SHORT-LIVED CLIMATE POLLUTANTS SPECIAL EDITION RESEARCH DIGEST

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TO REDUCE SHORT-LIVED CLIMATE POLLUTANTS

All SLCP research digests are available on the CCAC website (http://ccacoalition.org/en/research-digest)

Table of Contents

SLCP 4

Development of the Low Emissions Analysis Platform – Integrated Benefits Calculator (LEAP-IBC) tool to assess air quality and climate co-benefits: Application for Bangladesh 4

Multiple Benefits/Impacts & Crosscutting 4

Tradeoffs between air pollution mitigation and meteorological response in India 4

Evaluation of potential co-benefits of air pollution control and climate mitigation policies for China's electricity sector 5

The Global Atmospheric Pollution Forum (GAPF) emission inventory preparation tool and its application to Côte d'Ivoire 5

Methane 6

Estimating natural gas emissions from underground pipelines using surface concentration measurements 6

Methane emissions from natural gas vehicles in China 6

Black Carbon 6

Spatial distribution and sources of winter black carbon and brown carbon in six Chinese megacities 7

Regional and Sectoral Sources for Black Carbon Over South China in Spring and Their Sensitivity to East Asian Summer Monsoon Onset 7

Seasonal variability and source apportionment of black carbon over a rural high-altitude and an urban site in western India 7

A novel way to calculate shortwave black carbon direct radiative effect 8

Tropospheric Ozone 8

Role of export industries on ozone pollution and its precursors in China 8

Ozone a persistent challenge to food security in India: Current status and policy implications 9

Hydrofluorocarbons (HFCs) 9

Evaluation of low-GWP and mildly flammable mixtures as new alternatives for R410A in air-conditioning and heat pump system 9

Socio-Economic Impacts 9

Unprecedented health costs of smoke-related PM 2.5 from the 2019–20 Australian megafires 9

Impact of air pollution in health and socio-economic aspects: Review on future approach 10

Biomass Burning & Household Energy 10

Multiscale assessment of the impact on air quality of an intense wildfire season in southern Italy 10

Open waste burning causes fast and sharp changes in particulate concentrations in peripheral neighborhoods 11

Agriculture and Livestock 11

Genetic parameters for methane emission traits in Australian dairy cows 11

Strong mitigation of greenhouse gas emission impact via aerobic short pre-digestion of green manure

amended soils during rice cropping 12

Animal, feed and rumen fermentation attributes associated with methane emissions from sheep fed brassica crops 12

Transportation 13

On the effects of aviation on carbon-methane cycles and climate change during the period 2015-210013

On-road vehicle emission inventory and its spatio-temporal variations in North China Plain 13

Air pollution & Health Impacts 14

Comparison of hospitalization and mortality associated with short-term exposure to ambient ozone and PM2.5 in Canada 14

Rapid increase in mortality attributable to PM2.5 exposure in India over 1998–2015 14

PM2.5 air pollution contributes to the burden of frailty 14

Health benefits of achieving fine particulate matter standards in India – A nationwide assessment 15

Urban Air Pollution & Megacities 15

Urban and air pollution: a multi-city study of long-term effects of urban landscape patterns on air quality trends 15

Quantification of different processes in the rapid formation of a regional haze episode in north China using an integrated analysis tool coupling source apportionment with process analysis 16

Appraisal of regional haze event and its relationship with PM2.5 concentration, crop residue burning and meteorology in Chandigarh, India 16

Source apportionment of PM2.5 in the most polluted Central Plains Economic Region in China: Implications for joint prevention and control of atmospheric pollution 17

Impacts of multi-scale urban form on PM2.5 concentrations using continuous surface estimates with high-resolution in U.S. metropolitan areas 17

Increase in household energy consumption due to ambient air pollution 18

SLCPs & Vulnerable Regions 18

A review of black carbon in snow and ice and its impact on the cryosphere 18

Black Carbon Deposited in Hariqin Glacier of the Central Tibetan Plateau Record Changes in the Emission from Eurasia 18

SLCP

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

Development of the Low Emissions Analysis Platform – Integrated Benefits Calculator (LEAP-IBC) tool to assess air quality and climate co-benefits: Application for Bangladesh

Low- and middle-income countries have the largest health burdens associated with air pollution exposure, and are particularly vulnerable to climate change impacts. Substantial opportunities have been identified to simultaneously improve air quality and mitigate climate change due to overlapping sources of greenhouse gas and air pollutant emissions and because a subset of pollutants, short-lived climate pollutants (SLCPs), directly contribute to both impacts. However, planners in low- and middle-income countries often lack practical tools to quantify the air pollution and climate change impacts of different policies and measures. This paper presents a modelling framework implemented in the Low Emissions Analysis Platform – Integrated Benefits Calculator (LEAP-IBC) tool to develop integrated strategies to improve air quality, human health and mitigate climate change. The framework estimates emissions of greenhouse gases, SLCPs and air pollutants for historical years, and future projections for baseline and mitigation scenarios. These emissions are then used to quantify i) population-weighted annual average ambient PM2.5 concentrations across the target country, ii) household PM2.5 exposure of different population groups living in households cooking using different fuels/technologies and iii) radiative forcing from all emissions. Health impacts (premature mortality) attributable to ambient and household PM2.5 exposure and changes in global average temperature change are then estimated. This framework is applied in Bangladesh to evaluate the air quality and climate change benefits from implementation of Bangladesh's Nationally Determined Contribution (NDC) and National Action Plan to reduce SLCPs. Results show that the measures included to reduce GHGs in Bangladesh's NDC also have substantial benefits for air quality and human health. Full implementation of Bangladesh's NDC, and National SLCP Plan would reduce carbon dioxide, methane, black carbon and primary PM2.5 emissions by 25%, 34%, 46% and 45%, respectively in 2030 compared to a baseline scenario. These emission reductions could reduce population-weighted ambient PM2.5 concentrations in Bangladesh by 18% in 2030, and avoid approximately 12,000 and 100,000 premature deaths attributable to ambient and household PM2.5 exposures, respectively, in 2030. As countries are simultaneously planning to achieve the climate goals in the Paris Agreement, improve air quality to reduce health impacts and achieve the Sustainable Development Goals, the LEAP-IBC tool provides a practical framework by which planners can develop integrated strategies, achieving multiple air quality and climate benefits.

A, Johan C. I. Kuylenstierna , et al. "Development of the Low Emissions Analysis Platform – Integrated Benefits Calculator (LEAP-IBC) tool to assess air quality and climate co-benefits: Application for Bangladesh." Environment International 145.

Multiple Benefits/Impacts & Crosscutting

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

Tradeoffs between air pollution mitigation and meteorological response in India

To curb the staggering health burden attributed to air pollution, the sustainable solution for India would be to reduce emissions in future. Here we project ambient fine particulate matter (PM2.5) exposure in India for the year 2030 under two contrasting air pollution emission pathways for two different climate scenarios based on Representative Concentration Pathways (RCP4.5 and RCP8.5). All-India average PM2.5 is expected to increase from 41.4 ± 26.5 μg m−3 in 2010 to 61.1 ± 40.8 and 58.2 ± 37.5 μg m−3 in 2030 under RCP8.5 and RCP4.5 scenarios, respectively if India follows the current legislation (baseline) emission pathway. In contrast, ambient PM2.5 in 2030 would be 40.2 ± 27.5 (for RCP8.5) and 39.2 ± 25.4 (for RCP4.5) μg m−3 following the short-lived climate pollutant (SLCP) mitigation emission pathway. We find that the lower PM2.5 in the mitigation pathway

(34.2% and 32.6%, respectively for RCP8.5 and RCP4.5 relative to the baseline emission pathway) would come at a cost of 0.3–0.5 °C additional warming due to the direct impact of aerosols. The premature mortality burden attributable to ambient PM2.5 exposure is expected to rise from 2010 to 2030, but 381,790 (5–95% confidence interval, CI 275,620–514,600) deaths can be averted following the mitigation emission pathway relative to the baseline emission pathway. Therefore, we conclude that given the expected large health benefit, the mitigation emission pathway is a reasonable tradeoff for India despite the meteorological response. However, India needs to act more aggressively as the World Health Organization (WHO) annual air quality guideline (10 μg m−3) would remain far off.

