Chen, J. Sun, 2018. Enhanced light absorption due to the mixing state of black carbon in fresh biomass burning emissions. Atmospheric Environment, 180, pp. 184-191.

Tropospheric Ozone

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

Impacts of enhanced fertilizer applications on tropospheric ozone and crop damage over sub-Saharan Africa

Fertilizer-induced nitrogen oxides (NO_x) emissions in sub-Saharan Africa are expected to increase substantially in the coming decades, driven by increasing application of fertilizers to increase crop yields in an effort to attain food security across the continent. In many parts of sub-Saharan Africa, surface ozone (O₃) is sensitive to increasing atmospheric concentrations of NO_x. In this study, we employ the GEOS-Chem chemical transport model to conduct a preliminary investigation of the impacts on O₃ air quality and the consequential crop damage associated with increasing fertilizer-induced NO_x emissions in sub-Saharan Africa. Our simulation results, constrained by field NO flux measurements for the years 2011 and 2012 in response to a variety of fertilizer

application rates in western Kenya, show that the enhancements in NO flux with fertilizer application rate of 150 kg N ha⁻¹ can increase surface NO_x and O₃ concentrations by up to 0.36 and 2.8 ppbv respectively during the growing season. At the same time, accumulated O₃ exposure during the crop growing season (expressed as AOT40 values) could increase by up to 496 ppb h, leading to crop yield decline of about 0.8% for O₃-sensitive crops. Our results suggest that, when accounting for the consequential impacts on surface O₃ air quality and crop damage over sub-Saharan Africa, agricultural intensification is possible without substantial impacts on crop productivity because the relatively small decline of crop yield resulting from O₃ damage appears unlikely to outweigh the gain in crop yield from fertilization.

Huang, Y., Hickman, J.E. and Wu, S., 2018. Impacts of enhanced fertilizer applications on tropospheric ozone and crop damage over sub-Saharan Africa. *Atmospheric Environment*, 180, pp.117-125.

Hydrofluorocarbons (HFCs)

Description: This section includes articles addressing hydrofluorocarbon emissions, relevant new information about use sectors, alternative refrigerants and relevant analysis of energy efficiency.

Infrared absorption cross-sections, radiative efficiency and global warming potential of HFC-43-10mee

HFC-43-10mee (C₅H₂F₁₀) is a substitute for CFC-113, HCFC-141b and methyl chloroform, as well as an alternative to perfluorocarbons with high radiative efficiencies. Recent observations have shown that the global mean tropospheric abundance of HFC-43-10mee has increased steadily from the 1990s to reach 0.211 ppt in 2012. To date, the emission of this compound is not regulated.

The radiative efficiency (RE) of HFC-43-10mee has recently been re-evaluated at 0.42 W m⁻² ppb⁻¹, giving a 100-year time horizon global warming potential (GWP₁₀₀) of 1650. However, the initial RE, from which the new values were derived, originated from an unpublished source.

We calculated a new RE of 0.36 W m⁻² ppb⁻¹ and a GWP₁₀₀ of 1410 from laboratory absorption cross-section spectra of a pure vapour of HFC-43-10mee. Acquisitions were performed in the 550–3500 cm⁻¹ spectral range using Fourier transform spectroscopy. The results were compared with the broadened spectra from the Pacific Northwest National Laboratory (PNNL) database and with theoretical calculations using density functional theory.

Le Bris, K., DeZeeuw, J., Godin, P.J. and Strong, K., 2018. Infrared absorption cross-sections, radiative efficiency and global warming potential of HFC-43-10mee. *Journal of Molecular Spectroscopy*, 348, pp.64-67.

Low GWP halocarbon refrigerants: A review of thermophysical properties

In the present work, a large number of compounds described in the publicly available literature have been reviewed with the aim to identify possible substitutes for high-GWP HFCs in HVAC&R and organic Rankine cycle (ORC) applications. Taking into account various criteria (particularly low toxicity, low flammability, low GWP, and high energy efficiency), only a few single-component compounds are suitable for many of the relevant applications. In particular, in addition to natural fluids, studies have shown that there are only a few HFCs and a dozen or so HFOs, i.e. halogenated olefins characterized by the presence of a CC double bond in the molecule, that are potentially suitable for a number of relevant applications. Here, a review of the present state-of-the-art of experimentally-determined thermophysical properties of a number of HFOs working fluids and their mixtures also with other categories of refrigerants is presented, with particular emphasis placed on saturation and critical properties, vapor phase PVT data, liquid density, specific heat capacity, thermal conductivity, viscosity, and surface tension.

Bobbo, S., Di Nicola, G., Zilio, C., Brown, J.S. and Fedele, L., 2018. LOW GWP HALOCARBON REFRIGERANTS: A REVIEW OF THERMOPHYSICAL PROPERTIES. *International Journal of Refrigeration*.

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.

Impact of the biomass burning on methane variability during dry years in the Amazon measured from an aircraft and the AIRS sensor

The present study examines the spatiotemporal variability and interrelations of the atmospheric methane (CH₄), carbon monoxide (CO) and biomass burning (BB) outbreaks retrieved from satellite data over the Amazon region during the 2003–2012 period. In the climatological context, we found consistent seasonal cycles of BB outbreaks and CO in the Amazon, both variables showing a peak during the dry season. The dominant CO variability mode features the largest positive loadings in the southern Amazon, and describes the interannual CO variations related to BB outbreaks along the deforestation arc during the dry season. In line with CO variability and BB outbreaks, the results show strong correspondence with the spatiotemporal variability of CH₄ in the southern Amazon during years of intense drought. Indeed, the areas with the largest positive CH₄ anomalies in southern Amazon overlap the areas with high BB outbreaks and positive CO anomalies. The analyses also showed that high (low) BB outbreaks in the southern Amazon occur during dry (wet) years. In consequence, the interannual climate variability modulates the BB outbreaks in the southern Amazon, which in turn have considerable impacts on CO and CH₄ interannual variability in the region. Therefore, the BB outbreaks might play a major role in modulating the CH₄ and CO variations, at least in the southern Amazon. This study also provides a comparison between the estimate of satellite and aircraft measurements for the CH₄ over the southern Amazon, which indicates relatively small differences from the aircraft measurements in the lower troposphere, with errors ranging from 0.18% to 1.76%.

Ribeiro, I.O., Andreoli, R.V., Kayano, M.T., de Sousa, T.R., Medeiros, A.S., Guimarães, P.C., Barbosa, C.G., Godoi, R.H., Martin, S.T. and de Souza, R.A.F., 2018. Impact of the biomass burning on methane variability during dry years in the Amazon measured from an aircraft and the AIRS sensor. Science of The Total Environment, 624, pp.509-516.

Improved rice residue burning emissions estimates: Accounting for practice-specific emission factors in air pollution assessments of Vietnam

In Southeast Asia and Vietnam, rice residues are routinely burned after the harvest to prepare fields for the next season. Specific to Vietnam, the two prevalent burning practices include: a). piling the residues after hand harvesting; b). burning the residues without piling, after machine harvesting. In this study, we synthesized field and laboratory studies from the literature on rice residue burning emission factors for PM_{2.5}. We found significant differences in the resulting burning-practice specific emission factors, with 16.9 g kg⁻²(±6.9) for pile burning and 8.8 g kg⁻²(±3.5) for non-pile burning. We calculated burning-practice specific emissions based on rice area data, region-specific fuel-loading factors, combined emission factors, and estimates of burning from the literature. Our results for year 2015 estimate 180 Gg of PM_{2.5} result from the pile burning method and 130 Gg result from non-pile burning method, with the most-likely current emission scenario of 150 Gg PM_{2.5} emissions for Vietnam. For comparison purposes, we calculated emissions using generalized agricultural emission factors employed in global biomass burning studies. These results estimate 80 Gg PM_{2.5}, which is only 44% of the pile burning-based estimates, suggesting underestimation in previous studies. We compare our emissions to an existing all-combustion sources inventory, results show emissions account for 14–18% of Vietnam's total PM_{2.5} depending on burning practice. Within the highly-urbanized and cloud-covered Hanoi Capital region (HCR), we use rice area from Sentinel-1A to derive spatially-explicit emissions and indirectly estimate residue burning dates. Results from HYSPLIT back-trajectory analysis stratified by season show autumn has most emission trajectories originating in the North, while spring has most originating in the South,

suggesting the latter may have bigger impact on air quality. From these results, we highlight locations where emission mitigation efforts could be focused and suggest measures for pollutant mitigation. Our study demonstrates the need to account for emissions variation due to different burning practices.

Lasko, K. and Vadrevu, K., 2018. Improved rice residue burning emissions estimates: Accounting for practice-specific emission factors in air pollution assessments of Vietnam. Environmental Pollution, 236, pp.795-806.

An uncertainty quantification of PM_{2.5} emissions from residential wood combustion in Italy

Residential wood combustion from fireplaces and wood stoves represents a major source of aerosol emissions which can cause severe air quality deterioration, pose a serious threat to human health and climate change. Moreover, the emission estimates from this source have a high degree of uncertainty that in many emission inventories has not yet been assessed. This paper represents a first attempt to quantify the PM_{2.5} emission uncertainty from residential wood combustion in Italy. A bootstrap simulation analysis has been performed considering the data from the two most updated national surveys on wood consumption. The bootstrap simulations have been carried out both on a national and on a regional level varying wood consumption and emission factors of the different appliance type considered, but keeping constant their distribution in the whole national territory. The influence of the two resulting emission datasets on PM_{2.5} concentrations in Italy has been investigated with the MINNI model. The results show that the mean of PM_{2.5} total emissions for Italy is circa 120 kt, from a minimum of 97 kt to a maximum of 146 kt (-18.9%, +21.5% on the mean value). Moreover, a significant variation of annual average PM_{2.5} concentrations, with values higher than 10 µg/m³ in the most polluted areas, is shown by model results. The distribution influence of the different appliance types has been explored with a sensitivity test in the Veneto Region. This test reveals the importance of emission factors and technology share as the most important parameters influencing the uncertainty analysis.

