S-12
Evaluation of SLCP Environmental Impacts and Promotion of Climate Change Countermeasures through Seeking the Optimal Pathway

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Air pollution is a serious global problem, especially in Asia. There is a pressing need for countermeasures and society should promote them. Air pollutants include black carbon (BC), tropospheric ozone, methane, hydrofluorocarbons (HFCs) and other components that warm the Earth's systems, accelerating global warming. These are called “SLCPs” (Short-lived Climate Pollutants). Reduction of SLCPs is an important action to take for simultaneous mitigation of global warming, health damage and other issues. The short lifetime of SLCPs in the atmosphere assures a rapid reduction of the surface air temperature after implementing SLCP mitigation measures to contribute to the 2°C goal and 1.5°C effort goal of the UNFCCC Paris Agreement. On the other hand, past studies show large uncertainties to be involved in estimating the climate impacts of SLCPs as a result of their complex characteristics and feedback processes.

Strategic research project S-12 was performed with the aim of reducing the uncertainties in estimates of SLCP impacts and seeking optimum SLCP reduction pathways and effective countermeasures. For this purpose, the project performed the following activities: attribution of air quality change events and a REAS inventory update; AIM SLCP modeling and development of mitigation scenarios; evaluation of SLCP mitigation effects on climate and environmental problems using a MIROC-coupled atmosphere-ocean climate model with SPRINTARS aerosol and CHASER chemical models, the high resolution atmospheric model NICAM, and others (Fig. 1).

The study found that there were two major indirect effects in processes regarding BC and NO_x, which should be taken into account for constructing effective SLCP mitigation scenarios. First, BC reduction would not significantly decrease the surface air temperature due to cancellation of the BC effect by positive radiative forcing of cloud change generated by BC heating reduction (Fig. 2). Second, a large reduction of NO_x would cause a decrease in the OH radical by which the methane lifetime would be increased, and thus atmospheric methane concentrations would increase. These indirect effects clearly indicate that a suitable combination of reductions of BC, NO_x, OC and VOC, methane has to be designed based on careful investigation of SLCP impacts on the Earth's climate and environment.

Based on our investigation, the project constructed a series of SLCP mitigation scenarios, i.e., the Ref-, EoPmid-, EoPmax-, and 2D-scenarios. The 2D-scenarios include derivatives such as 2D-EoPmid-CCSBLD, -EoPmax-CCSBLD, -EoPmid-RESTRT, -EoPmax-RESTRT, -EoPmid-RESBLDTRT, and -EoPmax- RESBLDTR. These scenarios involve the use of a variety of mitigation technologies, i.e., EoP—end of pipe technology, enhancing EoP diffusion both in developed and developing countries by 2050 for SO_2, NO_x, BC, OC, $PM_{2.5}$ and PM_{10}; 2D—decarbonization mitigation measures toward the 2°C target, reaching a carbon price of 400US$/t$CO_2$ eq in 2050; CCS—enhancing an energy shift to coal and biomass power with CCS technology; RES—energy shift to renewables; BLD—electrification of the building sector across the world by 2050; and TRT—electrification of the passenger transport sector across the world by 2050.

Figure 3 shows an example of how BC and SO_2 emissions would change from 2010 to 2050 depending on the scenario. After extensive numerical simulation of climate and environmental problems, we concluded our best scenario would be the 2D-EoPmid-RESBLDTRT to simultaneously mitigate global warming and environmental problems. The best scenario could reduce the surface air temperate in most areas of globe by about 0.4°C, whereas use of only end of pipe technology (EoPmid and EoPmax) would increase the surface air temperature due to warming caused by large reductions of sulfate aerosols.