Upadhyay, Abhishek , et al. "Tradeoffs between air pollution mitigation and meteorological response in India." Scentific Reports 10.1(2020):14796.

Evaluation of potential co-benefits of air pollution control and climate mitigation policies for China's electricity sector

Since the rapid industrialisation, local air pollution has become one of China's most important environmental issues. In consequence, increasingly stringent air pollution control policies have been established by the Chinese government. These policies will inevitably affect China's future electric power investment given the key contribution of this sector to air pollution. This sector is also a key contributor to China’s greenhouse gas emissions and hence climate policy efforts. We present a study exploring what impacts of potential interactions and combinations of different policy efforts for local air pollutant control and carbon mitigation have on China's future electricity generation mix. The study utilises a novel generation portfolio model that explicitly incorporates key uncertainties in future technology costs and different policy approaches including carbon pricing and air emissions control. The findings highlight that China can achieve significant reductions for both greenhouse gas and local air pollutant emissions through a combination of climate change and air pollution control policies. Furthermore, there are potentially significant co-benefits from the perspectives of both air pollutant control and carbon mitigation and, notably, that the co-benefit from a sufficient carbon pricing policy to air pollution emission reductions is much stronger than that from stringent air pollutant control policies to carbon mitigation. Specifically, in order to achieve substantial local air pollution and greenhouse gas mitigation from China's electricity sector, it is necessary to close coal-fired power plants rather than merely seeking to clean their air pollution emissions up.

A, Xinyang Wei , et al. "Evaluation of potential co-benefits of air pollution control and climate mitigation policies for China's electricity sector." Energy Economics 92(2020).

The Global Atmospheric Pollution Forum (GAPF) emission inventory preparation tool and its application to Côte d’Ivoire

Low- and middle-income countries (LMICs) often lack the necessary tools, guidance, and capacity for compiling an emission inventory (EI) for air pollutants. A reliable EI is an important prerequisite for the identification of key emissions sources, as an input to modelling atmospheric transport and impacts of air pollutants, and the identification of appropriate mitigation policies. The publicly-available Global Atmospheric Pollution Forum Emission Inventory (GAPF-EI) tool meets the need of LMICs for a user-friendly tool allowing in-country practitioners to compile their own EIs. The species covered are SO2, NOX, CO, NMVOC, CH4, NH3, PM10, PM 2.5, black carbon, organic carbon and CO2. Output from the tool can therefore support the development of integrated air quality and climate change mitigation strategies. This tool incorporates default emission factors and inventory methods conforming with internationally recognised approaches. The GAPF-EI tool enables emissions to be estimated for technologies or practices that are often of little or no relevance to developed countries, but may represent key sources in LMICs. This paper describes the GAPF-EI tool and its application to Côte d’Ivoire where emissions from traditional biomass cookstoves, vegetation fires, traditional charcoal manufacture, road transport (including dust from unpaved roads) and open burning of municipal solid waste were found to be particularly important components of the inventory. The application of the GAPF-EI approach to Côte d’Ivoire has demonstrated its utility in addressing sources of particular relevance to LMICs in addition to providing a user-friendly, transparent and flexible EI preparation tool.

Vallack, Harry William , et al. "The Global Atmospheric Pollution Forum (GAPF) emission inventory preparation tool and its application to Cte d'Ivoire." Atmospheric Pollution Research (2020).

Methane

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

Estimating natural gas emissions from underground pipelines using surface concentration measurements

Rapid response to underground natural gas leaks could mitigate methane emissions and reduce risks to the environment, human health and safety. Identification of large, potentially hazardous leaks could have environmental and safety benefits, including improved prioritization of response efforts and enhanced understanding of relative climate impacts of emission point sources. However, quantitative estimation of underground leakage rates remains challenging, considering the complex nature of methane transport processes. We demonstrate a novel method for estimating underground leak rates based on controlled underground natural gas release experiments at the field scale. The proposed method is based on incorporation of easily measurable field parameters into a dimensionless concentration number, , which considers soil and fluid characteristics. A series of field experiments was conducted to evaluate the relationship between the underground leakage rate and surface methane concentration data over varying soil and pipeline conditions. Peak surface methane concentrations increased with leakage rate, while surface concentrations consistently decreased exponentially with distance from the source. Deviations between the estimated and actual leakage rates ranged from 9% to 33%. A numerical modeling study was carried out by the TOUGH3 simulator to further evaluate how leak rate and subsurface methane transport processes affect the resulting methane surface profile. These findings show that the proposed leak rate estimation method may be useful for prioritizing leak repair, and warrant broader field-scale method validation studies. A method was developed to estimate fugitive emission rates from underground natural gas pipeline leaks. The method could be applied across a range of soil and surface covering conditions.

Cho, Younki, et al. "Estimating natural gas emissions from underground pipelines using surface concentration measurements." Environmental Pollution 267 (2020): 115514.

Methane emissions from natural gas vehicles in China

Natural gas vehicles (NGVs) have been promoted in China to mitigate air pollution, yet our measurements and analyses show that NGV growth in China may have significant negative impacts on climate change. We conducted real-world vehicle emission measurements in China and found high methane emissions from heavy-duty NGVs (90% higher than current emission limits). These emissions have been ignored in previous emission estimates, leading to biased results. Applying our observations to life-cycle analyses, we found that switching to NGVs from conventional vehicles in China has led to a net increase in greenhouse gas (GHG) emissions since 2000. With scenario analyses, we also show that the next decade will be critical for China to reverse the trend with the upcoming China VI standard for heavy-duty vehicles. Implementing and enforcing the China VI standard is challenging, and the method demonstrated here can provide critical information regarding the fleet-level CH4 emissions from NGVs.

Pan, Da , et al. "Methane emissions from natural gas vehicles in China." Nature Communications.

Black Carbon

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

Spatial distribution and sources of winter black carbon and brown carbon in six Chinese megacities

The light-absorbing carbonaceous aerosols, including black carbon (BC) and brown carbon (BrC), influenced heavily on aerosol environmental quality and the Earth's radiation. Here, a winter campaign to characterize BC and BrC in PM2.5 was conducted simultaneously in six Chinese megacities (i.e., Harbin, Beijing, Xi'an, Shanghai, Wuhan, and Guangzhou) using continual aethalometers. The combinations of advanced aethalometer and generalized additive model (GAM) were used to precisely quantify the BC and BrC sources in these megacities. The averaged light-absorbing coefficients of BC (babs-BC) and BrC (babs-BrC) were 28.6 and 21.8 Mm−1 in northern cities, they were 1.4 and 2.7 times higher than those in southern cities. The BrC dominated the total babs (>40%) in northern cities but low to 20% in southern cities. On the other hand, the BC fractions were high in the southern cities, with the contributions of 62.4–79.7%, whereas much lower values of 53.7–59.4% in the northern cities. Source apportionment showed that the combustion of liquid fuels (e.g., gasoline or diesel) was highly dominant to babs-BC (>80%) in Guangzhou and Wuhan. This was further supported by the high NO2 loadings in the GAM model. Solid fuels (i.e., biomass or coal) contributed a substantial portion to total babs-BC in the other four cities where the high abundances of primary babs-BrC were observed. The diurnal trend showed the peaks of secondary-BrC (babs-BrCS) and babs-BrCS/ΔCO in the northern cities occurred at high relative humidity in nighttime, implying the secondary BrC formation was possibly related to aqueous reactions in winter. In contrast, in the southern cities of Shanghai and Guangzhou, the accumulation of vehicle emissions during the morning traffic rush hours lead the formation of secondary BrC through photochemical reactions. The results of this work can be applied for the development of more effective practices to control BC and BrC on regional scale.

