Short-Lived Climate Pollutants Research Digest

January - February

2020

The Scientific Advisory Panel

of the

CLIMATE & CLEAN AIR COALITION

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

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

Modelling of sectoral emissions of short-lived and long-lived climate pollutants under various control technological strategies

In India, air pollution has been acknowledged as the fifth most imperative cause of mortality due to high emissions from burning of fossil fuels in industries (brick kilns and thermal power plants), biomass burning, agricultural residue burning and transportation. The emissions of black carbon (BC) with the other air pollutants (CO2, CH4, N2O, HFC, PFC, and SF6), is taking considerable attention in the world because of its ability to effect air quality and weather. The Indo-Gangetic Plains (IGP) region has been considered as one of the greatest source of emissions in India. The short lived climate pollutants (SLCPs) like BC, methane, tropospheric ozone and hydrofluorocarbons have been considered as a climate forcing agent along with CO2. These pollutants have shorter lifetime in atmosphere compared to CO2 and account for the 40–45% of global warming. Among them, BC has a great global warming ability and can increase the Earth's temperature much quicker than carbon dioxide. After CO2, the second highest donors to global warming are CH4 and BC. Recognising the importance of these pollutants, daily concentrations of BC, PM2.5 and PM10 were monitored in three district of IGP during January 2015 to December 2016. The GAINS model was used for assessment of pollution effects, emissions of SLCPs, GHGs and identifying appropriate control actions. The outcomes of modelling advocate that low carbon strategies are more competent to reduce emissions as compared to other control strategies. But, application of low carbon strategies would be restricted by the accessibility of clean fuels. In some cases, finance will be needed to support monitoring of air pollution and other supportive technologies.

Arif, Mohammad, et al. "Modelling of sectoral emissions of short-lived and long-lived climate pollutants under various control technological strategies." Science of The Total Environment 699 (2020): 134358.

Multiple Benefits/Impacts & Crosscutting

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

Analysis of air quality and health co-benefits regarding electric vehicle promotion coupled with power plant emissions

Purpose of this study is to discuss the electric vehicle policy's effects on air pollution reduction in Taiwan. Since PM2.5 is one of Taiwan's major air-pollution issues, Environmental Protection Administration of Taiwan (TEPA) promoted a policy that the sale of cars powered by fossil fuels would be banned in 2040, which means all the pollutants emitted by petrol-engine vehicles will be reduced. But at the same time the electric vehicles require additional power consumption, therefore, it is important to investigate the effect of air quality and health benefit when mobile emission reduces but power plant emission increases.

To evaluate this clean air policy, Weather Research and Forecasting model (WRF) - Community Multi-scale Air Quality model (CMAQ) and Benefits Mapping and Analysis Program (BenMAP) were applied in scenarios discussion. The location of power plants to generate additional electric power and the seasonal variation were adapted in scenarios for considering the atmospheric transportation effects. The results showed if additional power supply was generated in northern, central, or southern Taiwan, the average annual PM2.5 concentration would be reduced by 2.88, 2.90, and 2.92 μg/m3, respectively. The associated health benefits would be 43.35 billion, 43.40 billion, and 43.54 billion USD. This evaluation presents adopting electric vehicles would improve the air quality of Taiwan significantly.

The analysis of seasonal scenarios also indicates the location to generate additional electric power is important when adopting electric vehicles policy. The prevailing wind of different season will transport the air pollutant to diverse downwind area. The additional electricity demand generated by northern power plants in summer and autumn but switched to southern power plants in spring and winter would reduce 2.95 μg/m3 PM2.5 and lead

to the best air quality and health benefits across Taiwan among the considered options.

Lin, Wen-Yinn, et al. "Analysis of air quality and health co-benefits regarding electric vehicle promotion coupled with power plant emissions." Journal of Cleaner Production 247 (2020): 119152.

Methane

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

Methane Mitigation: Methods to Reduce Emissions, on the Path to the Paris Agreement

The atmospheric methane burden is increasing rapidly, contrary to pathways compatible with the goals of the 2015 United Nations Framework Convention on Climate Change Paris Agreement. Urgent action is required to bring methane back to a pathway more in line with the Paris goals. Emission reduction from “tractable” (easier to mitigate) anthropogenic sources such as the fossil fuel industries and landfills is being much facilitated by technical advances in the past decade, which have radically improved our ability to locate, identify, quantify, and reduce emissions. Measures to reduce emissions from “intractable” (harder to mitigate) anthropogenic sources such as agriculture and biomass burning have received less attention and are also becoming more feasible, including removal from elevated-methane ambient air near to sources. The wider effort to use microbiological and dietary intervention to reduce emissions from cattle (and humans) is not addressed in detail in this essentially geophysical review. Though they cannot replace the need to reach “net-zero” emissions of CO2, significant reductions in the methane burden will ease the timescales needed to reach required CO2 reduction targets for any particular future temperature limit. There is no single magic bullet, but implementation of a wide array of mitigation and emission reduction strategies could substantially cut the global methane burden, at a cost that is relatively low compared to the parallel and necessary measures to reduce CO2, and thereby reduce the atmospheric methane burden back toward pathways consistent with the goals of the Paris Agreement.

Nisbet, E. G., et al. "Methane mitigation: methods to reduce emissions, on the path to the Paris Agreement." Reviews of Geophysics 58.1 (2020): e2019RG000675.