Nonetheless the SLCP process is complex, so we should continue our research to find good SLCP mitigation scenarios. The following are our recommendations for future studies and mitigation actions: (1) identifying an optimum solution for SLCP reduction, which requires consideration of the complex interactions among SLCPs, climate and the atmospheric environment; (2) evaluating SLCP impacts on health, agriculture and the water cycle, which are significant and must be elucidated as part of any SLCP-reduction strategy; (3) finding measures to reduce SLCPs, which should consider various possibilities, such as health- and global warming-oriented scenarios; (4) using the scenarios evaluated during the S-12 project to inform SLCP-reduction policies in Japan and the broader international discussion; (5) continuing scenario-based analyses in support of formulating international and domestic SLCP-reduction policies; (6) employing an S-12 type scenario-development system for evaluating SLCP impacts to better determine viable mitigation paths; (7) monitoring air pollutant emissions, which should continue with an update of the SLCP emission inventory in Asia to reflect changes in high socio-economic activity and environmental policies; (8) utilizing the integrated system of emission inventory, chemical transport modeling, and satellite inverse analysis for assessing the current state of air pollution and evaluating the effects of countermeasures to air pollution in Japan as well as other Asian countries.

Fig. 1 S-12 project flow for seeking the optimum SLCP reduction scenario for mitigation of global warming and environmental problems.

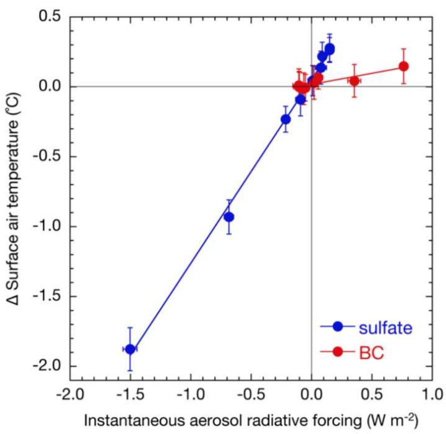

Fig. 2 Relationship between surface air temperature change and radiative forcing by sulfate and BC (cited from Takemura & Suzuki, 2019).

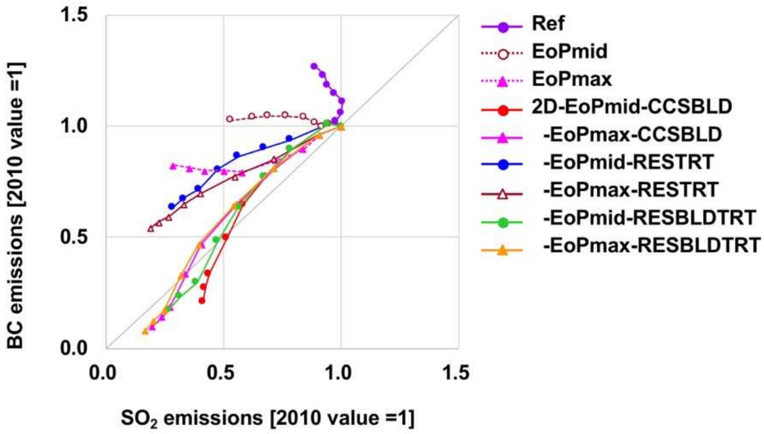

Fig. 3 BC and SO_2 emission changes in S-12 scenarios from 2010 to 2050 (cited from Hanaoka & Masui, 2019).

PUBLICATIONS from project S-12

Book chapters:

Goto, D., T. Nakajima, T. Dai, H. Yashiro, Y. Sato, K. Suzuki, J. Uchida, S. Misawa, R. Yonemoto, T.T.N. Trieu, H. Tomita and M. Satoh (2018) Multi-scale Simulations of Atmospheric Pollutants Using a Non-hydrostatic Icosahedral Atmospheric Model: *In*: K. Vadrevu, T. Ohara and C. Justice, eds., Land-Atmospheric Research Applications in South and Southeast Asia. Springer Remote Sensing/Photogrammetry. Springer, Cham.

Journal articles:

Cheng, B., H. Dai, P. Wang, Y. Xie, L. Chen, D. Zhao and T. Masui (2016) Impacts of low-carbon power policy on carbon mitigation in Guangdong Province, China. *Energy Policy*, 88: 515-527, doi: 10.1016/j.enpol.2015.11.006

Dai, T., N.A.J. Schutgens, D. Goto, G.-Y. Shi and T. Nakajima (2014) Improvement of aerosol optical propperties modeling over Eastern Asia with MODIS AOD assimilation in a global non-hydrostatic icosahedral aerosol transport model, *Environmental Pollution*, 195: 319-329, doi:10.1016/j.envpol.2014.06.021.