B, Qian Zhang A , et al. "Spatial distribution and sources of winter black carbon and brown carbon in six Chinese megacities." ence of The Total Environment (2020).

Regional and Sectoral Sources for Black Carbon Over South China in Spring and Their Sensitivity to East Asian Summer Monsoon Onset

Besides local emissions, biomass burning (BB) emissions in peninsula Southeast Asia (PSEA) and domestic anthropogenic emissions in North China (NC) are also significant black carbon (BC) sources over South China (SC) in spring. Meanwhile, the East Asian summer monsoon (EASM) is established with the wind field reversal, influencing the region-based contributions to BC over SC. Herein, BC sources for SC were tracked by region and by sector using the Community Earth System Model with a BC-tagging technique. During the spring of 2000–2014, 27% of BC surface concentration (BCS) and 64% of BC column burden (BCC) over SC stems from nonlocal sources. BC from NC is mainly transported below 850 hPa. It is the dominant nonlocal contribution to BCS (17%) and largely composed of residential and industrial sectors. Nonlocal emissions inside and outside China contribute 28% and 36% to BCC, respectively. Generally transported above 850 hPa, BC from PSEA is the largest nonlocal contributor (20%) to BCC and contributes 80% of BCC in BB sector. Additionally, the interannual variation in EASM onset times bring a maximum of −5% to +7%/−2% to +7% variation in BCC/BCS. The BC outflow/inflow contributed from NC dominates the BC decrease/increase over SC with southerly/northerly wind anomaly induced by early/late EASM onset, yet regional transport from PSEA contributes minor BC changes. The simulated BC is significantly positively correlated with the varying EASM onset times, but not with emissions, indicating the decisive role of meteorology in the interannual variation of BC over SC during springtime.

Fang, Chenwei , et al. "Regional and Sectoral Sources for Black Carbon over South China in Spring and Their Sensitivity to East Asian Summer Monsoon Onset." Journal of Geophysical Research: Atmospheres 125.20(2020).

Seasonal variability and source apportionment of black carbon over a rural high-altitude and an urban site in western India

Black carbon (BC) mass concentration observations were carried out using Aethalometer (AE-33) at an urban site Pune and at a high altitude forest site Mahabaleshwar during April 2018 to February 2019. The annual averaged BC mass concentration over Pune was observed to be ~2.8 times higher than Mahabaleshwar. Daily, seasonal and diurnal variations of BC over these two different environments were compared. The effect of

meteorological parameters on the BC was also evaluated. Planetary boundary layer (PBL) plays a pivotal role in diluting the atmospheric pollutant BC during daytime at Pune, whereas, contribution of combustion sources mostly dominated over PBL dilution at Mahabaleshwar. Higher wind speed regime also tends to dilute the atmosphere whereas higher BC concentration was observed during RH condition depicting the significance of low dispersion under these conditions. The contribution of different sources namely biomass burning (BB) and fossil fuel (FF), wavelength dependent source apportionment study was also evaluated. Traffic emission contributed 72%–75% of the BC loading at Mahabaleshwar, whereas at Pune it was estimated to be 82%–94% during all the seasons indicating BB contributed more at Mahabaleshwar. Cluster analysis and concentration weighted trajectory (CWT) analysis were also performed to visualize the importance of regional transport for both the locations. The study confers the significance of regional transport in addition to local emissions over both the sites.

A, Guman Singh Meena , et al. "Seasonal variability and source apportionment of black carbon over a rural high-altitude and an urban site in western India." Atmospheric Pollution Research (2020).

A novel way to calculate shortwave black carbon direct radiative effect

Black carbon (BC) aerosol has a strong radiative forcing effect and significantly affects human beings and the environment. Therefore, it is important to quantitatively calculate its direct radiative effect (BC DRE) at the surface (SFC) and the top of the atmosphere (TOA). Current studies mainly use empirical formula methods or broadband methods to calculate BC DRE. However, these two methods do not consider the differences of sky diffuse light ratios in different wavelength bands. To overcome this problem, a new scheme named the multiband synthetic method is proposed to calculate blue sky albedo at MODIS narrow bands, and then, the blue sky albedo at the whole shortwave band is synthesized with these separate narrowband blue sky albedos. Based on BC concentration measured in Xuzhou over two years (from May 2014 to July 2016), aerosol optical depth (AOD) and microphysical parameters provided by AERONET, and the black sky albedo (BSA) and white sky albedo (WSA) provided by Google Earth Engine (GEE) products, shortwave BC DRE was calculated numerically with the use of the 6S radiative transfer model. The range of BC DRE computed by the multiband synthetic method at the TOA and SFC are 0.84 ± 0.08 to 3.27 ± 1.01W/m2 and −14.57 ± 4.53 to −4.31 ± 0.36W/m2. The shortwave BC DRE calculated by the multiband synthetic method was higher than that calculated with the broadband method and empirical formula method by 0.11% to 0.36% (at the SFC), 0.14% to 1.4% (at the SFC) and 3.4% to 10.1% (at the TOA), 5.5% to 15.8% (at the TOA), respectively. The BC DREs calculated by these three methods have small differences at the SFC. However, the difference was large at the TOA. The results of this study suggest that it is important to consider the differences between different narrow bands when calculating the broadband shortwave blue sky albedo.

Chen, Wei, et al. "A novel way to calculate shortwave black carbon direct radiative effect." Science of The Total Environment (2020): 142961.

Tropospheric Ozone

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

Role of export industries on ozone pollution and its precursors in China

This study seeks to estimate how global supply chain relocates emissions of tropospheric ozone precursors and its impacts in shaping ozone formation. Here we show that goods produced in China for foreign markets lead to an increase of domestic non-methane volatile organic compounds (NMVOCs) emissions by 3.5 million tons in 2013; about 13% of the national total or, equivalent to half of emissions from European Union. Production for export increases concentration of NMVOCs (including some carcinogenic species) and peak ozone levels by 20–30% and 6–15% respectively, in the coastal areas. It contributes to an estimated 16,889 (3,839–30,663, 95% CI) premature deaths annually combining the effects of NMVOCs and ozone, but could be reduced by nearly 40% by closing the technology gap between China and EU. Export demand also alters the emission ratios between

NMVOCs and nitrogen oxides and hence the ozone chemistry in the east and south coast.

Ou, Jiamin , et al. "Role of export industries on ozone pollution and its precursors in China." Nature Communications.