Understanding atmospheric methane sub-seasonal variability over India

Atmospheric methane (CH4) is considered to be one of the most important greenhouse gases due to its increasing atmospheric concentrations and the fact that it has a warming potential 28 times that of atmospheric carbon dioxide (CO2). Over the Indian sub-continent, fluxes and transport both contribute towards CH4 seasonal variability. Its intra-seasonal variability however is more complex as it is additionally influenced by monsoonal activity during the Asian Summer Monsoon (ASM) period. In this study, the intra-seasonal variability of atmospheric CH4 is examined using ground-based observations at two sites located in the Southern Indian Peninsula, Sinhagad (SNG) and Cape Rama (CRI); and outputs from three different model simulations. Both, the ground based observations and multi-model simulations show that the dominant spectral variability of CH4 is coherent with 20–90 day oscillations in the dynamics of the monsoon (termed hereafter as Intra-Seasonal Oscillations, ISOs). The multi-model analysis revealed that CH4 is heavily influenced by advection due to this intra-seasonal variability. The simulations also display a clear northward propagation of CH4 anomalies over India. The co-evolution of CH4, outgoing long wave radiation (to represent convection) and OH radicals (proxy to CH4 sinks) is presented. The study quantifies CH4 variability at intra-seasonal timescales and also its spatial extent. The results suggest that the effect of ISOs on CH4 needs to be considered along with the corresponding observations for future inverse modeling.

Tiwari, Yogesh K., et al. "Understanding atmospheric methane sub-seasonal variability over India." Atmospheric Environment 223 (2020): 117206.

Technical potentials and costs for reducing global anthropogenic methane emissions in the 2050 timeframe –results from the GAINS model

Methane is the second most important greenhouse gas after carbon dioxide contributing to human-made global warming. Keeping to the Paris Agreement of staying well below two degrees warming will require a concerted

effort to curb methane emissions in addition to necessary decarbonization of the energy systems. The fastest way to achieve emission reductions in the 2050 timeframe is likely through implementation of various technical options. The focus of this study is to explore the technical abatement and cost pathways for reducing global methane emissions, breaking reductions down to regional and sector levels using the most recent version of IIASA's Greenhouse gas and Air pollution Interactions and Synergies (GAINS) model. The diverse human activities that contribute to methane emissions make detailed information on potential global impacts of actions at the regional and sectoral levels particularly valuable for policy-makers. With a global annual inventory for 1990–2015 as starting point for projections, we produce a baseline emission scenario to 2050 against which future technical abatement potentials and costs are assessed at a country and sector/technology level. We find it technically feasible in year 2050 to remove 54 percent of global methane emissions below baseline, however, due to locked in capital in the short run, the cumulative removal potential over the period 2020–2050 is estimated at 38 percent below baseline. This leaves 7.7 Pg methane released globally between today and 2050 that will likely be difficult to remove through technical solutions. There are extensive technical opportunities at low costs to control emissions from waste and wastewater handling and from fossil fuel production and use. A considerably more limited technical abatement potential is found for agricultural emissions, in particular from extensive livestock rearing in developing countries. This calls for widespread implementation in the 2050 timeframe of institutional and behavioural options in addition to technical solutions.

Höglund-Isaksson, Lena, et al. "Technical potentials and costs for reducing global anthropogenic methane emissions in the 2050 timeframe–results from the GAINS model." Environmental Research Communications (2020).

Airborne Mapping Reveals Emergent Power Law of Arctic Methane Emissions

Methane (CH4) emissions from thawing permafrost amplify a climate warming feedback. However, upscaling of site-level CH4 observations across diverse Arctic landscapes remains highly uncertain, compromising accuracy of current pan-Arctic CH4 budgets and confidence in model forecasts. We report a 30,000-km2 survey at 25-m2 resolution (~1 billion observations) of CH4 hotspot patterns across Alaska and northwestern Canada using airborne imaging spectroscopy. Hotspots covered 0.2% of the surveyed area, concentrated in the wetland-upland ecotone, and followed a two-component power law as a function of distance from standing water. Hotspots decreased sharply over the first 40 m from standing water (y = 0.21×−0.649, R2 = 0.97), mirroring in situ flux observations. Beyond 40 m, CH4 hotspots diminished gradually over hundreds of meters (y = 0.004×−0.164, R2 = 0.99). This emergent property quantifies the distribution of strong methanogenic zones from site to regional scales, vastly improving metrics for scaling ground-based CH4 inventories and validation of land models.

Elder, Clayton D., et al. "Airborne Mapping Reveals Emergent Power Law of Arctic Methane Emissions." Geophysical Research Letters 47.3 (2020): e2019GL085707.

Black Carbon

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

Atmospheric heating rate due to black carbon aerosols: Uncertainties and impact factors

This study investigates the impacts of black carbon (BC) properties (vertical concentration, shape, size, and mixing state) and atmospheric variables (cloud and aerosol loading, surface albedo, and solar zenith angle) on BC radiative effects, especially vertical distributions of heating rate due to BC absorption. BC and aerosol observations from aircraft in situ measurements, lidar, and the Aerosol Robotic Network (AERONET) are used to constrain their properties. The library for radiative transfer (Libradtran) model is used to calculate BC radiative forcing (RF). BC optical properties are obtained from numerical modeling with aggregate or spherical structures and different size distributions. By modifying optical properties, different BC geometries and size distributions result in uncertainties on RF and heating rate less than 30%, while the uncertainty with different BC mixing states is as large as ~80%. Vertical distribution of BC concentrations explain relative differences in RF and heating rate in the atmosphere by less than 10%, but can induce different heating rate vertical profiles, thus different

planetary boundary layer (PBL) stabilities. Due to the significant influence of cloudy and aerosol conditions on incident solar radiation, atmospheric conditions play an important role in determining BC heating rate. Meanwhile, the effects of surface albedo and solar zenith angle on heating rate are more significantly on the bottom. Taking the above factors into account, we introduce an empirical approximation of BC heating rate to estimate its influence on atmosphere. With the simple formula, the BC heating rate for a particular atmospheric layer can be approximated with the vertical condition generally known, and this can be further applied to determine whether BC promotes or suppresses PBL development. Considering the importance of BC vertical concentration on its heating rate, we suggest that light-absorbing aerosols, and their vertical distributions must be better measured and modeled, to improve the understanding of their radiative effects and interaction with PBL.