Rao, M., D'Elia, I. and Piersanti, A., 2018. An uncertainty quantification of PM_{2.5} emissions from residential wood combustion in Italy. Atmospheric Pollution Research, 9(3), pp.526-533.

Analysis of the Co-existence of Long-range Transport Biomass Burning and Dust in the Subtropical West Pacific Region

Biomass burning and wind-blown dust has been well investigated during the past decade regarding their impacts on environment, but their co-existence hasn't been recognized because they usually occur in different locations and episodes. In this study we reveal the unique co-existence condition that dust from the Taklamakan and Gobi Desert (TGD) and biomass burning from Peninsular Southeast Asia (PSEA) can reach to the west Pacific region simultaneously in boreal spring (March and April). The upper level trough at 700hPa along east coast of China favors the large scale subsidence of TGD dust while it travels southeastwards, and drives the PSEA biomass burning plume carried by the westerlies at 3–5 km to descend rapidly to around 1.5 km and mix with dust around southeast China and Taiwan. As compared to the monthly averages in March and April, surface observations suggested that concentrations of PM₁₀, PM_{2.5}, O₃, and CO were 69%, 37%, 20%, and 18% higher respectively during the 10 identified co-existence events which usually lasted for 2–3 days. Co-existence also lowers the surface O₃, NO_x, and SO₂ by 4–5% due to the heterogeneous chemistry between biomass burning and mineral dust as indicated by model simulations.

Dong, X., Fu, J.S., Huang, K., Lin, N.H., Wang, S.H. and Yang, C.E., 2018. Analysis of the Co-existence of Long-range Transport Biomass Burning and Dust in the Subtropical West Pacific Region. Scientific reports, 8(1), p.8962.

Modeling crop residue burning experiments to evaluate smoke emissions and plume transport

Crop residue burning is a common land management practice that results in emissions of a variety of pollutants with negative health impacts. Modeling systems are used to estimate air quality impacts of crop residue burning to support retrospective regulatory assessments and also for forecasting purposes. Ground and airborne measurements from a recent field experiment in the Pacific Northwest focused on cropland residue burning was used to evaluate model performance in capturing surface and aloft impacts from the burning events. The Community Multiscale Air Quality (CMAQ) model was used to simulate multiple crop residue burns with 2 km

grid spacing using field-specific information and also more general assumptions traditionally used to support National Emission Inventory based assessments. Field study specific information, which includes area burned, fuel consumption, and combustion completeness, resulted in increased biomass consumption by 123 tons (60% increase) on average compared to consumption estimated with default methods in the National Emission Inventory (NEI) process. Buoyancy heat flux, a key parameter for model predicted fire plume rise, estimated from fuel loading obtained from field measurements can be 30% to 200% more than when estimated using default field information. The increased buoyancy heat flux resulted in higher plume rise by 30% to 80%. This evaluation indicates that the regulatory air quality modeling system can replicate intensity and transport (horizontal and vertical) features for crop residue burning in this region when region-specific information is used to inform emissions and plume rise calculations. Further, previous vertical emissions allocation treatment of putting all cropland residue burning in the surface layer does not compare well with measured plume structure and these types of burns should be modeled more similarly to prescribed fires such that plume rise is based on an estimate of buoyancy.

Zhou, L., Baker, K.R., Napelenok, S.L., Pouliot, G., Elleman, R., O'Neill, S.M., Urbanski, S.P. and Wong, D.C., 2018. Modeling crop residue burning experiments to evaluate smoke emissions and plume transport. Science of the Total Environment, 627, pp.523-533.

Religious burning as a potential major source of atmospheric fine aerosols in summertime Lhasa on the Tibetan Plateau

We carried out field measurements of aerosols in Lhasa, a major city in the Tibetan Plateau that has been experiencing fast urbanization and industrialization. Aerosol number size distribution was continuously measured using an optical particle size spectrometer near the center of Lhasa city during the Asian summer monsoon season in 2016. The mass concentration of fine particles was modulated by boundary layer dynamics, with an average of 11 $\mu\text{g m}^{-3}$ and the high values exceeding 50 $\mu\text{g m}^{-3}$ during religious holidays. Daytime high concentration coincided with the religious burning of biomass and incense in the temples during morning hours, which produced heavy smoke. Factor analysis revealed a factor that likely represented religious burning. The factor contributed 34% of the campaign-average fine particle mass and the contribution reached up to 80% during religious holidays. The mass size distribution of aerosols produced from religious burnings peaked at ~500 nm, indicating that these particles could efficiently decrease visibility and promote health risk. Because of its significance, our results suggest that further studies of religious burning, a currently under-studied source, are needed in the Tibetan Plateau and in other regions of the world where religious burnings are frequently practiced.

Cui, Y.Y., Liu, S., Bai, Z., Bian, J., Li, D., Fan, K., McKeen, S.A., Watts, L.A., Ciciora, S.J. and Gao, R.S., 2018. Religious burning as a potential major source of atmospheric fine aerosols in summertime Lhasa on the Tibetan Plateau. Atmospheric Environment, 181, pp.186-191.

Aircraft measurement over the Gulf of Tonkin capturing aloft transport of biomass burning

A suite of aircraft measurements was conducted over the Gulf of Tonkin, located downwind to the east of Mainland Southeast Asia (MSE), between March 23rd and April 6th, 2015. To the best of our knowledge, this campaign of 11 flights (totaling 34.4 h) was the first in-flight measurement over the region. Measurements of sulfur dioxide, nitrogen oxides, ozone, carbon monoxide, black carbon and the particulate scattering coefficient were recorded at approximately 1 500 m (low level) and 3 000 m (high level). Significantly higher measurements of black carbon, carbon monoxide and ozone in the high level on March 23rd and April 5th and 6th were directly related to biomass burning in the MSE and were comparable to severe pollution events at the surface. Similarly, relatively low pollutant concentrations were observed at both altitudes between March 23rd and April 5th. A combined analysis of the measurements with meteorology and satellite data verified that the plumes captured at 3 000 m were attributed to transport in the high altitude originating from biomass burning in northern MSE. Furthermore, each plume captured by the measurements in the high level corresponded to heavy regional air pollution caused by biomass burning in northern MSE. In addition, relatively low levels of the measured pollutants corresponded to relatively light pollution levels in MSE and its adjacent areas. Taken together, these

results indicated that aircraft measurements were accurate in characterizing the variation in transport and pollutant levels. During the most active season of biomass burning in MSE, pollutant emissions and their regional impact could vary on an episodic basis. Nonetheless, such concentrated emissions from biomass burning is likely to lead to particularly high atmospheric-loading of pollutants at a regional level and, depending on weather conditions, has the potential of being transported over considerably longer distances. Further investigation of the short-term impacts of such concentrations therefore appears prudent.

Yang, X., Xu, J., Bi, F., Zhang, Z., Chen, Y., He, Y., Han, F., Zhi, G., Liu, S. and Meng, F., 2018. Aircraft measurement over the Gulf of Tonkin capturing aloft transport of biomass burning. Atmospheric Environment, 182, pp.41-50.

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

Short communication: Development of an equation for estimating methane emissions of dairy cows from milk Fourier transform mid-infrared spectra by using reference data obtained exclusively from respiration chambers

Evaluation and mitigation of enteric methane (CH₄) emissions from ruminant livestock, in particular from dairy cows, have acquired global importance for sustainable, climate-smart cattle production. Based on CH₄ reference measurements obtained with the SF₆ tracer technique to determine ruminal CH₄ production, a current equation permits evaluation of individual daily CH₄ emissions of dairy cows based on milk Fourier transform mid-infrared (FT-MIR) spectra. However, the respiration chamber (RC) technique is considered to be more accurate than SF₆ to measure CH₄ production from cattle. This study aimed to develop an equation that allows estimating CH₄ emissions of lactating cows recorded in an RC from corresponding milk FT-MIR spectra and to challenge its robustness and relevance through validation processes and its application on a milk spectral database. This would permit confirming the conclusions drawn with the existing equation based on SF₆ reference measurements regarding the potential to estimate daily CH₄ emissions of dairy cows from milk FT-MIR spectra. A total of 584 RC reference CH₄ measurements (mean ± standard deviation of 400 ± 72 g of CH₄/d) and corresponding standardized milk mid-infrared spectra were obtained from 148 individual lactating cows between 7 and 321 d in milk in 5 European countries (Germany, Switzerland, Denmark, France, and Northern Ireland). The developed equation based on RC measurements showed calibration and cross-validation coefficients of determination of 0.65 and 0.57, respectively, which is lower than those obtained earlier by the equation based on 532 SF₆ measurements (0.74 and 0.70, respectively). This means that the RC-based model is unable to explain the variability observed in the corresponding reference data as well as the SF₆-based model. The standard errors of calibration and cross-validation were lower for the RC model (43 and 47 g/d vs. 66 and 70 g/d for the SF₆ version, respectively), indicating that the model based on RC data was closer to actual values. The root mean squared error (RMSE) of calibration of 42 g/d represents only 10% of the overall daily CH₄ production, which is 23 g/d lower than the RMSE for the SF₆-based equation. During the external validation step an RMSE of 62 g/d was observed. When the RC equation was applied to a standardized spectral database of milk recordings collected in the Walloon region of Belgium between January 2012 and December 2017 (1,515,137 spectra from 132,658 lactating cows in 1,176 different herds), an average ± standard deviation of 446 ± 51 g of CH₄/d was estimated, which is consistent with the range of the values measured using both RC and SF₆ techniques. This study confirmed that milk FT-MIR spectra could be used as a potential proxy to estimate daily CH₄ emissions from dairy cows provided that the variability to predict is covered by the model.