Ozone a persistent challenge to food security in India: Current status and policy implications

With the rising population, urbanization and industrialization, tropospheric ozone (O3) pollution has become a serious challenge to India's food security. We have reviewed the O3 exposure-based Indian studies on yield and quality losses in important crops under the current and future concentrations of O3 to identify the current challenges and policy interventions to reduce the risk of O3 threat to food security in India. The order of sensitivity in major crops is wheat > mustard > rice > maize under ambient O3 concentration. However, the sensitivity of crops at elevated O3 (10–30 ppb) varied with exposure dose, stomatal flux, intrinsic defense response, etc. Effective implementation of the reduction in emission of O3 precursor gases and growing O3 tolerant crops might be helpful to mitigate the O3 impacts at local and national levels.

Mukherjee, Arideep , et al. "Ozone a persistent challenge to food security in India: Current status and policy implications - ScienceDirect." Current Opinion in Environmental ence & Health (2020).

Hydrofluorocarbons (HFCs)

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

Evaluation of low-GWP and mildly flammable mixtures as new alternatives for R410A in air-conditioning and heat pump system

To provide alternative refrigerants for R410A in those applications where the GWP (global warming potential) limit is extremely restrictive in the medium and long term. This work investigated refrigerant blends in both air-conditioning and heat pump applications that can provide similar theoretical cycle performance to R410A. We carried out an extensive screening of blends with a maximum of five components among a list of 12 pure refrigerants comprising three hydrofluoroolefins, five hydrofluorocarbons, two hydrocarbons, CO2 and R13I1. These mixtures were subjected to a multi-parameter optimization process consisting of GWP, flammability and thermodynamic models. The screening metrics included low GWP (⩽150), mild flammability, small temperature glide (⩽10 K), maximum COP (coefficient of performance) and similar volumetric capacity. In total, 34 mixtures were identified to fulfill all the criteria, all of them presented mild flammability and a GWP value below 150, in which 11 mixtures were less than 10. Most of the selected mixtures operated with temperature glide less than 5 K, the mixtures composed by R32/R1123/R13I1 offered an increment of -4% to 17% for the volumetric capacity, but the COPs decreased slightly from 5-10%. Finally, we found 4 mixtures that had almost the same vapor pressure to that of R410A, they were R32/R1123/R161/R13I1 (20/40/10/30), R1123/R161/R13I1 (65/5/30), R1123/R152a/R13I1 (65/5/30) and R1123/R1234ze(E)/R13I1 (65/5/30). The screening results fulfill all the restrictions for the first time, though a further experimental test is needed to confirm the real applicability.

Yu, Binbin , et al. "Evaluation of low-GWP and mildly flammable mixtures as new alternatives for R410A in air-conditioning and heat pump system." International Journal of Refrigeration (2020).

Socio-Economic Impacts

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

Unprecedented health costs of smoke-related PM 2.5 from the 2019–20 Australian megafires

In flammable landscapes around the globe, longer fire seasons with larger, more severely burnt areas are causing social and economic impacts that are unsustainable. The Australian 2019–20 fire season is emblematic of this

trend, burning over 8 million ha of predominately Eucalyptus forests over a six-month period. We calculated the wildfire-smoke-related health burden and costs in Australia for the most recent 20 fire seasons and found that the 2019–20 season was a major anomaly in the recent record, with smoke-related health costs of AU$1.95 billion. These were driven largely by an estimated 429 smoke-related premature deaths in addition to 3,230 hospital admissions for cardiovascular and respiratory disorders and 1,523 emergency attendances for asthma. The total cost was well above the next highest estimate of AU$566 million in 2002–03 and more than nine times the median annual wildfire associated costs for the previous 19 years of AU$211 million. There are substantial economic costs attributable to wildfire smoke and the potential for dramatic increases in this burden as the frequency and intensity of wildfires increase with a hotter climate.

Johnston, Fay H., et al. "Unprecedented health costs of smoke-related PM 2.5 from the 2019–20 Australian megafires." Nature Sustainability (2020): 1-6.

Impact of air pollution in health and socio-economic aspects: Review on future approach

Air contamination is mainly induced by human activity and environmental pollution. Consumption of Air pollution in fewer amounts leads to a significant range of harmful effects on public safety. Nevertheless, with the accelerated pace of economic growth and modernization and the high quantity of electricity need results in huge amounts of pollutants and waste creates significant air pollution. The latest research has shown that because humans only use a tiny part of their day to drive, their constant air quality intake is primarily attributed to the commuting microenvironment. The nature of life on this planet is dependent on clean air. This article presents the literature to include a review of the effect on different facets of human existence of air emissions. The effect is narrowly classified into health and climate change. The study shows that air contamination has a broad variety of consequences, from infectious illnesses and life-threatening disorders and the breakdown of particular organ systems and psychological health. There is no question that this problem has to be addressed with the utmost focus. Such results should be used to prompt further work and to deliver clean air initiatives to officials.

Sivarethinamohan, R., et al. "Impact of air pollution in health and socio-economic aspects: Review on future approach." Materials Today: Proceedings (2020).

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.

Multiscale assessment of the impact on air quality of an intense wildfire season in southern Italy

The summer of 2017 in the Calabria Region (South Italy) was an exceptional wildfire season with the largest area burned by wildfires in the last 11 years (2008–2019). The equivalent black carbon (EBC) and carbon monoxide (CO) measurements, recorded at the high-altitude Global Atmosphere Watch (GAW) Monte Curcio (MCU) regional station, were analyzed to establish the wildfires' impact on air quality, human health, and the ecosystem. A method was applied to identify the possible wildfires that influenced the air quality based on the integration of fire data (both satellite and ground-based) and the high-resolution WRF-HYSPLIT trajectories. The satellite-based fires applied to WRF-HYSPLIT with 10 km of spatial resolution allowed us to establish that for 52.5% of total cases, wildfires were located outside the Calabria Region, and they were influenced by long-range transport. Nonetheless, the impact on human health, qualitatively evaluated in terms of passively smoked cigarettes (PSC) corresponding to the EBC, was greater when wildfires were local. Indeed, for wildfires located mainly in Calabria, the equivalent PSC ranged from 2.75 to 11.08. This maximum PSC value was close to the daily number of smoked cigarettes in Calabria (approximately 12.4). Even if this analogy does not imply a proportional effect between the estimated number of cigarettes smoked and the effective wildfire EBC exposure, this result suggests that wildfire emissions may have negative effects on people's health. Moreover, a focus on the Calabria Region was conducted using high-resolution ground-based GPS and higher resolution WRF-HYSPLIT back-trajectories (2 km)

to measure wildfires. The validity of the methodology was confirmed by the EBC and CO positive correlation with the ratio between the identified ground-based burned areas and the distance from the sampling station. Moreover, the impact on the ecosystem was studied by analyzing the land vegetation loss due to the wildfires that contributed to air quality reduction at the MCU station. A total of more than 1679 ha of vegetation burned, the main losses comprising forests and shrubland.

A, Jessica Castagna , et al. "Multiscale assessment of the impact on air quality of an intense wildfire season in southern Italy." ence of The Total Environment (2020).