Lu, Qiao, et al. "Atmospheric heating rate due to black carbon aerosols: Uncertainties and impact factors." Atmospheric Research (2020): 104891.

Tropospheric Ozone

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

Assessment of O3-induced yield and economic losses for wheat in the North China Plain from 2014 to 2017, China

Tropospheric ozone (O3) is a pollutant of widespread concern in the world and especially in China for its negative effects on agricultural crops. For the first time, yield and economic losses of wheat between 2014 and 2017 were estimated for the North China Plain (NCP) using observational hourly O3 data from 312 monitoring stations and exposure-response functions based on AOT40 index (accumulated hourly O3 concentration above 40 ppb) from a Chinese study. AOT40 values from 2014 to 2017 during the wheat growing seasons (75-days, 44 before and 30 after mid-anthesis) ranged from 3.1 to 14.9 ppm h, 4.9–17.5 ppm h, 7.3–17.6 ppm h, and 0.5–18.6 ppm h, respectively. The highest AOT40 values were observed in the Beijing-Tianjin-Hebei region. The values of relative yield losses from 2014 to 2017 were in the ranges of 6.4–30.5%, 10.0–35.8%, 14.9–34.1%, and 21.6–38.2%, respectively. The total wheat production losses in NCP for 2014–2017 accounted for 18.5%, 22.7%, 26.2% and 30.8% in the whole production, while the economic losses amounted to 6,292 million USD, 8,524 million USD, 10,068 million USD, and 12,404 million USD, respectively. The important impact of O3 in this area, which is of global importance, should be considered when assessing wheat yield production. Our results also show an increasing trend in AOT40, relative yield loss, total crop production loss and economic loss in the four consecutive years.

Hu, Tingjian, et al. "Assessment of O3-induced yield and economic losses for wheat in the North China Plain from 2014 to 2017, China." Environmental Pollution 258 (2020): 113828.

Hydrofluorocarbons (HFCs)

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

Assessment of the low-GWP refrigerants R600a, R1234ze(Z) and R1233zd(E) for heat pump and organic Rankine cycle applications

This paper performs the thermodynamic and the heat-transfer assessment of the low-GWP refrigerants R600a, R1234ze(Z) and R1233zd(E) as alternative to the traditional low-pressure HFC refrigerants, such as R245fa, for Heat Pump (HP) and Organic Rankine Cycle (ORC) applications. The thermodynamic assessment shows that R1234ze(Z) exhibits efficiency very similar to those of R245fa, while R1233zd(E) presents higher efficiency and R600a lower efficiency than those of R245fa both in HP and ORC applications. The heat transfer assessment is carried out in condensation inside a 4 mm ID horizontal smooth tube at three different saturation temperatures (30, 35, and 40 °C), at different vapour qualities and mass velocities. R600a, R1234ze(Z) and R1233zd(E) show

very similar condensation heat transfer and pressure drop performances under operating conditions typical for HP and ORC applications. The results of the thermodynamic and the heat transfer assessment show that R600a, R1234ze(Z) and R1233zd(E) are valuable long-term low-GWP substitutes for the traditional low-pressure HFC refrigerants, both in HP and ORC applications.

Longo, Giovanni A., et al. "Assessment of the low-GWP refrigerants R600a, R1234ze (Z) and R1233zd (E) for heat pump and organic Rankine cycle applications." Applied Thermal Engineering 167 (2020): 114804.

HCFO-1224yd(Z) as HFC-245fa drop-in alternative in low temperature ORC systems: Experimental analysis in a waste heat recovery real facility

The organic Rankine cycle (ORC) has been growing in importance as a technology for producing electricity from low temperature waste and renewable heat sources. In small-scale applications, the most used working fluid has been HFC-245fa, although this is being substituted for low GWP alternatives. A new HCFO working fluid, HCFO-1224yd(Z), has appeared as a possible alternative for HFC-245fa. In this study, this alternative working fluid is analysed and, finally, the working fluid is experimentally tested as drop-in alternative in a commercial ORC system. The main purpose is to determine the feasibility of using HCFO-1224yd(Z) as a drop-in replacement for HFC-245fa in a real facility that was initially designed to operate with HFC-245fa. The results show how the use of HCFO-1224yd(Z) offers power output that ranges from 7.5% to 17.4% lower than that provided by HFC-245fa. Although HFC-245fa offers higher power output, the results show that HCFO-1224yd(Z) offers up to 7.7% higher cycle net efficiency; this is due to the higher input thermal rate required by HFC-245fa. Finally, HCFO-1224yd(Z) has been stated as a suitable alternative to HFC-245fa as a drop-in replacement in a small-scale, low-temperature ORC, which increases its attractiveness for heat source with higher temperatures.

Navarro-Esbrí, Joaquín, et al. "HCFO-1224yd (Z) as HFC-245fa drop-in alternative in low temperature ORC systems: Experimental analysis in a waste heat recovery real facility." Energy 193 (2020): 116701.

Increase in global emissions of HFC-23 despite near-total expected reductions

Under the Kigali Amendment to the Montreal Protocol, new controls are being implemented to reduce emissions of HFC-23 (CHF_3), a by-product during the manufacture of HCFC-22 ($CHClF_2$). Starting in 2015, China and India, who dominate global HCFC-22 production (75% in 2017), set out ambitious programs to reduce HFC-23 emissions. Here, we estimate that these measures should have seen global emissions drop by 87% between 2014 and 2017. Instead, atmospheric observations show that emissions have increased and in 2018 were higher than at any point in history (15.9 ± 0.9 Gg yr^{-1}). Given the magnitude of the discrepancy between expected and observation-inferred emissions, it is likely that the reported reductions have not fully materialized or there may be substantial unreported production of HCFC-22, resulting in unaccounted-for HFC-23 by-product emissions. The difference between reported and observation-inferred estimates suggests that an additional ~309 Tg CO_2-equivalent emissions were added to the atmosphere between 2015 and 2017.