Vanlierde, A., Soyeurt, H., Gengler, N., Colinet, F.G., Froidmont, E., Kreuzer, M., Grandl, F., Bell, M., Lund, P., Olijhoek, D.W. and Eugène, M., 2018. Development of an equation for estimating methane emissions of dairy cows from milk Fourier transform mid-infrared spectra by using reference data obtained exclusively from respiration chambers. Journal of dairy science.

Annual emissions of CO₂, CH₄ and N₂O from a temperate peat bog: Comparison of an undrained and four drained sites under permanent grass and arable crop rotations with cereals and potato

Peatlands drained for agriculture are sources of atmospheric carbon dioxide (CO₂) and nitrous oxide (N₂O). Resulting emissions may depend on land-use, often as grassland or cropland, but few studies have directly compared the effects of land-uses. Here, we measured annual emissions of CO₂, N₂O and methane (CH₄) from five sites in a temperate bog, representing an undrained natural bog (NB) site, and four drained sites used as permanent grassland (PG) and croplands with rotations of oat-potato, oat-spring barley and potato-spring barley (PO:SB) in the study year. Gas fluxes were measured at 1–2 week intervals using static chambers, and auxiliary data were obtained, such as temperature, depth of water table, ratio-vegetation index, pH and soil mineral N. Annual CO₂ emissions were derived from empirical modelling, whereas CH₄ and N₂O emissions were linearly interpolated between measurement dates by bootstrapping. Soil respiration was lower at the NB site (1.8 Mg CO₂-C ha⁻¹ yr⁻¹) than at the drained sites where emissions were in the range of 5.0–8.8 Mg CO₂-C ha⁻¹ yr⁻¹. The N₂O emission was negligible at NB (0.3 kg N₂O ha⁻¹ yr⁻¹), low at three of the drained sites (1.5–3.7 kg N₂O ha⁻¹ yr⁻¹), but high at PO:SB (37.7 kg N₂O ha⁻¹ yr⁻¹). The CH₄ emission was high at NB (172 kg CH₄ ha⁻¹ yr⁻¹), but negligible at the drained sites (–1.5 to 1.5 kg CH₄ ha⁻¹ yr⁻¹). The soil respiration at the drained sites indicated that peat losses were rather similar among the different cropping systems and depended mostly on drainage status, although soil respiration and peat mineralization may not scale directly. The pattern of N₂O emissions suggested an increased risk of N₂O emission from potato cultivation before and after the period of potato growth, likely due to microbial availability of NO₃⁻ outside the growing season. For initiatives aiming at reduction of greenhouse gas emissions from agricultural peat soils, this means that, e.g., conversion from cropland to permanent grassland should preferably be accompanied by measures of rewetting, whereas for potato cropping, N availability outside the growing season should be minimized.

Kandel, T.P., Lærke, P.E. and Elsgaard, L., 2018. Annual emissions of CO₂, CH₄ and N₂O from a temperate peat bog: Comparison of an undrained and four drained sites under permanent grass and arable crop rotations with cereals and potato. Agricultural and Forest Meteorology, 256, pp.470-481.

Dietary manipulation: a sustainable way to mitigate methane emissions from ruminants

Methane emission from the enteric fermentation of ruminant livestock is a main source of greenhouse gas (GHG) emission and a major concern for global warming. Methane emission is also associated with dietary energy loss; hence, reduce feed efficiency. Due to the negative environmental impacts, methane mitigation has come forward in last few decades. To date numerous efforts were made in order to reduce methane emission from ruminants. No table mitigation approaches are rumen manipulation, alteration of rumen fermentation, modification of rumen microbial biodiversity by different means and rarely by animal manipulations. However, a comprehensive exploration for a sustainable methane mitigation approach is still lacking. Dietary modification is directly linked to changes in the rumen fermentation pattern and types of end products. Studies showed that changing fermentation pattern is one of the most effective ways of methane abatement. Desirable dietary changes provide two fold benefits i.e. improve production and reduce GHG emissions. Therefore, the aim of this review is to discuss biology of methane emission from ruminants and its mitigation through dietary manipulation.

Haque, M.N., 2018. Dietary manipulation: a sustainable way to mitigate methane emissions from ruminants. Journal of Animal Science and Technology, 60(1), p.15.

Prediction of enteric methane emission from beef cattle in Southeast Asia

We conducted a meta-data analysis to develop prediction equations to estimate enteric methane (CH₄) emission from beef cattle in Southeast Asia. The dataset was obtained from 25 studies, which included 332 individual observations on nutrient intakes, digestibilities, and CH₄ emissions. Cattle were provided tropical forage or rice straw, with or without concentrates in individual pens equipped with indirect open-circuit head hood apparatus. The simplest and best equation to predict daily CH₄ emission was CH₄ (g/day) = 22.71 (±1.008) × dry matter intake (DMI, kg/day) + 8.91 (±10.896) [R² = 0.77; root mean square error (RMSE) = 19.363 g/day]. The best

equation to predict CH₄ energy as a proportion of gross energy intake (CH₄-E/GEI, J/100 J) was obtained using DMI per body weight (DMIBW, kg/100 kg), content (g/100 g DM) of ether extract (EE) and crude protein (CP), and DM digestibility (DMD, g/100 g); CH₄-E/GEI = -0.782 (±0.2526) DMIBW - 0.436 (±0.0548) EE - 0.073 (±0.0218) CP + 0.049 (±0.0097) DMD + 8.654 (±0.6517) (R² = 0.39; RMSE = 1.3479 J/100 J GEI). It was indicated that CH₄ emissions from beef cattle in Southeast Asia are predictable using present developed models including simple indices.

Suzuki, T., Sommart, K., Anghong, W., Nguyen, T.V., Chaokaur, A., Nitipot, P., Phromloungsri, A., Cai, Y., Sakai, T., Nishida, T. and Terada, F., 2018. Prediction of enteric methane emission from beef cattle in Southeast Asia. Animal Science Journal.

Rotatinuous stocking: A grazing management innovation that has high potential to mitigate methane emissions by sheep

To test the hypothesis that the best sward structure in the grazing management strategy based on animal behaviour, called “Rotatinuous” stocking, results in higher nutrient intake and lower methane emission and intensity by sheep grazing Italian ryegrass pastures, two grazing management strategies were studied: the traditional rotational stocking (RT) with pre- and post-grazing sward target heights of 25 and 5 cm, respectively and, “Rotatinuous” stocking (RN) with pre- and post-grazing sward target heights of 18 and 11 cm, respectively. Male castrated sheep were used. The experiment was carried out in 2014 and 2015 in southern Brazil. The experimental design was a randomized complete block with four replicates. The RN treatment had better herbage chemical composition in terms of quality than that of the RT treatment, with greater (P < 0.05) crude protein and lower neutral and acidic detergent fibre. The ideal sward structure and greater chemical composition of Italian ryegrass pastures found under RN treatment resulted in greater herbage digestibility and intake of organic matter and metabolizable energy by grazing sheep than under the RT treatment. Our study highlights that management is the key strategy to reduce the environmental impact of grazing through lower CH₄ emissions in livestock grazing systems. “Rotatinuous” stocking was the more efficient grazing management strategy for mitigation of CH₄ emissions and intensity by grazing sheep, with 64% less CH₄ production per area and 170% less CH₄ emission per unit of animal product when compared to the RT treatment.

Savian, J.V., Schons, R.M.T., Marchi, D.E., de Freitas, T.S., da Silva Neto, G.F., Mezzalira, J.C., Berndt, A., Bayer, C. and de Faccio Carvalho, P.C., 2018. Rotatinuous stocking: A grazing management innovation that has high potential to mitigate methane emissions by sheep. Journal of Cleaner Production, 186, pp.602-608.

Transportation

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

Sources of variance in BC mass measurements from a small marine engine: Influence of the instruments, fuels and loads

Knowledge of black carbon (BC) emission factors from ships is important from human health and environmental perspectives. A study of instruments measuring BC and fuels typically used in marine operation was carried out on a small marine engine. Six analytical methods measured the BC emissions in the exhaust of the marine engine operated at two load points (25% and 75%) while burning one of three fuels: a distillate marine (DMA), a low sulfur, residual marine (RMB-30) and a high-sulfur residual marine (RMG-380). The average emission factors with all instruments increased from 0.08 to 1.88 gBC/kg fuel in going from 25 to 75% load. An analysis of variance (ANOVA) tested BC emissions against instrument, load, and combined fuel properties and showed that both engine load and fuels had a statistically significant impact on BC emission factors. While BC emissions were impacted by the fuels used, none of the fuel properties investigated (sulfur content, viscosity, carbon residue

and CCAI) was a primary driver for BC emissions. Of the two residual fuels, RMB-30 with the lower sulfur content, lower viscosity and lower residual carbon, had the highest BC emission factors. BC emission factors determined with the different instruments showed a good correlation with the PAS values with correlation coefficients $R^2 > 0.95$. A key finding of this research is the relative BC measured values were mostly independent of load and fuel, except for some instruments in certain fuel and load combinations.