Open waste burning causes fast and sharp changes in particulate concentrations in peripheral neighborhoods

The open burning of municipal solid waste (MSW) –frequently observed in developing countries– emits harmful pollutants, including fine particulate matter (PM2.5) and black carbon (BC), and deteriorates the air quality in urban areas. This work reports on PM2.5 and BC measurements (fixed and mobile) conducted in a residential neighborhood on the outskirts of a Brazilian city (Londrina), complemented by a public opinion survey to understand the open burning in the context of waste management. Mean (± standard deviation) BC concentration (1.48 ± 1.40 μg m−3) at the fixed sites of the neighborhood was lower than downtown, while PM2.5 (9.68 ± 8.40 μg m−3) concentration was higher. The mobile monitoring showed higher mean PM2.5 concentrations but lower BC/PM2.5 ratios than downtown, with sharp and fast spikes (up to 317.87 and 565.21 μg m−3 for BC and PM2.5, respectively). The large spatial heterogeneity of particulate concentrations was associated with the occurrence of MSW burning events. Our observations were verified by the survey respondents who identified poor waste management practices: garbage in streets, waste burning, and illegal dump sites. Even though the area has a municipal waste collection service, the majority of the respondents (87%) had seen waste burning close to their homes on a weekly basis, and think that people burn waste out of habit (54%) and because they are not patient to wait for the collection services (67%). To combat this illegal practice, we suggest raising the public awareness through campaigns at local level, adopting education initiatives and economic incentives for correct waste segregation, and enforcing regular inspection of burning events by the authorities. Our research method proved to be a time- and cost-effective approach for mapping particulate concentrations and for identifying undesirable waste practices, and could be effectively applied to other global cities.

Krecl, Patricia, et al. "Open waste burning causes fast and sharp changes in particulate concentrations in peripheral neighborhoods." Science of The Total Environment (2020): 142736.

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

Genetic parameters for methane emission traits in Australian dairy cows

Methane is a greenhouse gas of high interest to the dairy industry, with 57% of Australia's dairy emissions attributed to enteric methane. Enteric methane emissions also constitute a loss of approximately 6.5% of ingested energy. Genetic selection offers a unique mitigation strategy to decrease the methane emissions of dairy cattle, while simultaneously improving their energy efficiency. Breeding objectives should focus on improving the overall sustainability of dairy cattle by reducing methane emissions without negatively affecting important economic traits. Common definitions for methane production, methane yield, and methane intensity are widely accepted, but there is not yet consensus for the most appropriate method to calculate residual methane production, as the different methods have not been compared. In this study, we examined 9 definitions of residual methane production. Records of individual cow methane, dry matter intake (DMI), and energy corrected milk (ECM) were obtained from 379 animals and measured over a 5-d period from 12 batches across 5 yr using the SF6 tracer method and an electronic feed recording system, respectively. The 9 methods of calculating residual methane involved genetic and phenotypic regression of methane production on a

combination of DMI and ECM corrected for days in milk, parity, and experimental batch using phenotypes or direct genomic values. As direct genomic values (DGV) for DMI are not routinely evaluated in Australia at this time, DGV for FeedSaved, which is derived from DGV for residual feed intake and estimated breeding value for bodyweight, were used. Heritability estimates were calculated using univariate models, and correlations were estimated using bivariate models corrected for the fixed effects of year-batch, days in milk, and lactation number, and fitted using a genomic relationship matrix. Residual methane production candidate traits had low to moderate heritability (0.10 ± 0.09 to 0.21 ± 0.10), with residual methane production corrected for ECM being the highest. All definitions of residual methane were highly correlated phenotypically (>0.87) and genetically (>0.79) with one another and moderately to highly with other methane candidate traits (>0.59), with high standard errors. The results suggest that direct selection for a residual methane production trait would result in indirect, favorable improvement in all other methane traits. The high standard errors highlight the importance of expanding data sets by measuring more animals for their methane emissions and DMI, or through exploration of proxy traits and combining data via international collaboration.

Richardson, C. M., et al. "Genetic parameters for methane emission traits in Australian dairy cows." Journal of Dairy Science (2020).

Strong mitigation of greenhouse gas emission impact via aerobic short pre-digestion of green manure amended soils during rice cropping

To increase soil carbon (C) stock, cover crop cultivation during the fallow season and its biomass incorporation as green manure (GM) is strongly suggested in mono-rice paddy. On the other hand, biomass application can highly increase greenhouse gas (GHG) emission, in particular methane (CH4) during irrigated cropping season. Aerobic short pre-digestion of biomass applied soils was very effective to suppress CH4 emission. However, its effect on other GHG (CO2 and N2O) emissions was not clear. To assess the integrated influence of aerobic short pre-digestion of green manured soils on global warming impact, cover crop biomass as GM was amended with different time interval before flooding (0–30 days) and aerobically decomposed under upland condition. Aerobic short pre-digestion over 10 days significantly decreased seasonal CH4 flux, but did not affect N2O emission. As aerobic pre-digestion days became longer, net ecosystem C balance (NECB) which implies the difference between C input and output was slightly increased, but not statistically different. The net primary productivity of rice plant as a C input source was not significantly differentiated by aerobic short pre-digestion. As a C output source, the respired C loss that was composed with CO2-C and CH4-C emission was not considerably discriminated among 0–30 days of aerobic short pre-digestion. As a consequence, due to big reduction of CH4 emission, aerobic short pre-digestion significantly decreased net GWP which means integration of seasonal CH4 and N2O fluxes and NECB as CO2 equivalent. In conclusion, aerobic short pre-digestion of biomass applied soil could be a sustainable management practice to decrease GHG emission impact without SOC stock change in temperate rice paddy field.

Song, Hyeon Ji, et al. "Strong mitigation of greenhouse gas emission impact via aerobic short pre-digestion of green manure amended soils during rice cropping." Science of The Total Environment (2020): 143193.

Animal, feed and rumen fermentation attributes associated with methane emissions from sheep fed brassica crops

Methane emissions from ruminants enhance global warming and lead to a loss of feed energy. The emissions are low when fed brassica crops, but the factors contributing to low emissions are unknown. A meta-analysis was conducted with individual animal data collected from seven experiments. In these experiments, methane emissions were measured using respiration chambers. Animal characteristics, feed chemical composition and rumen fermentation parameters were included for the analysis using multiple regression models. Feed intake level, animal live weight and age were animal factors that were weakly and negatively related to methane yield (g/dry matter intake). The duration in which sheep were fed brassica crops was a significant contributor in the model, suggesting that the effect on emissions diminishes with time. Among a range of feed chemical composition characters, acid detergent fibre and hot-water-soluble carbohydrate contributed significantly to the model, suggesting that both structural and soluble carbohydrates affect methane formation in the rumen.

There was no significant correlation between the concentration of sulphate in brassicas and emissions, but nitrate was moderately and negatively correlated with methane yield (r = −.53). Short-chain fatty acid profiles in the rumen of animals fed brassicas were different from those fed pasture, but these parameters only moderately correlated to methane emissions (r = .42). Feeding forage rape resulted in low rumen pH. The pH before morning feeding was strongly correlated to methane yield (r = .90). Rumen pH, together with microbial communities mediated by pH, might lead to low emissions. Bacteria known to produce hydrogen were relatively less abundant in the rumen contents of brassica-fed animals than pasture-fed animals. In conclusion, animal and feed factors, rumen fermentation and microbial communities all affect methane emissions to some extent. The interactions of these factors with each other thus contribute to methane emissions from brassica-fed sheep.

He, Yuhua , X. Sun , and P. You . "Animal, feed and rumen fermentation attributes associated with methane emissions from sheep fed brassica crops." Journal of Animal Physiology and Animal Nutrition (2020).