Stanley, K. M., et al. "Increase in global emissions of HFC-23 despite near-total expected reductions." Nature Communications 11.1 (2020): 1-6.

Socio-Economic Impacts

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

Climate effects of aerosols reduce economic inequality

The climate effects of anthropogenic aerosols have masked some of the warming induced by GHGs along with some impacts of that warming. These temperature effects may be beneficial but are almost certainly overwhelmed by aerosols' negative health impacts. Recent analyses of economic impacts have concluded that warming harms economies in warm climates, but provides economic benefits in cold climates4. Here we investigate whether aerosol-induced cooling would have a positive effect on less wealthy economies in hotter regions and a negative effect on wealthier economies in colder regions. Climate simulations over the historical period both with and without anthropogenic aerosol emissions, using a fully coupled ocean and atmosphere

climate model, indicate that in year 2010 anthropogenic aerosol emissions were cooling the Earth by 0.72 ± 0.02 °C relative to a scenario without such emissions. Due to opposing economic impacts in different regions, the net economic impact of aerosol-induced cooling is likely to be small at the global scale. However, these results suggest that the cooling effects of anthropogenic aerosols benefit developing tropical economies while harming developed high-latitude economies, and thus the temperature effects of past aerosol emissions have probably diminished global economic inequality.

Zheng, Yixuan, et al. "Climate effects of aerosols reduce economic inequality." Nature Climate Change (2020): 1-5.

Affluent countries inflict inequitable mortality and economic loss on Asia via PM2.5 emissions

This research sets out to quantify the mortality and economic loss in individual Asian countries caused by the PM2.5 emissions induced by the consumption of the world's five highest-consuming countries (US, China, Japan, Germany, UK). In 2010 alone, the economic impact of these five countries' consumption caused a loss of almost 45 billion US dollars due to the premature deaths of more than 1 million people in Asia, including 15 thousand children younger than 5 years old. The percentage ratio of economic loss to value-added driven by consumers via trade differed greatly among the impacted countries. For the US, the highest percentage loss was 4.1% in Laos, followed by 2.0% in Bangladesh, both markedly higher than the figures for the more developed countries, such as 0.21% for Japan and 0.18% for Korea. This reflects the inequitable value chain existing between consumer countries and impacted countries, and implies that developing countries are obtaining value-added in exchange for unintentionally increased health risks, delaying their development and potentially creating a vicious circle that hinders much-needed improvements in areas like poverty reduction and public health. This inequitable situation needs to be redressed through introduction of clean energy and other types of technological assistance to help achieve United Nations Sustainable Development Goals 7, 10 and 13. Such as move is essential if premature infant deaths are to be curtailed.

Nansai, Keisuke, et al. "Affluent countries inflict inequitable mortality and economic loss on Asia via PM2. 5 emissions." Environment international 134 (2020): 105238.

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.

Emission inventories of rice straw open burning in the Red River Delta of Vietnam: Evaluation of the potential of satellite data

Although rice straw open burning is one of the main sources of air pollution in Asian countries, problems remain in collecting the activity data needed to calculate emission inventories. In Vietnam, the results from traditional data collection methods, which are reported by the Vietnam General Statistics Office high levels of uncertainty. This is largely due to a lack of human and financial resources. To improve upon this, this study critically assessed the benefits of incorporating cultivation area data obtained by the Sentinel-1 Synthetic Aperture Radar (SAR) satellite in combination with crop production records during the period of 2015–2017. The results suggested that incorporating remote sensing data, especially satellite data, into a process-based crop model can improve the spatial distribution of yield estimates. Satellite data for 2018 were also applied to estimate emissions from rice straw open burning in the Red River Delta, Vietnam, for which official statistics are not otherwise yet available. The results show that a total of 3.24 Mt of burnt rice straw produced 3.82 Mt of CO2, 301 Gg of CO, 29.5 Gg of PM10, and 27 Gg of PM2.5. The estimated emission amounts for the common air pollutants SO2, NOx, and NH3 were 583 tonnes, 7.4 Gg, and 13.3 Gg, respectively. Hydrocarbon emissions were 31 Gg for CH4 and 22.7 Gg for NMVOC. The emission of BC, which is one of the main short-lived climate forcers, totalled 1.6 Gg. Based on these results, satellite data demonstrate great potential for estimating emissions from rice croplands, having the advantages of timely availability and cost competitiveness.

Le, Hoang Anh. "Emission inventories of rice straw open burning in the Red River Delta of Vietnam: Evaluation of

the potential of satellite data." Environmental Pollution (2020): 113972.

Practical design considerations for secondary air injection in wood-burning cookstoves: An experimental study

Billions of households worldwide cook using biomass fires and suffer from the toxic smoke emitted into their homes. Laboratory studies of wood-burning cookstoves demonstrate that secondary air injection can greatly reduce the emission of harmful air pollution, but these experimental advancements are not easily translated into practical cookstove designs that can be widely adopted. In this study, we use a modular cookstove platform to experimentally quantify the practical secondary air injection design requirements (e.g., flow rate, pressure, and temperature) to reduce mass emissions of particulate matter (PM), carbon monoxide (CO), and black carbon (BC) by at least 90% relative to a traditional cooking fire. Over the course of 111 experimental trials, we illuminate the physical mechanisms that drive emission reductions, and outline fundamental design principles to optimize cookstove performance. Using the experimental data, we demonstrate that low-cost (<$10) fans and blowers are available to drive the secondary flow, and can be independently powered using an inexpensive thermoelectric generator mounted nearby. Furthermore, size-resolved PM measurements show that secondary air injection inhibits particle growth, but the total number of particles generated remains relatively unaffected. We discuss the potential impacts for human health and investigate methods to mitigate the PM formation mechanisms that persist.