Jiang, Y., Yang, J., Gagné, S., Chan, T.W., Thomson, K., Fofie, E., Cary, R.A., Rutherford, D., Comer, B., Swanson, J. and Lin, Y., 2018. Sources of variance in BC mass measurements from a small marine engine: Influence of the instruments, fuels and loads. Atmospheric Environment, 182, pp.128-137.

Emission measurement of diesel vehicles in Hong Kong through on-road remote sensing: Performance review and identification of high-emitters

A two-year remote sensing measurement program was carried out in Hong Kong to obtain a large dataset of on-road diesel vehicle emissions. Analysis was performed to evaluate the effect of vehicle manufacture year (1949–2015) and engine size (0.4–20 L) on the emission rates and high-emitters. The results showed that CO emission rates of larger engine size vehicles were higher than those of small vehicles during the study period, while HC and NO were higher before manufacture year 2006 and then became similar levels between manufacture years 2006 and 2015. CO, HC and NO of all vehicles showed an unexpectedly increasing trend during 1998–2004, in particular ≥ 6001 cc vehicles. However, they all decreased steadily in the last decade (2005–2015), except for NO of ≥ 6001 cc vehicles during 2013–2015. The distributions of CO and HC emission rates were highly skewed as the dirtiest 10% vehicles emitted much higher emissions than all the other vehicles. Moreover, this skewness became more significant for larger engine size or newer vehicles. The results indicated that remote sensing technology would be very effective to screen the CO and HC high-emitters and thus control the on-road vehicle emissions, but less effective for controlling NO emissions. No clear correlation was observed between the manufacture year and percentage of high-emitters for ≤ 3000 cc vehicles. However, the percentage of high-emitters decreased with newer manufacture year for larger vehicles. In addition, high-emitters of different pollutants were relatively independent, in particular NO emissions, indicating that high-emitter screening criteria should be defined on a CO-or-HC-or-NO basis, rather than a CO-and-HC-and-NO basis.

Huang, Y., Organ, B., Zhou, J.L., Surawski, N.C., Hong, G., Chan, E.F. and Yam, Y.S., 2018. Emission measurement of diesel vehicles in Hong Kong through on-road remote sensing: Performance review and identification of high-emitters. Environmental Pollution, 237, pp.133-142.

A technology-based mass emission factors of gases and aerosol precursor and spatial distribution of emissions from on-road transport sector in India

This study presents a new emission estimate of gaseous pollutants including CO, CO₂, and NO_x from on-road transport sector of India for the base year 2013. For the first time, a detailed vintage-wise on-road measured emission factors used for reducing uncertainties in emission estimates. The consumptions of diesel, gasoline, and compressed natural gas (CNG) were also estimated at the national level and disaggregated at the state level. The national average use of diesel, gasoline, and CNG and their 95% confidence interval estimated as 52 (39–66), 24 (18–30), and 1.6 (1.2–2.0) MTy⁻¹ for the year 2013. The CO, CO₂, and NO_x emissions were estimated as 7349 (3220–11477) Gg y⁻¹, 261 (179–343) Tg y⁻¹, and 4052 (2127–5977) Gg y⁻¹, respectively from on-road transport sector for the year 2013. New vehicles registered after 2005 emit 70–80% of national level CO₂, and NO_x, while rest 20–30% were emitted by old vehicles registered before 2005. Old and new vehicles both equally contributed to CO emissions. Superemitters accounted for 14% of total traffic volume, but they were responsible for 17–57% of total CO₂, CO and NO_x emissions. The uncertainties in emission estimates were reduced to 48–56% compared to previous estimates (62–136%). The comparison with recent studies for nationwide emission estimates from 4-wheelers indicated that use of emission factors from dynamometer studies can underestimate the emissions by 32–92% for various pollutants, while an overestimation by 20–82% was seen with the use of emission model derived emission factors. Similarly for Delhi city recent CO and NO_x emission estimates for 4-wheelers based on emission factors reported from dynamometer studies were 23–89% lower than present work.

The present work revealed the need for representative vintage wise emission factor database development from on-road measurement and the more comprehensive assessment of activity data through survey.

Prakash, J. and Habib, G., 2018. A technology-based mass emission factors of gases and aerosol precursor and spatial distribution of emissions from on-road transport sector in India. Atmospheric Environment, 180, pp.192-205.

Real world vehicle fleet emission factors: Seasonal and diurnal variations in traffic related air pollutants

Temporal variations of vehicle emissions are affected by various compounding factors in the real world. The focus of this study is to determine the effects of ambient conditions and post-tailpipe changes on traffic emissions measured in the near-road region. Emission factors allowed for the isolation of the traffic signal and accounted for effects of local meteorology and dilution. Five month-long measurement campaigns were conducted at an urban near-road site that exhibited a broad range of ambient conditions with temperatures ranging between -18 and $+30$ °C. Particle number emission factors were $2.0\times$ higher in the winter relative to the summer, which was attributed to changes in particles post-tailpipe. Conversely, toluene emissions were $2.5\times$ higher in the summer relative to the winter, attributed to changes in fuel composition. Diurnal trends of emission factors showed substantial increases in emissions during the morning rush hour for black carbon ($1.9\times$), particle number ($2.4\times$), and particle-bound polycyclic aromatic hydrocarbons ($3.0\times$), affected by fleet make-up. In contrast, particle number emission factors were highest midday with mean values $3.7\times$ higher than at night. This midday increase was attributed to particle formation or growth from local traffic emissions and showed different wind direction dependence than regional events.

Wang, J.M., Jeong, C.H., Zimmerman, N., Healy, R.M. and Evans, G.J., 2018. Real world vehicle fleet emission factors: Seasonal and diurnal variations in traffic related air pollutants. Atmospheric Environment, 184, pp.77-86.

Waste and Waste Management

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

Assessment of a landfill methane emission screening method using an unmanned aerial vehicle mounted thermal infrared camera – A field study

An unmanned aerial vehicle (UAV)-mounted thermal infrared (TIR) camera's ability to delineate landfill gas (LFG) emission hotspots was evaluated in a field test at two Danish landfills (Hedeland landfill and Audebo landfill). At both sites, a test area of 100 m^2 was established and divided into about 100 measuring points. The relationship between LFG emissions and soil surface temperatures were investigated through four to five measuring campaigns, in order to cover different atmospheric conditions along with increasing, decreasing and stable barometric pressure. For each measuring campaign, a TIR image of the test area was obtained followed by the measurement of methane (CH_4) and carbon dioxide (CO_2) emissions at each measuring point, using a static flux chamber. At the same time, soil temperatures measured on the surface, at 5 cm and 10 cm depths, were registered. At the Hedeland landfill, no relationship was found between LFG emissions and surface temperatures. In addition, CH_4 emissions were very limited, on average $0.92\text{--}4.52\text{ g CH}_4\text{ m}^{-2}\text{ d}^{-1}$, and only measurable on the two days with decreasing barometric pressure. TIR images from Hedeland did not show any significant temperature differences in the test area. At the Audebo landfill, an area with slightly higher surface temperatures was found in the TIR images, and the same pattern with slightly higher temperatures was found at a depth of 10 cm. The main LFG emissions were found in the area with the higher surface temperatures. LFG emissions at Audebo were influenced significantly by changes in barometric pressure, and the average CH_4 emissions varied between $111\text{ g m}^{-2}\text{ d}^{-1}$ and $314\text{ g m}^{-2}\text{ d}^{-1}$, depending on whether the barometric pressure

gradient had increased or decreased, respectively. The temperature differences observed in the TIR images from both landfills were limited to between 0.7 °C and 1.2 °C. The minimum observable CH₄ emission for the TIR camera to identify an emission hotspot was 150 g CH₄ m⁻² d⁻¹ from an area of more than 1 m².

Fjelsted, L., Christensen, A.G., Larsen, J.E., Kjeldsen, P. and Scheutz, C., 2018. Assessment of a landfill methane emission screening method using an unmanned aerial vehicle mounted thermal infrared camera—A field study. Waste Management.

Uncontrolled burning of solid waste by households in Mexico is a significant contributor to climate change in the country

Uncontrolled burning of municipal solid waste (MSW) is an important source of air pollution and is wide spread in many developing countries, but only limited data quantify the extent of domestic open burning of household waste. Here, we present some of the first field data to be reported on the uncontrolled domestic burning of waste. A representative community of Mexico (Huejutla de Reyes Municipality) was investigated and household surveys, interviews with waste operators and a waste characterisation analysis were completed to assess the extent of, and factors controlling, the open burning of waste. Waste collection provision to rural communities was very limited and, consequently 92% of households in rural areas reported that they disposed of waste by uncontrolled burning in backyards or unofficial dumps. Overall, 24% of the total MSW generated in the Municipality was disposed by uncontrolled burning. Urban and periurban areas received twice-weekly collections and the rate of uncontrolled burning was considerably smaller compared to rural households, corresponding to approximately 2% of total waste generation. Carbon equivalency calculations showed that burning waste in backyards represented approximately 6% of the total and 8.5% of fuel related CO₂Eq emissions by the municipality. Moreover, the equivalent carbon dioxide (CO₂Eq) from black carbon (BC) emitted by uncontrolled burning in backyards was over fifteen times larger compared to methane (CH₄) potentially released from equivalent amounts of combustible biodegradable waste disposal at the official dumpsite. An assessment of local respiratory health data showed the incidence of disease was higher in rural than in urban areas, when the opposite trend is typically observed in the international literature; given the high rate of burning activity found in rural areas we suggest that open burning of waste could be a major reason for the apparent poorer respiratory health status of the rural population and requires further investigation. The results emphasise the importance of including BC from uncontrolled burning of waste in international emission inventories of greenhouse gases and in the assessment of the health status of local communities in developing countries where this practice is prevalent.