Transportation

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

On the effects of aviation on carbon-methane cycles and climate change during the period 2015-2100

The effects of aviation on the Earth's atmosphere are mainly focused on greenhouse gases emissions, since CO2 and CH4 emissions are an important part of climate change contribution. The purpose of this paper is to discuss and evaluate this contribution using a coupled model of global CO2 and CH4 cycles, taking into account the maximum number of reservoirs and fluxes of these gases. According to this approach, a method based on a simple climate model and a simulation model of global CO2 and CH4 cycles is proposed, as a tool to determine the aviation's role in climate change. This coupled model consists of eight separate blocks that perform specific functions to evaluate the impacts of aviation emissions on climate change in a series of scenarios. The proposed method can calculate the global temperature change in various scenarios by processing the available data in the current literature. Based on these data it has been shown that global temperature and CO2 concentration in the atmosphere can increase by 1–3 °C and up to 570–750 ppm, respectively, depending on the anthropogenic scenario. The global temperature forecast is obtained with an average error of 3.4%.The results of this study show that the aviation's contribution to these changes during 2015–2100 is1.5 ± 0.1%.

A, Costas Varotsos , et al. "On the effects of aviation on carbon-methane cycles and climate change during the period 2015-2100." Atmospheric Pollution Research (2020).

On-road vehicle emission inventory and its spatio-temporal variations in North China Plain

Vehicle emissions are a major contributor to air pollution in China. In this study, a high-resolution inventory of eight on-road vehicle-emitted pollutants in 53 cities within the North China Plain (NCP) was established for 152 sub-sources. Monthly emission factors were then simulated using the COPERT v5 model and their spatial distribution at 4 km × 4 km resolution was allocated based on the transportation network. In 2017, emissions of BC, CO, NH3, NMVOCs, NOx, PM10, PM2.5, and SO2 were 38.3, 2900, 21.8, 578, 2460, 113, 85.9, and 4.7 kt, respectively. These emissions and their sources differed between cities, mainly due to different vehicle populations, fleet compositions, emission share rates of different vehicle types, and emission standards in each city. Small-medium petrol passenger cars and both 20–26 t and 40–50 t heavy-duty diesel trucks of China 3 and 4 emissions standards were the main contributors for all pollutants. Higher cold-start emission factors caused higher emissions of CO, NMVOCs, NOx, and PM2.5 in winter. The cities of Beijing, Zhengzhou, Tianjin, Tangshan, Xuzhou, Qingdao, Jinan, Jining, and Zibo had the highest emission intensities. Overall, emissions decreased from the city centers toward surrounding areas. The higher contributions of heavy-duty trucks meant that higher emissions appeared along highways in a vein-like distribution. These results provide a theoretical basis for the effective prevention and control of air pollution in the NCP.

A, Peiyu Jiang , X. Z. B , and L. L. A . "On-road vehicle emission inventory and its spatio-temporal variations in

North China Plain - ScienceDirect." Environmental Pollution 267(2020).

Air pollution & Health Impacts

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

Comparison of hospitalization and mortality associated with short-term exposure to ambient ozone and PM2.5 in Canada

Background: Hospitalization and mortality (H-M) have been linked to air pollution separately. However, previous studies have not adequately compared whether air pollution is a stronger risk factor for hospitalization or mortality. This study aimed to investigate differences in H-M risk from short-term ozone and PM2.5 exposures, and determine whether differences are modified by season, age, and sex. Methods: Daily ozone, PM2.5, temperature, and all-cause H-M counts (ICD-10, A00-R99) were collected for 22–24 Canadian cities for up to 29 years. Generalized additive Poisson models were employed to estimate associations between each pollutant and health outcome, which were compared across season (warm, cold, or year-round), age (all ages or seniors > 65), and sex. Results: Overall, ozone and PM2.5 showed higher season-specific risk of mortality than hospitalization: warm-season ozone: 0.54% (95% credible interval, 0.20, 0.85) vs. 0.14% (0.02, 0.27) per 10 ppb; and year-round PM2.5: 0.90% (0.33, 1.41) vs. 0.29% (0.03, 0.56) per 10 μg/m3. While age showed little H-M difference, sex appeared to be a modifier of H-M risk. While females had higher mortality risk, males had higher hospitalization risk: for females, ozone 0.87% (0.36, 1.35) vs. −0.03% (−0.18, 0.11) and PM2.5 1.19% (0.40, 1.90) vs. 0.19% (−0.10, 0.47); and for males ozone 0.20% (−0.28, 0.65) vs. 0.35% (0.18, 0.51). Conclusion: This study found H-M differences attributable to ozone and PM2.5, suggesting that both are stronger risk factors for mortality than hospitalization. In addition, there were clear H-M differences by sex: specifically, females showed higher mortality risk and males showed higher hospitalization risk.

B, Hwashin Hyun Shin A , et al. "Comparison of Hospitalization and Mortality Associated with Short-term Exposure to Ambient Ozone and PM 2.5 in Canada." Chemosphere (2020).

Rapid increase in mortality attributable to PM2.5 exposure in India over 1998–2015

PM2.5-attributable deaths and years of life lost (YLL) due to specific causes during 1998–2015 in India were estimated using the integrated exposure-response (IER) model. The estimated PM2.5-mortality in India revealed an annual increasing rate of 2.7% during the study period. Spatially, deaths due to the exposure to ambient PM2.5 concentrated mostly in populated North India, and four northern states contributed 43% to the national PM2.5-attributable deaths in 2015. PM2.5-attributable deaths in India increased by 21% during 1998–2015 due to the changes of PM2.5 only, and deaths due to lung cancer (LC) revealed the largest sensitivity to increasing ambient PM2.5. The findings of this study suggest that aggressive air pollution control strategies should be implemented in North India due to their dominant contributions to the current health risks. Moreover, the rapid growth of LC related deaths with increasing ambient PM2.5 should not be neglected.

Jia, Beixi , et al. "Rapid increase in mortality attributable to PM 2.5 exposure in India over 1998-2015." Chemosphere (2020).

PM2.5 air pollution contributes to the burden of frailty

Frailty is common among older people and results in adverse health outcomes. We investigated whether exposure to PM2.5 is associated with frailty. This cross-sectional study involved 20,606 community-dwelling participants aged ⩾ 65 years, residing in New Taipei City, Taiwan. Analytic data included phenotypic frailty, disease burden by Charlson Comorbidity Index (CCI), urban or rural residence, and household income. PM2.5 exposure was calculated from air quality monitoring records, with low exposure defined as the lowest quartile of the study population. 1,080 frail participants (5.2%) were older, predominantly female, had more comorbidities, lived rurally, and had low PM2.5 exposure (all $p < 0.001$). In multinomial logistic regression

analyses, the likelihood of high PM2.5 exposure was higher in prefrail (OR 1.4, 95% CI 1.3–1.5) and frail adults (OR 1.5, 95% CI 1.2–1.9) than in robust individuals, with stronger associations in those who were male (frail: OR 2.1, 95% CI 1.5–3.1; prefrail: OR 2.2, 95% CI 1.9–2.6), ⩾ 75 years old (frail: OR 1.8, 95% CI 1.3–2.4; prefrail: OR 1.5, 95% CI 1.3–1.8), non-smokers (frail: OR 1.6, 95% CI 1.3–2.0; prefrail: OR 1.4, 95% CI 1.2–1.5), had CCI ⩾ 2 (frail: OR 5.1, 95% CI 2.1–12.6; prefrail: OR 2.1, 95% CI 1.2–3.8), and with low household income (frail: OR 4.0, 95% CI 2.8–5.8; prefrail: OR 2.7, 95% CI 2.2–3.3). This study revealed a significant association between PM2.5 exposure and frailty, with a stronger effect in vulnerable groups.

Lee, Wei Ju , et al. "air pollution contributes to the burden of frailty." entific Reports.