Caubel, Julien J., et al. "Practical design considerations for secondary air injection in wood-burning cookstoves: An experimental study." Development Engineering 5 (2020): 100049.

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

Tillage and irrigation system effects on soil carbon dioxide (CO2) and methane (CH4) emissions in a maize monoculture under Mediterranean conditions

Irrigation as well as soil tillage management are considered two possible strategies to reduce carbon dioxide (CO2) and methane (CH4) emissions from the soil in Mediterranean agroecosystems. The objective of this work was to assess the impact of the irrigation system (i.e. flood, F; and sprinkler, S) and the soil tillage system (i.e. conventional tillage, CT; no-tillage maintaining the maize stover, NTr; and no-tillage removing the maize stover, NT) on CO2 and CH4 emissions from the soil during three growing seasons (2015, 2016 and 2017) and two fallow periods between growing seasons (15–16 fallow and 16–17 fallow) in a maize (Zea mays L.) monoculture system. Soil temperature and water-filled pore space (WFPS) had a great influence on daily soil CO2 fluxes but not on daily soil CH4 fluxes. In all tillage-irrigation treatments, daily soil CO2 fluxes showed an increase with soil temperature, being this increment greater when soil temperature was above 15 °C in coincidence with the maize plant growth. In contrast, soil WFPS differently affected daily soil CO2 fluxes depending on the irrigation system. Under S irrigation, daily soil CO2 fluxes increased with soil WFPS, whereas under F irrigation a threshold value of 60% WFPS was found, with a positive or negative effect on CO2 fluxes for values below or above this threshold value, respectively. Over the three maize growing seasons, CT-S presented the greatest cumulative soil CO2 emissions with a seasonal average value of 3.28 Mg CO2-C ha−1. In contrast, for the same period, NTr-S cumulative soil CO2 emissions were up to 42% lower than the CT-S cumulative soil CO2 emissions. Cumulative CH4 emissions were only affected by soil tillage during the 16–17 fallow period, resulting both NTr and NT in greater net CH4 uptake compared with CT. This work highlights the importance of irrigation and soil tillage systems as key agricultural practices to minimize soil CO2 and CH4 emissions under Mediterranean conditions.

Franco-Luesma, Samuel, et al. "Tillage and irrigation system effects on soil carbon dioxide (CO2) and methane (CH4) emissions in a maize monoculture under Mediterranean conditions." Soil and Tillage Research 196 (2020): 104488.

The potential of Turkey's province-based livestock sector to mitigate GHG emissions through biogas production

Methane and nitrous oxide are the two leading greenhouse gases (GHG) that are released to the atmosphere due to livestock enteric fermentation and manure management. This study examines Turkey's province-based GHG emissions released by its livestock sector due to these processes. Besides, this study focusses on biogas production through anaerobic digestion, which is one of the most effective GHG mitigation options from manure management. This study aims to show the importance of the livestock sector in regards to GHG emissions in Turkey based on estimations made by the Intergovernmental Panel on Climate Change (IPCC) 2006 Guidelines. As a result of these estimations, for the year 2015, 33.85 million tons of carbon dioxide equivalent (CO2-eq) were produced from enteric fermentation and manure management system. The study also aims to evaluate Turkey's province-based biogas production potential from animal manure through the anaerobic digestion (AD) technology. Two different biogas potential scenarios with varying manure recovery rates were developed. Scenario 1 was developed based on the assumption of that total amount of produced animal manure would be used in AD for biogas production, and scenario 2 was developed based on the realistic manure recovery rates that vary with the type of livestock. Biogas potentials for scenario 1 and scenario 2 were determined as 8.41 billion m3 and 4.18 billion m3 in 2015, respectively. These values can meet Turkey's total electricity demand at a rate of 5.25% for scenario 1, and the rate of 2.3% for scenario 2. In addition, according to Turkey's GHG Inventory, submitted annually to the United Nations Framework Convention on Climate Change (UNFCCC), GHG emissions from manure management can be reduced by 1.13% through biogas production.

Ersoy, Erdinc, and Aysenur Ugurlu. "The potential of Turkey's province-based livestock sector to mitigate GHG emissions through biogas production." Journal of Environmental Management 255 (2020): 109858.

Estimation of methane emissions based on crop yield and remote sensing data in a paddy field

Quantifying agricultural greenhouse gas (GHG) emissions is important for addressing global warming. In this regard, empirical models were constructed to evaluate the feasibility of using rice yield and canopy spectral properties for estimating paddy cumulative methane (CH4) emissions (CCE). A field experiment with shading treatments was conducted in 2017. A static chamber-gas chromatography was used to measure CH4 fluxes during the growing season. Canopy hyperspectral reflectance was measured and then used to calculate the multispectral normalized difference vegetation index (NDVI), the ratio vegetation index (RVI), and the enhanced vegetation index (EVI). The results show that CH4 emissions were positively correlated to rice yield and biomass, indicating that higher biomass provided more substrates for CH4 generation. O2 availability maybe a main factor in the CCE differences under shading treatments. RVI and EVI showed a stronger positive relationship to CH4 emissions than NDVI. The empirical model including yield and EVI-JS (EVI of jointing-booting stage) as input variables performed better (adj-R2 = 0.85, root mean square error [RMSE] = 12.26 kg ha−1) than the model that included only yield (adj-R2 = 0.5, RMSE = 22.5 kg ha−1). This study suggests that it is feasible to apply remote sensing in paddy CH4 estimation, providing a referable attempt for future regional agricultural GHG emissions quantification.

Shi, Yifan, et al. "Estimation of methane emissions based on crop yield and remote sensing data in a paddy field." Greenhouse Gases: Science and Technology.