Reyna-Bensusan, N., Wilson, D.C. and Smith, S.R., 2018. Uncontrolled burning of solid waste by households in Mexico is a significant contributor to climate change in the country. Environmental research, 163, pp.280-288.

PM2.5 and Air Pollution

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

Global distribution and evolution of urbanization and PM2.5 (1998–2015)

PM2.5 concentrations increased and have been one of the major social issues along with rapid urbanization in many regions of the world in recent decades. The development of urbanization differed among regions, PM2.5 pollution also presented discrepant distribution across the world. Thus, this paper aimed to grasp the profile of global distribution of urbanization and PM2.5 and their evolutionary relationships. Based on global data for the proportion of the urban population and PM2.5 concentrations in 1998–2015, this paper investigated the spatial distribution, temporal variation, and evolutionary relationships of global urbanization and PM2.5. The results showed PM2.5 presented an increasing trend along with urbanization during the study period, but there was a

variety of evolutionary relationships in different countries and regions. Most countries in East Asia, Southeast Asia, South Asia, and some African countries developed with the rapid increase in both urbanization and PM_{2.5}. Under the impact of other socioeconomic factors, such as industry and economic growth, the development of urbanization increased PM_{2.5} concentrations in most Asian countries and some African countries, but decreased PM_{2.5} concentrations in most European and American countries. The findings of this study revealed the spatial distributions of global urbanization and PM_{2.5} pollution and provided an interpretation on the evolution of urbanization-PM_{2.5} relationships, which can contribute to urbanization policies making aimed at successful PM_{2.5} pollution control and abatement.

Yang, D., Ye, C., Wang, X., Lu, D., Xu, J. and Yang, H., 2018. Global distribution and evolution of urbanization and PM_{2.5} (1998–2015). Atmospheric Environment, 182, pp.171-178.

Sources of particulate matter in China: Insights from source apportionment studies published in 1987–2017

Particulate matter (PM) in the atmosphere has adverse effects on human health, ecosystems, and visibility. It also plays an important role in meteorology and climate change. A good understanding of its sources is essential for effective emission controls to reduce PM and to protect public health. In this study, a total of 239 PM source apportionment studies in China published during 1987–2017 were reviewed. The documents studied include peer-reviewed papers in international and Chinese journals, as well as degree dissertations. The methods applied in these studies were summarized and the main sources in various regions of China were identified. The trends of source contributions at two major cities with abundant studies over long-time periods were analyzed. The most frequently used methods for PM source apportionment in China are receptor models, including chemical mass balance (CMB), positive matrix factorization (PMF), and principle component analysis (PCA). Dust, fossil fuel combustion, transportation, biomass burning, industrial emission, secondary inorganic aerosol (SIA) and secondary organic aerosol (SOA) are the main source categories of fine PM identified in China. Even though the sources of PM vary among seven different geographical areas of China, SIA, industrial, and dust emissions are generally found to be the top three source categories in 2007–2016. A number of studies investigated the sources of SIA and SOA in China using air quality models and indicated that fossil fuel combustion and industrial emissions were the most important sources of SIA (total contributing 63.5%–88.1% of SO₄²⁻, and 47.3%–70% NO₃⁻), and agriculture emissions were the dominant source of NH₄⁺ (contributing 53.9%–90%). Biogenic emissions were the most important source of SOA in China in summer, while residential and industrial emissions were important in winter. Long-term changes of PM sources at two megacities of Beijing and Nanjing indicated that the contributions of fossil fuel and industrial sources have been declining after stricter emission controls in recent years. In general, dust and industrial contributions decreased and transportation contributions increased after 2000. PM_{2.5} emissions are predicted to decline in most regions during 2005–2030, even though the energy consumptions except biomass burning are predicted to continue to increase. Industrial, residential, and biomass burning sources will become more important in the future in the business-as-usual scenarios. This review provides valuable information about main sources of PM and their trends in China. A few recommendations are suggested to further improve our understanding the sources and to develop effective PM control strategies in various regions of China.

Zhu, Y., Huang, L., Li, J., Ying, Q., Zhang, H., Liu, X., Liao, H., Li, N., Liu, Z., Mao, Y. and Fang, H., 2018. Sources of particulate matter in China: Insights from source apportionment studies published in 1987–2017. Environment international, 115, pp.343-357.

Characterization of air quality and sources of fine particulate matter (PM_{2.5}) in the City of Calgary, Canada

With concern about fine particulate matter (PM_{2.5}) pollution in urban areas and levels approaching a new Canadian Ambient Air Quality Standards (CAAQS), an exploratory study of air quality characteristics and potential sources affecting PM_{2.5} levels was undertaken in the City of Calgary, Alberta. The study was performed for the economic recession period 2014 to 2016 using hourly concentrations of criteria air pollutants at two monitoring stations (Calgary central and Calgary northwest). The overall mean and median PM_{2.5}

concentrations were similar at both Calgary central (arithmetic mean: 7.7 $\mu\text{g}/\text{m}^3$, median: 6.0 $\mu\text{g}/\text{m}^3$) and Calgary northwest (arithmetic mean: 7.5 $\mu\text{g}/\text{m}^3$, median: 6.0 $\mu\text{g}/\text{m}^3$). Three-year averages of annual average daily 24 h PM_{2.5} concentrations at both stations were below the 2015 annual CAAQS of 10 $\mu\text{g}/\text{m}^3$ during the study period 2014–2016. A multivariate receptor model positive matrix factorization (PMF) revealed five sources, where secondary aerosol was identified as the largest source of PM_{2.5} contributing 54% at Calgary central and 42% at Calgary northwest. Other sources included combustion (18%, 39%), traffic (18%, 12%), an O₃-rich source (8%, 4%), and a mixed urban source (2%, 3%) at Calgary central and Calgary northwest, respectively. Variations in annual contributions of secondary aerosol, combustion and traffic were observed at Calgary downtown for 2014–2016. At Calgary northwest no variation was found for annual traffic contributions. These findings offer preliminary information about the contributions of different potential sources to PM_{2.5} in Calgary; and this information can support policy makers in developing appropriate air quality management initiatives for PM_{2.5} pollution if needed.

Bari, M.A. and Kindzierski, W.B., 2018. Characterization of air quality and sources of fine particulate matter (PM_{2.5}) in the City of Calgary, Canada. Atmospheric Pollution Research, 9(3), pp.534-543.

A regional high-resolution emission inventory of primary air pollutants in 2012 for Beijing and the surrounding five provinces of North China

A high resolution regional emission inventory of typical primary air pollutants (PAPs) for the year 2012 in Beijing and the surrounding five provinces (BSFP) of North China is developed. It is compiled with the combination of bottom-up and top-down methods, based on city-level collected activity data and the latest updated specific emission factors for different sources. The considered sources are classified into 12 major categories and totally 36 subcategories with respect to their multi-dimensional characteristics, such as economic sector, combustion facility or industrial process, installed air pollution control devices, etc. Power plant sector is the dominant contributor of NO_x emissions with an average contribution of 34.1%, while VOCs emissions are largely emitted from industrial process sources (33.9%). Whereas, other stationary combustion sources represent major sources of primary PM_{2.5}, PM₁₀ and BC emissions, accounting for 22.7%, 30.0% and 33.9% of the total emissions, respectively. Hebei province contributes over 34% of the regional total CO emissions because of huge volume of iron and steel production. By comparison, Shandong province ranks as the biggest contributor for NO_x, PM₁₀, PM_{2.5}, SO₂, VOCs and OC. Further, the BSFP regional total emissions are spatially distributed into grid cells with a high resolution of 9 km × 9 km using GIS tools and surrogate indexes, such regional population, gross domestic product (GDP) and the types of arable soils. The highest emission intensities are mainly located in Beijing-Tianjin-Tangshan area, Jinan-Laiwu-Zibo area and several other cities such as Shijiazhuang, Handan, and Zhengzhou. Furthermore, in order to establish a simple method to estimate and forecast PAPs emissions with macroscopic provincial-level statistical parameters in China, multi-parameter regression equations are firstly developed to estimate emissions outside the BSFP region with routine statistics (e.g. population, total final coal consumption, area of cultivated land and possession of civil vehicles) using the software 1stOpt. We find the estimated PAPs emissions of 31 provinces show close correlation with the well-recognized MEIC inventory. This high resolution multi-pollutants inventory provides necessary input data for regional air quality models that could help to identify and appoint the major influence sources, better understand the complex regional air pollution formation mechanism, and benefit for developing the corresponding joint prevention and control policies of regional complex air pollution in North China.

Liu, H., Wu, B., Liu, S., Shao, P., Liu, X., Zhu, C., Wang, Y., Wu, Y., Xue, Y., Gao, J. and Hao, Y., 2018. A regional high-resolution emission inventory of primary air pollutants in 2012 for Beijing and the surrounding five provinces of North China. Atmospheric Environment, 181, pp.20-33.