Health benefits of achieving fine particulate matter standards in India – A nationwide assessment

Ambient fine particulate matter (PM2.5) is one of the leading risk factors in India. The elevated levels of PM2.5 exposure concentration in India are related to higher premature mortality. However, health benefits or avoidable premature mortality by reducing PM2.5 concentration is uncertain. Here we simulated the health benefits by assuming the achievement of 1) National Ambient Air Quality Standards of India (PM2.5 annual average = 40 µg m−3), 2) National Clean Air Programme policy (30% reduction) and 3) World Health Organization standard (10 µg m−3). Using Environmental Benefits Mapping and Analysis Program – Community Edition (BenMAP-CE), the health benefits are estimated at national, state and district levels for various health endpoints viz., all-cause, ischaemic heart disease (IHD), chronic obstructive pulmonary disease (COPD), lung cancer and stroke. PM2.5 data, concentration-response coefficient, population, and baseline incidence rate are specified as input data in BenMAP–CE. At the national level, all-cause health benefits in three simulations range from 0.79 to 2.1 million cases during 2019. Similarly, IHD, COPD, lung cancer, and stroke related health benefits are in the range of 0.28–0.68, 0.17–0.39, 0.01–0.03, and 0.14–0.34 million cases, respectively. State-level estimates showed that Uttar Pradesh, Bihar, and West Bengal are having maximum health benefits whereas north-eastern states are found with lowest estimates. Districts such as Allahabad, Lucknow, Muzaffarpur, Patna, and Sultanpur are estimated to have highest health benefits. States and districts with higher PM2.5 concentration and exposed population are found with maximum health benefits. Among the three simulations, achievement of the World Health Organization standard resulted in highest estimates. Further, the limitations and sensitivity of input parameters used in this study are discussed in detail. Study results highlighted the need for state and district-specific air quality management measures to increase PM2.5 related health benefits.

Manojkumar, N., and B. Srimuruganandam. "Health benefits of achieving fine particulate matter standards in India–A nationwide assessment." Science of The Total Environment (2020): 142999.

Urban Air Pollution & Megacities

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

Urban and air pollution: a multi-city study of long-term effects of urban landscape patterns on air quality trends

Most air pollution research has focused on assessing the urban landscape effects of pollutants in megacities, little is known about their associations in small- to mid-sized cities. Considering that the biggest urban growth is projected to occur in these smaller-scale cities, this empirical study identifies the key urban form determinants of decadal-long fine particulate matter (PM2.5) trends in all 626 Chinese cities at the county level and above. As the first study of its kind, this study comprehensively examines the urban form effects on air quality in cities of different population sizes, at different development levels, and in different spatial-autocorrelation positions. Results demonstrate that the urban form evolution has long-term effects on PM2.5 level, but the dominant factors shift over the urbanization stages: area metrics play a role in PM2.5 trends of small-sized cities at the early urban development stage, whereas aggregation metrics determine such trends mostly in mid-sized cities. For large cities exhibiting a higher degree of urbanization, the spatial connectedness of urban patches is positively associated with long-term PM2.5 level increases. We suggest that, depending on the city's

developmental stage, different aspects of the urban form should be emphasized to achieve long-term clean air goals.

Liang, Lu , and P. Gong . "Urban and air pollution: a multi-city study of long-term effects of urban landscape patterns on air quality trends." entific Reports.

Quantification of different processes in the rapid formation of a regional haze episode in north China using an integrated analysis tool coupling source apportionment with process analysis

North China Plain (NCP) is one of the most of heavily polluted regions in the world, air pollution associated with haze threatens human health. A high PM2.5 concentration event in the NCP from 30 November to 10 December 2017 was simulated and analyzed by using the Weather Research and Forecasting (WRF) model and the Nested Air Quality Prediction Modeling System (NAQPMS) with an integrated analysis tool coupling source apportionment with process analysis. The weather field simulated by the WRF model and the PM2.5 concentration simulated by NAQPMS agreed well with observations, and the correlation coefficient of PM2.5 between the simulation and observation data remained >0.8 during the study period. We found that this high PM2.5 event can be divided into three phases in NCP: The accumulation of PM2.5 in Phase I was slow and dominated by south or weak winds in the stable boundary layer. In Phase II, PM2.5 concentrations kept a high value in the short term under northern winds resulting from the edge of a cold front. The sustainable high value of PM2.5 concentration in the middle and south of the NCP under northly wind has been less reported. An integrated process contribution analysis and source apportionment technology coupled with NAQPMS showed that the PM2.5 in the north and middle of the NCP were transported to the southern area by the horizontal transmission process. This transport kept PM2.5 high in the south of the NCP and even exceeded the contribution of local emissions. In the Phase III, the strong northern winds from main body of the cold front brought clear air masses and caused the PM2.5 decrease in the whole NCP. The study shows that high dense emissions in the middle of NCP are the main cause for the high PM2.5 events in the whole region, and the north wind could transport the pollutants form upstream region to downstream region, causing the continued high PM2.5 in the middle and south of NCP.

B, Tao Wang A , et al. "Quantification of different processes in the rapid formation of a regional haze episode in north China using an integrated analysis tool coupling source apportionment with process analysis." Atmospheric Pollution Research (2020).

Appraisal of regional haze event and its relationship with PM2.5 concentration, crop residue burning and meteorology in Chandigarh, India

Air pollution affects not only the air quality in megacities but also in medium and small-sized cities due to rapid urbanization, industrialization, and other anthropogenic activities. From October 28, 2015 to November 3, 2015, the Indo-Gangetic Plains region, including Chandigarh encountered an episode of poor visibility during the daytime. The daily average PM2.5 concentration reached 191 µg/m3, and visibility reduced by ~2.2 times in the Chandigarh region. PM2.5 concentration was found around 4 times higher than a non-haze day and more than 3 times higher than National Ambient Air Quality Standards for 24 h. A significant correlation between PM2.5 and CO (r: 0.87) during the haze period indicated similarity in their emission sources; which was attributed to the burning of solid organic matter. Further, satellite data and back-trajectory analysis of air masses showed large-scale rice stubble burning in the agricultural fields, adjoining to the city areas. The transboundary movement of air masses below 500 m and meteorological conditions played a major role in building the pollution load in the Chandigarh region. Moreover, the enhanced concentration of biomass burning tracers, i.e., organic carbon (~3.8 times) and K+ ions (2~ times) in PM2.5 and acetonitrile (~2.3 times) in ambient air was observed during the haze event. The study demonstrates how regional emissions and meteorological conditions can affect the air quality in a city; which can be useful for proper planning and mitigation policies to minimize high air pollution episodes.

Ravindra, Khaiwal, et al. "Appraisal of regional haze event and its relationship with PM2. 5 concentration, crop residue burning and meteorology in Chandigarh, India." Chemosphere (2020): 128562.