Estimation and mitigation of greenhouse gases in typical paddy-upland rotation systems in the middle and lower reaches of the Yangtze River, China

Agricultural greenhouse gas (GHG) has a significant effect on climate change. The ability to quantify agricultural GHG and implement practices to mitigate its emissions is of great significance. Optimal GHG mitigation practices in the middle and lower reaches of the Yangtze River, China, have not been well documented. In this study, historical (2000–2014) and projected (2015–2049) methane (CH4) and nitrous oxide (N2O) emissions from paddy-upland crop rotations were simulated at a county scale using the denitrification–decomposition model. The results demonstrated (1) historical mean emissions of CH4, N2O, and global warming potential (GWP) were 158.6 kg-C ha−1 year−1, 0.75 kg-N ha−1 year−1, and 22.15 Tg CO2-eq year−1 in the study area (1 Tg = 1012 g); (2) CH4 emission rates significantly increased, while there was no significant change in N2O under projected RCP4.5 and RCP8.5 climate scenarios, and RCP8.5 induced 10% more CH4 than RCP4.5; (3) marginal flooding

coupled with reduced-tillage practice was the optimal strategy to mitigate GHG emissions due to its lowest GWP. This study would provide insight into the agricultural GHG emissions, as well as the impact on climate change. Also, a theoretical basis for policymaking would be provided by this study.

Shi, Yifan, et al. "Estimation and mitigation of greenhouse gases in typical paddy-upland rotation systems in the middle and lower reaches of the Yangtze River, China." Greenhouse Gases: Science and Technology.

Transportation

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

On-road tailpipe emission characteristics and ozone formation potentials of VOCs from gasoline, diesel and liquefied petroleum gas fueled vehicles

Volatile organic compounds (VOCs) of motor vehicles contribute greatly to ground-level ozone formation, especially in the megacity regions. While the variations of tailpipe VOC emissions along with the vehicle technologies and road conditions are rarely investigated systematically. Thus, on-road tailpipe VOC emissions from in-use vehicles, including light-duty gasoline vehicles (LDGV), light-duty diesel trucks (LDDT), heavy-duty diesel truck (HDDT) and liquefied petroleum gas-electric hybrid bus (LPGB), were sampled with a combined portable emission measurement system (PEMS). A total of 102 individual VOC species were quantified by a gas chromatography mass spectrometry detector (GC-MSD), and the maximum incremental reactivity (MIR) scale was used to calculate the ozone formation potentials (OFPs). Results showed that aromatics and alkanes were the major VOC groups regardless of the vehicle type, accounting for 68.1–98.0%. For the LDGV, i-pentane, acetone, and propane were the top three VOC species. Naphthalene, dodecane and n-undecane were main VOC constituents in the diesel exhaust. Acetone was the most abundant VOC species for the LPGB, followed by i-pentane, i-butane and n-butane. Road conditions had a significant impact on the VOC emission factors. Specifically, emission factors on urban roads were 3.3–7.0 times those on the highway. The OFPs were 70.7, 128.1, 2189.4 and 124.7 mg O3/km for the LDGV, LDDT, HDDT and LPGB, respectively; aromatics were the main contributors, occupying 49.6–93.4% of the total OFPs. Results indicated that emission factors and dominant species of VOCs were strongly affected by vehicle technologies and road conditions, but aromatics were the major group for both VOC composition and OFPs.

Wang, Menglei, et al. "On-road tailpipe emission characteristics and ozone formation potentials of VOCs from gasoline, diesel and liquefied petroleum gas fueled vehicles." Atmospheric Environment (2020): 117294.

Air pollution & Health Impacts

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

The association between short-term residential black carbon concentration on blood pressure in a general population sample

Exposure to black carbon indoors may be associated with blood pressure; however, evidence is limited to vulnerable subpopulations and highly exposed individuals. Our objective was to explore the relationship between indoor black carbon at various exposure windows on resting blood pressure in a general population sample. Black carbon was measured in the home of 76 individuals aged 10-71 in New Orleans, Louisiana. Exposure was measured every 1 minute for up to 120 hours using an AE51 microaethalometer. Systolic blood pressure and diastolic blood pressure were measured at the conclusion of exposure monitoring. In adjusted models, at all exposure windows, increasing black carbon was associated with increased systolic blood pressure. The period 0-72 hours prior to blood pressure measurement showed the strongest effect; a 1 μg/m3 increase in black carbon was associated with a 7.55 mm Hg (P = .02) increase in systolic blood pressure. The relationship was stronger in participants reporting doctor-diagnosed hypertension (β = 6.47 vs β = 3.27). Black carbon was not associated with diastolic blood pressure. Increasing black carbon concentration indoors is positively

associated with increasing systolic blood pressure with the most relevant exposure window being 0-72 hours prior to blood pressure measurement. Individuals with hypertension may be a more susceptible population.

Rabito, Felicia A., et al. "The Association Between Short-term Residential Black Carbon Concentration on Blood Pressure in a General Population Sample." Indoor air (2020).

Premature mortality related to United States cross-state air pollution

Outdoor air pollution adversely affects human health and is estimated to be responsible for five to ten per cent of the total annual premature mortality in the contiguous United States1,2,3. Combustion emissions from a variety of sources, such as power generation or road traffic, make a large contribution to harmful air pollutants such as ozone and fine particulate matter (PM2.5)4. Efforts to mitigate air pollution have focused mainly on the relationship between local emission sources and local air quality2. Air quality can also be affected by distant emission sources, however, including emissions from neighbouring federal states5,6. This cross-state exchange of pollution poses additional regulatory challenges. Here we quantify the exchange of air pollution among the contiguous United States, and assess its impact on premature mortality that is linked to increased human exposure to PM2.5 and ozone from seven emission sectors for 2005 to 2018. On average, we find that 41 to 53 per cent of air-quality-related premature mortality resulting from a state's emissions occurs outside that state. We also find variations in the cross-state contributions of different emission sectors and chemical species to premature mortality, and changes in these variations over time. Emissions from electric power generation have the greatest cross-state impacts as a fraction of their total impacts, whereas commercial/residential emissions have the smallest. However, reductions in emissions from electric power generation since 2005 have meant that, by 2018, cross-state premature mortality associated with the commercial/residential sector was twice that associated with power generation. In terms of the chemical species emitted, nitrogen oxides and sulfur dioxide emissions caused the most cross-state premature deaths in 2005, but by 2018 primary PM2.5 emissions led to cross-state premature deaths equal to three times those associated with sulfur dioxide emissions. These reported shifts in emission sectors and emission species that contribute to premature mortality may help to guide improvements to air quality in the contiguous United States.