PM_{2.5} and gaseous pollutants in New York State during 2005–2016: Spatial variability, temporal trends, and economic influences

Over the past decades, mitigation strategies have been adopted both by federal and state agencies in the United States (US) to improve air quality. Between 2007 and 2009, the US faced a financial/economic crisis that lowered activity and reduced emissions. At the same time, changes in the prices of coal and natural gas drove a shift in

fuels used for electricity generation. Seasonal patterns, diel cycles, spatial gradients, and trends in PM_{2.5} and gaseous pollutants concentrations (NO_x, SO₂, CO and O₃) monitored in New York State (NYS) from 2005 to 2016 were examined. Relationships between ambient concentrations, changes in NYS emissions retrieved from the US EPA trends inventory, and economic indicators were studied. PM_{2.5} and primary gaseous pollutants concentrations decreased across NYS. By 2016, PM_{2.5} and SO₂ attained relatively homogeneous concentrations across the state. PM_{2.5} concentrations decreased significantly at all sites. Similarly, SO₂ concentrations declined at all sites within this period, with the highest slopes observed at the urban sites. Reductions in NO_x emissions likely contributed to summertime average ozone reductions. NO_x and VOCs controls reduced O₃ peak concentrations as seen in significant relationships between the annual O₃ 4th-highest daily maximum 8-h concentrations and estimated NO_x emissions at rural and suburban sites ($r^2 \sim 0.7$). Spring maxima were not reduced with most sites showing insignificant slopes or significant positive slopes (e.g., +2.6% $y-1$ and +2% $y-1$, at CCNY and PFI, respectively). Increases in autumn and winter ozone concentrations were found (e.g., $6.6 \pm 0.4\%$ $y-1$ on average in New York City). Significant relationships were observed between PM_{2.5}, primary pollutants, and economic indicators. Overall, a decrease in electricity generation with coal, and the simultaneous increase in natural gas consumption for power generation, led to a decrease in PM_{2.5} and gaseous pollutants concentrations.

Squizzato, S., Masiol, M., Rich, D.Q. and Hopke, P.K., 2018. PM_{2.5} and gaseous pollutants in New York State during 2005–2016: Spatial variability, temporal trends, and economic influences. Atmospheric Environment, 183, pp.209-224.

Source apportionment of PM_{2.5} organic carbon in the San Joaquin Valley using monthly and daily observations and meteorological clustering

Two hundred sixty-three fine particulate matter (PM_{2.5}) samples collected on 3-day intervals over a 14-month period at two sites in the San Joaquin Valley (SJV) were analyzed for organic carbon (OC), elemental carbon (EC), water soluble organic carbon (WSOC), and organic molecular markers. A unique source profile library was applied to a chemical mass balance (CMB) source apportionment model to develop monthly and seasonally averaged source apportionment results. Five major OC sources were identified: mobile sources, biomass burning, meat smoke, vegetative detritus, and secondary organic carbon (SOC), as inferred from OC not apportioned by CMB. The SOC factor was the largest source contributor at Fresno and Bakersfield, contributing 44% and 51% of PM mass, respectively. Biomass burning was the only source with a statistically different average mass contribution (95% CI) between the two sites. Wintertime peaks of biomass burning, meat smoke, and total OC were observed at both sites, with SOC peaking during the summer months. Exceptionally strong seasonal variation in apportioned meat smoke mass could potentially be explained by oxidation of cholesterol between source and receptor and trends in wind transport outlined in a Residence Time Analysis (RTA). Fast moving nighttime winds prevalent during warmer months caused local emissions to be replaced by air mass transported from the San Francisco Bay Area, consisting of mostly diluted, oxidized concentrations of molecular markers. Good agreement was observed between SOC derived from the CMB model and from non-biomass burning WSOC mass, suggesting the CMB model is sufficiently accurate to assist in policy development. In general, uncertainty in monthly mass values derived from daily CMB apportionments were lower than that of CMB results produced with monthly marker composites, further validating daily sampling methodologies. Strong seasonal trends were observed for biomass and meat smoke OC apportionment, and monthly mass averages had lowest uncertainty when derived from daily CMB apportionments.

Skiles, M.J., Lai, A.M., Olson, M.R., Schauer, J.J. and de Foy, B., 2018. Source apportionment of PM_{2.5} organic carbon in the San Joaquin Valley using monthly and daily observations and meteorological clustering. Environmental Pollution, 237, pp.366-376.

Characteristics and sources of aerosol pollution at a polluted rural site southwest in Beijing, China

Annual average PM_{2.5} concentration in south Beijing was 30% and 40% higher than the whole Beijing city in 2015 and 2016, respectively. Few studies have been conducted to investigate what leads to the characteristics and sources of heavy pollution in the south rural area of Beijing. This study conducted an observation with

Aerosol Chemical Speciation Monitor (ACSM) at a southwest rural site (Liulihe) in Beijing during 2014–2016, to investigate the seasonal aerosol characteristics and their sources. Positive matrix factorization (PMF) algorithm was used to distinguish different components of organic aerosol measured by ACSM. Biomass burning is an important pollution source, mainly due to the open burning after harvest season in autumn, regional transport in spring, and local residential biofuel use in winter. Coal consumption is the largest primary organic aerosol source in winter. Heavy duty diesel trucks contributed significantly to organic aerosol at night-time in the rural area. Results of this study show residential solid fuel burning is the most important source of aerosol pollution in the rural area of Beijing and the results focusing on urban Beijing might have underestimate the contribution from residential emissions in the Beijing-Tianjin-Hebei region.

Hua, Y., Wang, S., Jiang, J., Zhou, W., Xu, Q., Li, X., Liu, B., Zhang, D. and Zheng, M., 2018. Characteristics and sources of aerosol pollution at a polluted rural site southwest in Beijing, China. Science of The Total Environment, 626, pp.519-527.

Air pollution & Health Impacts

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

Long-term trends and health impact of PM_{2.5} and O₃ in Tehran, Iran, 2006–2015

The main objectives of this study were (1) investigation of the temporal variations of ambient fine particulate matter (PM_{2.5}) and ground level ozone (O₃) concentrations in Tehran megacity, the capital and most populous city in Iran, over a 10-year period from 2006 to 2015, and (2) estimation of their long-term health effects including all-cause and cause-specific mortality. For the first goal, the data of PM_{2.5} and O₃ concentrations, measured at 21 regulatory monitoring network stations in Tehran, were obtained and the temporal trends were investigated. The health impact assessment of PM_{2.5} and O₃ was performed using the World Health Organization (WHO) AirQ+ software updated in 2016 by WHO European Centre for Environment and Health. Local baseline incidences in Tehran level were used to better reveal the health effects associated with PM_{2.5} and O₃. Our study showed that over 2006–2015, annual mean concentrations of PM_{2.5} and O₃ varied from 24.7 to 38.8 µg m⁻³ and 35.4 to 76.0 µg m⁻³, respectively, and were significantly declining in the recent 6 years (2010–2015) for PM_{2.5} and 8 years (2008–2015) for O₃. However, Tehran citizens were exposed to concentrations of annual PM_{2.5} exceeding the WHO air quality guideline (WHO AQG) (10 µg m⁻³), U.S. EPA and Iranian standard levels (12 µg m⁻³) during entire study period. We estimated that long-term exposure to ambient PM_{2.5} contributed to between 24.5% and 36.2% of mortality from cerebrovascular disease (stroke), 19.8% and 24.1% from ischemic heart disease (IHD), 13.6% and 19.2% from lung cancer (LC), 10.7% and 15.3% from chronic obstructive pulmonary disease (COPD), 15.0% and 25.2% from acute lower respiratory infection (ALRI), and 7.6% and 11.3% from all-cause annual mortality in the time period. We further estimated that deaths from IHD accounted for most of mortality attributable to long-term exposure to PM_{2.5}. The years of life lost (YLL) attributable to PM_{2.5} was estimated to vary from 67,970 to 106,706 during the study period. In addition, long-term exposure to O₃ was estimated to be responsible for 0.9% to 2.3% of mortality from respiratory diseases. Overall, long-term exposure to ambient PM_{2.5} and O₃ contributed substantially to mortality in Tehran megacity. Air pollution is a modifiable risk factor. Appropriate sustainable control policies are recommended to protect public health.

Faridi, S., Shamsipour, M., Krzyzanowski, M., Künzli, N., Amini, H., Azimi, F., Malkawi, M., Momeniha, F., Gholampour, A., Hassanvand, M.S. and Naddafi, K., 2018. Long-term trends and health impact of PM 2.5 and O₃ in Tehran, Iran, 2006–2015. Environment international, 114, pp.37-49.

Long-term exposure to ambient PM_{2.5} associated with fall-related injury in six low- and middle-income countries

Exposure to ambient air pollution has been linked with adverse health outcomes of the circulatory and nervous systems. Given that falls are closely related to circulatory and nervous health, we hypothesize that air pollution

may adversely affect fall-related injury. We employed Wave 1 data from 36,662 participants aged ≥ 50 years in WHO's Study on Global AGEing and Adult Health in six low- and middle-income countries. Ambient annual concentration of PM_{2.5} was estimated using satellite data. A three-level logistic regression model was applied to examine the long-term association between ambient PM_{2.5} and the prevalence of fall-related injury, and associated disease burden, as well as the potential effect modification of consumption of fruit and vegetables. Ambient PM_{2.5} was found to be significantly associated with the risk of fall-related injury. Each 10 $\mu\text{g}/\text{m}^3$ increase corresponded to 18% (OR = 1.18, 95% CI: 1.09, 1.28) increase in fall-related injury after adjusting for various covariates. The association was relatively stronger among participants with lower consumption of fruit (OR = 1.22, 95% CI: 1.12, 1.33) than higher consumption (OR = 1.06, 95% CI: 0.92, 1.23), and among those with lower vegetable consumption (OR = 1.18, 95% CI: 1.08, 1.28) than higher consumption (OR = 1.08, 95% CI: 0.91, 1.27). Our study suggests that ambient PM_{2.5} may be one risk factor for fall-related injury and that higher consumption of fruit and vegetables could alleviate this effect.