Source apportionment of PM2.5 in the most polluted Central Plains Economic Region in China: Implications for joint prevention and control of atmospheric pollution

With continuous strengthening of emission control actions, the air quality in northern China during winter has been improved in recent years. However, the fine particulate matter (PM2.5) concentration remains high in the Central Plains Economic Region (CPER). The Nested Air Quality Prediction Modeling System coupled with an on-line source-tagged model was applied to investigate the source apportionment of primary and secondary PM2.5 in the most polluted area of China from November 2017 to March 2018. On average, local emissions represent the largest contributor to ambient PM2.5 levels, followed by transport from circumjacent cities at five receptors in northern CPER. Under high PM2.5 concentrations (more than 150 μg/m3), 60%–70% of the primary PM2.5 is freshly emitted on the current day, while the contribution of the current day, one day ago, and two or more days ago are comparable to secondary aerosols. The estimation of contributions based on distance shows that the contribution from regions within 200 km reaches more than 80% of the primary PM2.5, while the contribution from long-range transport within 200–500 km still accounts for more than 20% of the secondary PM2.5 at the receptor sites. These results indicate that control measures of primary particle emission should be effective to reduce the primary PM2.5 levels within local and nearby regions, and control measures of gas phase precursors one or more days in advance should be beneficial to surrounding regions within 500 km. The process analysis results of the change in PM2.5 mass over the northern part of the CPER during increased PM2.5 periods illustrate that the existing particle total transport is smaller than the secondary aerosol chemical production and primary aerosol emissions since the westerly and southerly net inputs are mostly offset by the large net outputs at the east boundary in both cases. This finding indicates that the ambient PM2.5 mass in a selected area is strongly affected by the upstream region; meanwhile, the PM2.5 in this area also spreads to the downstream region. Joint prevention and control measures that cooperate with upstream regions for both primary particles and gas phase precursor emissions are crucial for improving the air quality over polluted areas. As the emission control measures would lead to some economic losses, beneficiary downstream regions could reasonably provide certain economic compensation to upstream regions if emergency control measures are taken.

Yang, Wenyi, et al. "Source apportionment of PM2. 5 in the most polluted Central Plains Economic Region in China: Implications for joint prevention and control of atmospheric pollution." Journal of Cleaner Production (2020): 124557.

Impacts of multi-scale urban form on PM2.5 concentrations using continuous surface estimates with high-resolution in U.S. metropolitan areas

This study explores the relationship between urban form at the metropolitan and neighborhood scale and fine particulate matter (PM2.5) concentrations by establishing multi-level regression models. This study has different assumptions about urban form depending on the scale used. While at the metropolitan scale, the urban form is related to the change in travel behavior, at the neighborhood scale, it is related to proximate emission sources such as roads, emissions facilities, employment centers, etc. The study shows that at the metropolitan scale, higher urban fragments, population density, and road density are associated with higher PM2.5 concentrations; higher job-resident balance and accessibility to schools are associated with lower PM2.5. At the neighborhood scale, a higher density of the nearby emission sources and higher accessibility to destinations are associated with higher PM2.5 concentrations. Urban fragments and land use mix have consistent impacts on air quality compared to preexisting studies. While population density and road density have two conflicting assumptions regarding PM2.5, in this study, the net effect of population density and road density on air quality is negative. Accessibility to destinations has different associations with PM2.5 depending on the scale of urban form measurement. At the metropolitan scale, high accessibility to destinations lessens PM2.5 concentrations by reducing vehicle distance. On the other hand, at the neighborhood scale, high accessibility to destinations makes it close to areas, which concentrate air emissions. We suggest that urban planners and decision-makers establish different strategies depending on urban form types when there are urban development plans.

Lee, Changyeon . "Impacts of multi-scale urban form on PM2.5 concentrations using continuous surface estimates with high-resolution in U.S. metropolitan areas." Landscape and Urban Planning 204.

Increase in household energy consumption due to ambient air pollution

In response to acute environmental stresses such as air pollution, households may resort to quick and convenient adaptation measures that increase energy use, amplifying the environmental impact and requiring additional adaptation. This cycle of energy-intensive adaptation has so far received little consideration by the broader energy community. Here, we analyse the response of Korean households to PM2.5 (ultrafine dust), based on real-time hourly smart meter data. We show that a 75 μg m–3 increase in PM2.5 concentration led to an 11.2% increase in electricity consumption, equivalent to the impact of a 3.5 °C increase in the average summer temperature. The magnitude of the energy-intensive adaptation correlated with households' lifestyles and was higher on weekends and during daytime hours on both weekdays and weekends. The responses also reflected seasonal differences and had a U-shape relationship with temperature. We illustrate the importance of integrating the broader impacts of air pollution into policymaking to strike a proper balance between its mitigation and adaptation.

Eom, Jiyong , et al. "Increase in household energy consumption due to ambient air pollution." Nature Energy.

SLCPs & Vulnerable Regions

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

A review of black carbon in snow and ice and its impact on the cryosphere

Black carbon (BC) has emerged as an important short-lived climate forcer. Due to its light absorption properties, BC can darken the snow/ice surface, affect the energy balance, and further lead to acceleration of the melting of the cryosphere (e.g., glaciers, snow cover, and sea ice). By reviewing the recent published literatures, we present an overview of the historical changes, spatial distribution of BC in snow/ice, and how these changes are related to the cryospheric melting. Ice core records show a rapid increase of BC concentrations that began in the 1850s and continued throughout the 20th century, which is consistent with an increase of BC emissions owing to industrialization. A decrease of BC amount since 1970s in Arctic and European ice cores has been partially attributed to the Clean Air Act. However, in the Himalayas, BC records show a continuous increase during this period. Generally, BC concentrations in snow and ice in the mid-latitude regions are one to two orders of magnitude higher than those in the polar regions. In particular, BC concentrations in aged snow and granular ice in the ablation areas of mountain glaciers are one to three orders of magnitude higher than those in fresh snow or snowpits in the glacier accumulation areas due to BC accumulation during melting season. BC in the surface snow/ice is responsible for about 20% of the albedo reduction in the Tibetan Plateau during glacier melt season. Globally, observations and modeling results indicate that radiative forcing (RF) induced by BC in snow and ice is highest in the mid-latitudes, ranging from several W m−2 in fresh snow to hundreds of W m−2 in aged snow and granular ice in the glacier ablation areas. The large BC-in-snow RF and associated snow albedo feedback lead to an acceleration in the total glacier melt (approximately 20%) and/or a reduction in the duration of the snow cover by several days, resulting in an increase of glacier discharge. Given our limited understanding of quantifying the role of BC in cryospheric melting, it is important to synthesize the existing research on the multi-scale processes related to BC in snow and ice to identify the gaps in our understanding of these processes and to propose a path forward to improve the quality of our observations of the aforementioned phenomena to fill these gaps.

Kang, Shichang , et al. "A review of black carbon in snow and ice and its impact on the cryosphere." Earth-Science Reviews (2020):103346.

Black Carbon Deposited in Hariqin Glacier of the Central Tibetan Plateau Record Changes in the Emission from Eurasia

Black carbon (BC), by the combustion of fossil fuels and biomass, has profound effects on climate change and glacier retreat in industrial eras. In the present study, we report refractory BC (rBC) in an ice core spanning 1850–

2014, retrieved from the Hariqin Glacier of the Tanggula Mountains in the central Tibetan Plateau, measured using a single particle soot photometer (SP2). The rBC concentration shows a three-fold increase since the 1950s. The mean rBC concentration was 0.71±0.52 ng mL-1 during 1850s–1940s and 2.11±1.60 ng mL-1 during 1950s–2010s. The substantial increase in rBC since the 1950s is consistent with rBC ice core records from the Tibetan Plateau and Eastern Europe. According to the predominant atmospheric circulation patterns over the glacier and timing of changes in regional emissions, the post-1950 amplification of rBC concentration in the central Tibetan Plateau most likely reflects increases in emissions in Eastern Europe, former USSR, the Middle East, and South Asia. Despite the low-level background rBC concentrations in the ice cores from the Tibetan Plateau, the present study highlights a remarkable increase in anthropogenic BC emissions in recent decades and the consequent influence on glaciers in the Tibetan Plateau.

Wang, Mo, et al. "Black Carbon Deposited in Hariqin Glacier of the Central Tibetan Plateau Record Changes in the Emission from Eurasia." Environmental Pollution (2020): 115778.