Dedoussi, Irene C., et al. "Premature mortality related to United States cross-state air pollution." Nature 578.7794 (2020): 261-265.

Revealing the impacts of transboundary pollution on PM2.5-related deaths in China

Long-range transport of air pollutants may cause significant health impacts in the receptor regions. In this study, we calculated the transboundary health impact from different foreign regions using a state-of-the-art air quality model at hemispheric scale. Our results reveal that transboundary PM2.5 pollution from outside China was of great significance, causing 100 thousand (95% CI, 45 thousand-200 thousand) premature deaths in China in 2015, which accounted for 9.60% PM2.5 related premature death in China. The impact of transboundary pollution in China was most significant in winter, in which the average PM2.5 concentration increased by 3.7 μg/m3, and was least significant in summer, with the average PM2.5 concentration increasing by 0.5 μg/m3. Liaoning and Yunnan provinces were extremely susceptible to transboundary pollution, whose annual average PM2.5 concentrations were increased by 10.2 and 11.4 μg/m3 respectively. Among all foreign regions, the impact from South Asia was most significant, causing 30 thousand (95% CI, 12 thousand-62 thousand) premature deaths annually in China. This study only reveals the transboundary impact under the integrated exposure-response (IER) model and fixed meteorology field in 2015. Further studies are needed to investigate how different exposure-response functions and meteorology affect the transboundary PM2.5 pollution and its related death.

Liu, Shuchang, et al. "Revealing the impacts of transboundary pollution on PM2. 5-related deaths in China." Environment international 134 (2020): 105323.

Air pollution control strategies directly limiting national health damages in the US

Exposure to fine particulate matter (PM2.5) from fuel combustion significantly contributes to global and US mortality. Traditional control strategies typically reduce emissions for specific air pollutants and sectors to maintain pollutant concentrations below standards. Here we directly set national PM2.5 mortality cost reduction targets within a global human-earth system model with US state-level energy systems, in scenarios to 2050, to identify endogenously the control actions, sectors, and locations that most cost-effectively reduce PM2.5

mortality. We show that substantial health benefits can be cost-effectively achieved by electrifying sources with high primary PM2.5 emission intensities, including industrial coal, building biomass, and industrial liquids. More stringent PM2.5 reduction targets expedite the phaseout of high emission intensity sources, leading to larger declines in major pollutant emissions, but very limited co-benefits in reducing CO2 emissions. Control strategies limiting health damages achieve the greatest emission reductions in the East North Central and Middle Atlantic states.

Ou, Yang, et al. "Air pollution control strategies directly limiting national health damages in the US." Nature Communications 11.1 (2020): 1-11.

Influence of marine vessel emissions on the atmospheric PM2.5 in Japan's around the congested sea areas

In recent years, PM2.5 concentrations in Japan have decreased as China's measures against the emission of air pollutants were strengthened and the subsequent transport of air pollutants to Japan decreased. On the other hand, along the coast of the Seto inland sea in Japan, the PM2.5 concentration remains high. In this study, in order to evaluate the impact of air pollutants from marine vessels on PM2.5 along the coast of the Seto inland sea, PM2.5 was seasonally collected in the vicinity of a congested sea lane (Akashi Strait) in 2016 and 2017, and a receptor-source analysis was performed to determine the main components of the collected PM2.5. In Japan's congested sea lane, the vanadium (V) concentration was very high and showed a strong correlation with the nickel (Ni) concentration. Also, the V/Ni ratio rose when the wind blew from the sea lane. Positive Matrix Factorization (PMF) analysis clarified that the contributions from marine vessel emissions to PM2.5 at the current observation sites were 2.5–2.7 μg m−3 (17.3–21.4%), and the marine vessel emissions were the main source of PM2.5 along the coast of the Seto inland sea. Fuel oil regulations for marine vessels to be introduced in January 2020 are expected to improve the air quality of coastal areas.

Nakatsubo, Ryohei, et al. "Influence of marine vessel emissions on the atmospheric PM2. 5 in Japan's around the congested sea areas." Science of The Total Environment 702 (2020): 134744.

Urban Air Pollution & Megacities

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

On the environmental effectiveness analysis of energy policies: A case study of air pollution in the megacity of Tehran

The present study compared different approaches to assessing the environmental cost-effectiveness of energy policy scenarios. As a case study, the megacity of Tehran in Iran was studied. A key policy challenge in this city is to curb high concentrations of PM2.5 and mitigate the associated adverse impacts. The results demonstrated that in the business as usual case, the spatially averaged primary and secondary PM2.5 concentration in Tehran will increase by 30% in the 2010–2030 period. Adopting certain planned policy scenarios and the corresponding pollutant concentration reductions in Tehran shows that although most of the emission comes from industrial activities around the city, the distribution of the transportation emission sources may play the most effective role in decreasing pollution levels in transport-related energy policies. Next, based on environmental damage costs and abatement costs in different pollution mitigation scenarios, the best (most environmentally cost-effective) scenarios were evaluated. The eco-efficiencies of the energy policies were assessed based on two proxies of environmental impacts: the reduced damage cost as a function of the reduced emission rates of the pollutants and the decreased number of polluted days in the year. In a sample area in which the simulated concentrations were verified by local measurements, the most efficient mitigation scenario would decrease the average concentration of PM2.5 by 35% in 2030 and the number of polluted days by 20%. These findings indicate how far the linear functionality of the damage cost from emission levels may mislead environmental impact assessments. This is due to neglecting the source distribution effects and geographical conditions of the environment.