Guo, Y., Lin, H., Shi, Y., Zheng, Y., Li, X., Xiao, J., Liu, T., Zeng, W., Vaughn, M.G., Cummings-Vaughn, L.A. and Nelson, E.J., 2018. Long-term exposure to ambient PM_{2.5} associated with fall-related injury in six low-and middle-income countries. Environmental pollution, 237, pp.961-967.

Nitrogen dioxide exposure in school classrooms of inner-city children with asthma

Ambient and home exposure to nitrogen dioxide (NO₂) causes asthma symptoms and decreased lung function in children with asthma. Little is known about the health effects of school classroom pollution exposure. We aimed to determine the effect of indoor classroom NO₂ on lung function and symptoms in inner-city school children with asthma. Children enrolled in the School Inner-City Asthma Study were followed for 1 academic year. Subjects performed spirometry and had fraction of exhaled nitric oxide values measured twice during the school year at school. Classroom NO₂ was collected by means of passive sampling for 1-week periods twice per year, coinciding with lung function testing. Generalized estimating equation models assessed lung function and symptom relationships with the temporally nearest classroom NO₂ level. The mean NO₂ value was 11.1 ppb (range, 4.3-29.7 ppb). In total, exposure data were available for 296 subjects, 188 of whom had complete spirometric data. At greater than a threshold of 8 ppb of NO₂ and after adjusting for race and season (spirometry standardized by age, height, and sex), NO₂ levels were associated highly with airflow obstruction, such that each 10-ppb increase in NO₂ level was associated with a 5% decrease in FEV₁/forced vital capacity ratio ($\beta = -0.05$; 95% CI, -0.08 to -0.02 ; $P = .01$). Percent predicted forced expiratory flow between the 25th and 75th percentile of forced vital capacity was also inversely associated with higher NO₂ exposure ($\beta = -22.8$; 95% CI, -36.0 to -9.7 ; $P = .01$). There was no significant association of NO₂ levels with percent predicted FEV₁, fraction of exhaled nitric oxide, or asthma symptoms. Additionally, there was no effect modification of atopy on lung function or symptom outcomes. In children with asthma, indoor classroom NO₂ levels can be associated with increased airflow obstruction.

Gaffin, J.M., Hauptman, M., Petty, C.R., Sheehan, W.J., Lai, P.S., Wolfson, J.M., Gold, D.R., Coull, B.A., Koutrakis, P. and Phipatanakul, W., 2018. Nitrogen dioxide exposure in school classrooms of inner-city children with asthma. Journal of Allergy and Clinical Immunology, 141(6), pp.2249-2255.

Association between air pollution from residential wood burning and dementia incidence in a longitudinal study in Northern Sweden

There is highly suggestive evidence for an effect of air pollution exposure on dementia-related outcomes, but evidence is not yet present to clearly pinpoint which pollutants are the probable causal agents. The aims of this study was to assess the longitudinal association between exposures of fine ambient particulate matter (PM_{2.5}) from residential wood burning, and vehicle exhaust, with dementia. We used data from the Betula study, a longitudinal study of dementia in Umeå, Northern Sweden. The study size was 1 806 and the participants were followed from study entry (1993–1995) to 2010. Modelled levels of source-specific fine particulate matter at the residential address were combined with information on wood stoves or wood boilers, and with validated data on dementia diagnosis and individual-level characteristics from the Betula study. Cox proportional hazards models were used to estimate Hazard Ratios (HRs) and their 95% CIs for dementia incidence (vascular dementia

and Alzheimer's disease), adjusted for individual-level characteristics. The emission of PM_{2.5} from local residential wood burning was associated with dementia incidence with a hazard ratio of 1.55 for a 1 µg/m³ increase in PM_{2.5} (95% Confidence Interval (CI): 1.00–2.41, p-value 0.05). Study participants with an address in an area with the highest quartile of PM_{2.5} from residential wood burning and who also had a wood-burning stove were more likely to develop dementia than those in the lower three quartiles without a wood-burning stove with hazard ratios of 1.74 (CI: 1.10–2.75, p-value 0.018). Particulate matter from traffic exhaust seemed to be associated with dementia incidence with hazard ratios of 1.66, (CI: 1.16–2.39), p-value 0.006, and 1.41 (CI: 0.97–2.23), p-value 0.07, in the third and fourth quartiles, respectively. If the associations we observed are causal, then air pollution from residential wood burning, and air pollution from traffic, might be independent important risk factors for dementia.

Oudin, A., Segersson, D., Adolfsson, R. and Forsberg, B., 2018. Association between air pollution from residential wood burning and dementia incidence in a longitudinal study in Northern Sweden. PloS one, 13(6), p.e0198283.

Atmospheric concentrations of SO₂, NO₂, ozone and VOCs in Düzce, Turkey using passive air samplers: Sources, spatial and seasonal variations and health risk estimation

In this research, seasonal and spatial distributions of inorganic and organic pollutants (sulphur dioxide (SO₂), nitrogen dioxide (NO₂) and ozone (O₃) and also volatile organic compounds (VOCs)), were determined by passive sampling technique. Fifty sampling sites were selected considering possible sources in the study area. The sampling area were classified as urban (n = 23), industrial (n = 17) and rural (n = 10) regions. Sampling campaigns were carried out for two-week periods in fall, winter, spring and summer seasons in all regions. Benzene and toluene concentrations were found to be the highest in winter at the traffic-dense sites and lowest concentrations were measured at rural sampling sites in summer. Concentrations of NO₂ were higher at sampling sites with high traffic density in winter. A much uniform distribution was observed for SO₂ in all seasons. However higher levels were observed in winter compared to other seasons due to use of coal for domestic heating. Low O₃ concentrations were measured in winter while higher concentrations were measured in summer. Based on principal component analysis (PCA), four factors (gasoline vehicle emissions, diesel vehicle emissions, industrial emissions and fossil fuel combustion) were identified that could explain about 78% of the system variance of the measured pollutants in the city. Health risk assessment revealed that the safe level of 1 × 10⁻⁶ (United States Environmental Protection Agency's (USEPA) acceptable risk value) was exceeded for benzene in all sampling sites in whole region, but non-carcinogenic risk values were at safe level.

Bozkurt, Z., Üzmez, Ö.Ö., Döğeroğlu, T., Artun, G. and Gaga, E.O., 2018. Atmospheric concentrations of SO₂, NO₂, ozone and VOCs in Düzce, Turkey using passive air samplers: Sources, spatial and seasonal variations and health risk estimation. Atmospheric Pollution Research.

Exposure to household air pollution from biomass-burning cookstoves and HbA1c and diabetic status among Honduran women

Household air pollution from biomass cookstoves is estimated to be responsible for more than two and a half million premature deaths annually, primarily in low and middle-income countries where cardiometabolic disorders, such as Type II Diabetes, are increasing. Growing evidence supports a link between ambient air pollution and diabetes, but evidence for household air pollution is limited. This cross-sectional study of 142 women (72 with traditional stoves and 70 with cleaner-burning *Justa* stoves) in rural Honduras evaluated the association of exposure to household air pollution (stove type, 24-hour average kitchen and personal fine particulate matter [PM_{2.5}] mass and black carbon) with glycated hemoglobin (HbA1c) levels and diabetic status based on HbA1c levels. The prevalence ratio (PR) per interquartile range increase in pollution concentration indicated higher prevalence of prediabetes/diabetes (vs normal HbA1c) for all pollutant measures (eg, PR per 84 µg/m³ increase in personal PM_{2.5}, 1.49; 95% confidence interval [CI], 1.11–2.01). Results for HbA1c as a continuous variable were generally in the hypothesized direction. These results provide some evidence linking household air pollution with the prevalence of prediabetes/diabetes, and, if confirmed, suggest that the global public health impact of household air pollution may be broader than currently estimated.

Rajkumar, S., Clark, M.L., Young, B.N., Benka-Coker, M.L., Bachand, A.M., Brook, R.D., Nelson, T.L., Volckens, J., Reynolds, S.J., L'Orange, C. and Good, N., 2018. Exposure to Household Air Pollution from Biomass-Burning Cookstoves and HbA1c and Diabetic Status among Honduran Women. Indoor air.

Other SLCP Source Sectors & Measures

Description: This section includes articles relating to SLCP emissions and measures from sources not currently addressed by the CCAC

A high temporal-spatial resolution pollutant emission inventory for agricultural machinery in China

Agricultural machinery is an important non-road mobile source, which can exhaust multi-pollutants, making primary and secondary contributions to the air pollution. China is a significant agricultural country of the world; however, the agricultural machinery emissions research is at an early stage, and an emission inventory with a high temporal-spatial resolution is still needed. In this study, a comprehensive emission inventory with a high temporal-spatial resolution for agricultural machinery in China was first developed. The results showed that the total emissions in 2014 were 262.69 Gg, 249.25 Gg, 1211.39 Gg, 2192.05 Gg, 1448.16 Gg and 25.14 Gg for PM₁₀, PM_{2.5}, THC, NO_x, CO and SO₂, respectively. Tractors and farm transport vehicles were the top two greatest contributors, accounting for approximately 39.9%-53.6% and 17.4%-24.6%, respectively, of the total emissions of the five pollutants (except THC). The farm transport vehicles contributed the most (81.8%) to the THC emissions. The county-level emissions were further allocated into 1 km × 1 km grids according to source-specific allocation surrogates. The spatial characteristic analysis indicated that high emissions were distributed in northeast, north and central-south China. To obtain a high temporal resolution emission inventory, a comprehensive investigation on the agricultural practice timing in different provinces was conducted. Then, the annual emissions in the different provinces were distributed to a spatial resolution of ten-day periods (i.e. the early, mid- and late ten-day periods in each month). It was found that higher emissions in China occurred in late April, mid-June and early October. In addition, the emission uncertainty was also analyzed based on the Monte Carlo simulation. The estimated high temporal-spatial resolution emission inventory could provide important basic information for environmental/climate implications research, emission control policy making, and air quality modeling.

Lang, J., Tian, J., Zhou, Y., Li, K., Chen, D., Huang, Q., Xing, X., Zhang, Y. and Cheng, S., 2018. A high temporal-spatial resolution air pollutant emission inventory for agricultural machinery in China. Journal of Cleaner Production, 183, pp.1110-1121.

Evaluation of future energy consumption on PM_{2.5} emissions and public health economic loss in Beijing

Energy consumption has promoted a continuous development for economy and society, but it has also brought serious environmental pollution problems which endanger public health. In order to focus on the impact of PM_{2.5} emissions from future energy consumption on human health better, this paper estimated PM_{2.5} emissions caused by energy consumption in Beijing in 2020, 2025 and 2030 by setting the baseline scenario, emission reduction scenario, intensified emission reduction scenario and the data of the base year 2015, which will be 162.6 thousand tons, 195.9 thousand tons and 235.9 thousand tons in the baseline scenario, 143.1 thousand tons, 151.8 thousand tons and 160.9 thousand tons under the emission reduction scenario, and 132.6 thousand tons, 130.2 thousand tons, 127.9 thousand tons under the intensified emission reduction scenario. Finally the paper measured the number of different health effect ends caused by PM_{2.5} emissions and the economic loss. The results showed that there was a rapid increase, a mild increase and a moderate decrease in energy consumption and PM_{2.5} emissions in Beijing under the three scenarios from 2015 to 2030. Besides, under the same scenario and the same concentration level baseline, the number of the internal medicine (over the age of 15) was the largest, and the economic loss caused by total death rate was the biggest. This article

provides suggestions to reduce PM_{2.5} emissions and public health effect ends for Beijing in the future.

Li, L., Lei, Y., Wu, S., Huang, Z., Luo, J., Wang, Y., Chen, J. and Yan, D., 2018. Evaluation of future energy consumption on PM_{2.5} emissions and public health economic loss in Beijing. Journal of Cleaner Production, 187, pp.1115-1128.

Air quality study in Hanoi, Vietnam in 2015–2016 based on a one-year observation of NO_x, O₃, CO and a one-week observation of VOCs

The number of vehicles, especially motorcycles, which are the dominant source of Hanoi's air pollution, has rapidly increased in recent decades. To investigate air quality in Hanoi, a 1-week observation of VOCs, CO and O₃ in September 2015 and a year-long campaign to measure O₃, NO_x and CO between October 2015 and December 2016 were conducted in the inner city area. Overall mean values of O₃, CO and NO₂ mixing ratios were 19.3 ± 15.3 ppb, 1.3 ± 0.8 ppm and 21.4 ± 11.8 ppb, respectively. The O₃ mixing ratio often exceeded the WHO guideline value of 50 ppb (daily 8-h mean). Although less frequently exceeding the WHO short-term (1-h mean) guideline of 106 ppb, the observed NO₂ overall mean value was greater than the WHO guideline value of 21 ppb. A diurnal profile and analysis of the composition of VOCs indicates that atmospheric VOCs in Hanoi mainly originated from motorcycles, which dominate Hanoi's vehicle fleet. The good correlation between measurements of VOCs and CO also indicates motorcycles as the main source of CO. The NO_x/CO ratio, which is specific to a given emission source, was largely unchanged throughout the year, indicating that vehicles including motorcycles as well as buses, trucks and cars are the main source of O₃ precursors year-round. The estimated VOC/NO_x ratio of 12 ± 5 suggests that Hanoi's air quality can be categorized as NO_x-limited regime with regards to O₃-formation. Therefore, controlling NO_x emissions from not only motorcycles and also other vehicles would be highly effective at decreasing Hanoi's O₃ levels. Furthermore, the results suggest the relationship between the northeast monsoon and an O₃ burst in the winter season.

Sakamoto, Y., Shoji, K., Bui, M.T., Phạm, T.H., Ly, B.T. and Kajii, Y., 2018. Air quality study in Hanoi, Vietnam in 2015–2016 based on a one-year observation of NO_x, O₃, CO and a one-week observation of VOCs. Atmospheric Pollution Research, 9(3), pp.544-551.

Urban SLCPs

Description: This section includes articles addressing SLCP emissions, trends, and measures specifically in urban environments

Quantitative evaluation of source interventions for urban air quality improvement- A case study of Delhi city

Air pollution in Delhi city is an alarming level from last few years. The major challenge for the policy makers is to reduce/manage the elevated air pollution level and related acute and chronic health impacts. Air pollution continues to be a nightmare for Delhiites despite implementation of several diversified source interventions. However, the efficacy of these interventions in the reduction of air pollution level did not evaluate before their implementation in the city. The present study has made an attempt towards the quantitative evaluation of selected management strategies in the reduction of air pollution in Delhi city. The results indicate that efficient cleaning of road dust, restricted use of coal based tandoors in hotels/restaurants and together can reduce the PM_{2.5} concentrations at selected locations up to 25%. The NO_x concentration can reduce by restricting the use of diesel generator sets and coal based tandoors in the hotels up to 6%. Results also indicated that individual sources are not sufficient in controlling the increasing air pollution in the city. A stringent policy portfolio involving the combination of various mitigation measures is necessary to attain the NAAQS along with the policies to control the transboundary movement of air pollutants.

Gulia, S., Mittal, A. and Khare, M., 2018. Quantitative evaluation of source interventions for urban air quality improvement-A case study of Delhi city. *Atmospheric Pollution Research*, 9(3), pp.577-583.

Soot and the city: Evaluating the impacts of Clean Heat policies on indoor/outdoor air quality in New York City apartments

New York City has had a long history of implementing local policies to reduce air pollution. Enacted as a part of PlaNYC, the Clean Heat policies aim to lower wintertime ambient air pollution by phasing out dirty No. 6 heating fuel oil and transitioning to comparatively cleaner No. 4, No. 2, or natural gas. This study evaluates the impacts of policies on ambient air pollution and, given that people spend the majority of their time inside, importantly, indoor air pollution. Using a natural experiment, we evaluate the effects of the policies by measuring average two-week levels of indoor and outdoor black carbon (BC) and fine particulate matter (PM_{2.5}) in 48 upper Manhattan apartments in successive winter heating seasons before and after mandated fuel transition. We failed to observe systematic improvements in indoor BC and PM_{2.5} concentrations in follow-up. However, outdoor levels of PM_{2.5} did improve, with statistical differences observed among buildings converting to the cleanest fuels. Non-statistical improvements were observed for outdoor BC. However, when accounting for meteorological differences, apartment characteristics, and behavioral patterns that may have influenced air pollution measurements, these differences were not significant. The study results have important policy and equity implications considering the differential improvements in air quality by conversion to No. 4 oil as compared to the cleaner No. 2 oil and natural gas.

Gould, C.F., Chillrud, S.N., Phillips, D., Perzanowski, M.S. and Hernández, D., 2018. Soot and the city: Evaluating the impacts of Clean Heat policies on indoor/outdoor air quality in New York City apartments. *PloS one*, 13(6), p.e0199783.

SLCPs & Vulnerable Regions

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

Modeled Response of Greenland Snowmelt to the Presence of Biomass Burning-Based Absorbing Aerosols in the Atmosphere and Snow

Biomass burning produces smoke aerosols that are emitted into the atmosphere. Some smoke constituents, notably black carbon, are highly effective light-absorbing aerosols (LAA). Emitted LAA can be transported to high-albedo regions like the Greenland Ice Sheet (GrIS) and affect local snowmelt. In the summer, the effects of LAA in Greenland are uncertain. To explore how LAA affect GrIS snowmelt and surface energy flux in the summer, we conduct idealized global climate model simulations with perturbed aerosol amounts and properties in the GrIS snow and overlying atmosphere. The in-snow and atmospheric aerosol burdens we select range from background values measured on the GrIS to unrealistically high values. This helps us explore the linearity of snowmelt response and to achieve high signal-to-noise ratios. With LAA operating only in the atmosphere, we find no significant change in snowmelt due to the competing effects of surface dimming and tropospheric warming. Regardless of atmospheric LAA presence, in-snow black carbon-equivalent mixing ratios greater than ~60 ng/g produce statistically significant snowmelt increases over much of the GrIS. We find that net surface energy flux changes correspond well to snowmelt changes for all cases. The dominant component of surface energy flux change is solar energy flux, but sensible and longwave energy fluxes respond to temperature changes. Atmospheric LAA dampen the magnitude of solar radiation absorbed by in-snow LAA when both varieties are simulated. In general, the significant melt and surface energy flux changes we simulate occur with LAA quantities that have never been recorded in Greenland.



Ward, J.L., Flanner, M.G., Bergin, M., Dibb, J.E., Polashenski, C.M., Soja, A.J. and Thomas, J.L., 2018. Modeled Response of Greenland Snowmelt to the Presence of Biomass Burning-Based Absorbing Aerosols in the Atmosphere and Snow. Journal of Geophysical Research: Atmospheres.