Taksibi, Farzaneh, Hossein Khajehpour, and Yadollah Saboohi. "On the environmental effectiveness analysis of

energy policies: A case study of air pollution in the megacity of Tehran." Science of The Total Environment 705 (2020): 135824.

Managing future air quality in megacities: Emission inventory and scenario analysis for the Kolkata Metropolitan City, India

Air pollution in Indian cities is a serious problem and a threat to human health. Kolkata Metropolitan City (KMC) is one of the Indian metro cities urgently requiring policy interventions to ensure breathable air in the near future. We developed a detailed emissions inventory of key air pollutants for 2015 in KMC, considering both particulate matter (PM10, PM2.5, BC, OC) and gaseous pollutants (SO2, NOx, CO, VOC and NH3). We estimated the emissions in a business-as-usual (BAU) scenario for the year 2030, while accounting for the impacts of current and planned policies. Our results reveal that current policies/measures are not sufficient to reduce PM2.5 emissions substantially in KMC by 2030. We thus explored three alternative policy scenarios considering various emission control strategies and non-technical city-specific control measures, along with associated cost implications. Our results indicate that significant emission reductions can be achieved (35% for PM2.5 and 45% for NOx) by spending €1.15 billion for advanced control measures across various sectors, compared with the business-as-usual scenario, are expected to cost €0.78 billion by 2030. Advanced control measures, coupled with the control of non-technical emission sources, may prove to be the most effective solution, yielding a significant reduction of key air pollutants (51% for PM2.5 and 54% for NOx) with a cost implication of €1.18 billion by 2030. Low carbon policies may also be able to substantially reduce key air pollutants with the additional co-benefit of reduced emissions of greenhouse gas, CO2 by 24% in 2030, with a running cost of €0.70 billion.

Majumdar, Dipanjali, et al. "Managing future air quality in megacities: Emission inventory and scenario analysis for the Kolkata Metropolitan City, India." Atmospheric Environment 222 (2020): 117135.

Characteristics analysis of industrial atmospheric emission sources in Beijing–Tianjin–Hebei and Surrounding Areas using data mining and statistics on different time scales

Cities of Beijing–Tianjin–Hebei (BTH) and its surrounding areas are a focus of air pollution control in China. This study analyzed the emission characteristics of industrial pollution sources within these cities from the perspective of big data, using 37,123,000 continuous monitoring data for enterprises in 31 cities. Three indicators were proposed to compare the spatial emission characteristics: industrial pollutant emission intensity (IPEI), industrial pollution concentration emission intensity (IPCEI) and the density of waste gas monitoring enterprise (DWGME). The IPEI and IPCEI of Yangquan, Taiyuan, Changzhi, Xingtai, Handan, and Hebi were considerably higher than the average level of the air pollution transmission channel cities (APTCC). The industrial SO2 concentration emission intensity in Yangquan, Hebi, Laiwu were 1826.9, 462.8, 301.4 mg m−3 per trillion yuan, more than twice the regional average for the 31 cities. We found there was a significant positive correlation between different industrial pollutants in the BTH and surrounding areas. Industrial SO2 emission have a positive correlation with industrial NOx emission in most of BTH cities, the correlation in Xingtai, Hengshui, Taiyuan were respectively 0.855, 0.969,0.696. Data mining and statistics on different time scales could be used to analyze the characteristics of industrial atmospheric emission sources, and could be applied in environmental decision support systems to make air pollution management more objective, reliable, and powerful.

Xiao, Cuicui, et al. "Characteristics analysis of industrial atmospheric emission sources in Beijing–Tianjin–Hebei and Surrounding Areas using data mining and statistics on different time scales." Atmospheric Pollution Research 11.1 (2020): 11-26.

SLCPs & Vulnerable Regions

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

Investigation of distribution, transportation, and impact factors of atmospheric black carbon in the Arctic region based on a regional climate-chemistry model

Black carbon (BC) as the main component of pollutants in the Arctic plays an important role on regional climate

change. In this study, we applied the regional climate-chemistry model, WRF-Chem, to investigate the spatial distribution, transportation, and impact factors of BC in the Arctic. Compared with reanalysis data and observations, the WRF-Chem performed well in terms of the seasonal variations of meteorological parameters and BC concentrations, indicating the applicability of this model on Arctic BC simulation works. Our results showed that the BC concentrations in the Arctic had an obviously seasonal variation pattern. Surface BC concentrations peaked during winter and spring seasons, while the minimum occurred during summer and autumn seasons. For the vertical distribution, BC aerosols mainly concentrated in the Arctic lower troposphere, and most of BC distributed near the surface during winter and spring seasons and in the higher altitude during other seasons. The seasonality of BC was associated with the seasonal change of meteorological field. During winter, the significant northward airflow prevailing in northern Eurasia caused the transport of accumulated pollutants from this region into the Arctic. The similar but weakened northward airflow pattern and the anticyclone activity during spring can allow pollutants to be transported to the Arctic lower troposphere. Moreover, the more stable atmosphere during winter and spring seasons made BC accumulated mainly near the surface. During summer and autumn seasons, the less stable boundary layer and the cyclone activity in the Arctic facilitated the diffusion of pollutants into the higher altitude. Meanwhile, the higher relative humidity can promote the wet removal process and lead to the relatively lower BC concentrations near the surface. Compared with the seasonal change of emission, our analysis showed that the seasonal variation of meteorological field was the main contributor for the seasonality of BC in the Arctic.

Chen, Xintong, Shichang Kang, and Junhua Yang. "Investigation of distribution, transportation, and impact factors of atmospheric black carbon in the Arctic region based on a regional climate-chemistry model." Environmental Pollution 257 (2020): 113127.