Dai H., X. Xie, Y. Xie, J. Liu and T. Masui (2016) Green growth: The economic impacts of large-scale renewable energy development in China. *Applied Energy*, 162: 435-449, doi: 10.1016/j.apenergy.2015.10.049

Dong H., H. Dai, Y. Geng, T. Fujita, Z. Liu, Y. Xie, R. Wu, M. Fujii, T. Masui and L. Tang (2017) Exploring impact of carbon tax on China. *Renewable and Sustainable Energy Reviews*, 77: 596-603, doi: 10.1016/j.rser.2017.04.044

Goto, D., T. Dai, M. Satoh, H. Tomita, J. Uchida, S. Misawa, T. Inoue, H. Tsuruta, K. Ueda, C.F.S. Ng, A.Takami, N. Sugimoto, A. Shimizu, T. Ohara and T. Nakajima (2015) Application of a global nonhydrostatic model with a stretched-grid system to regional aerosol simulations around Japan, *Geoscientific Model Development*, 8: 235-259, doi:10.5194/gmd-8-235-2015.

Goto, D., T. Nakajima, T. Dai, M. Kajino, H. Matsui, A. Takami, S. Hatakeyama, N. Sugimoto, A. Shimizu and T. Ohara (2015) An evaluation of simulated sulfate over East Asia through global model inter-comparison. *Journal of Geophysical Research: Atmosphere*, 120 (12): 6247-6270, doi:10.1002/2014JD021693.

Goto, D., K. Ueda, C. F. S. Ng, A. Takami, T. Ariga, K. Matsuhashi and T. Nakajima (2016) Estimation of excess mortality due to long-term exposure to PM2.5 in Japan using a high-resolution model for present and future scenarios. *Atmospheric Environment*, 140: 320-332. doi:10.1016/j.atmosenv.2016.06.015.

Goto D., Y. Sato, H. Yashiro, K. Suzuki and T. Nakajima (2017) Validation of high-resolution aerosol optical thickness simulated by a global non-hydrostatic model against remote sensing measurements. *AIP Conf. Proc*. 1810, 100002, doi:10.1063/1.4975557.

Goto, D., M. Kikuchi, K. Suzuki, M. Hayasaki, M. Yoshida, T. M. Nagao, M. Choi, J. Kim, N. Sugimoto, A. Shimizu, E. Oikawa and T. Nakajima (2019) Aerosol model evaluation using two geostationary satellites over East Asia in May 2016. *Atmospheric Research*, 217: 93-113, doi:10.1016/j.atmosres.2018.10.016.

Hanaoka, T. and T. Masui (2018) Co-benefits of Short-Lived Climate Pollutants and Air Pollutants by 2050 while achieving the 2 degree target in Asia. *Journal of Sustainable Development of Energy, Water and Environment Systems*, 6 (3): 505-520. doi:10.13044/j.sdewes.d6.0218.

Hanaoka, T. and T. Masui (2019 in press) Exploring Effective Short-Lived Climate Pollutant Mitigation Scenarios by Considering Synergies and Trade-offs of Combinations of Air Pollutant Measures and Low Carbon Measures towards the Level of the 2 °C Target in Asia, *Environmental Pollution*

Hirayama, T., K. Fujiwara, G. Hibino, T. Hanaoka and T. Masui (2017) Analysis on ancillary effects on climate change mitigation actions on air pollutants and SLCP: Case study in India. Environmental systems research, 73 (6): II_301-II_308. doi:10.2208/jscejer.73.II_301

Madhu, V. and K. Sudo (2019) Quasi-Biennial oscillations in atmospheric ozone from the chemistry-climate model and ozone reanalyses. *American Journal of Climate Change*, 8: 110-136, doi:10.4236/ajcc.2019.81007.

Masutomi, Y., K. Ono, M. Mano, A. Maruyama and A. Miyata (2016) A land surface model combined with a crop growth model for paddy rice (MATCRO-Rice Ver. 1) – Part I: Model description. *Geoscientific Model Development*, 9: 4133-4154, doi:10.5194/gmd-9-4133-2016.

Masutomi, Y., K. Ono, T. Takimoto, M. Mano, A. Maruyama and A. Miyata (2016) A land surface model combined with a crop growth model for paddy rice (MATCRO-Rice Ver. 1) – Part II: Model validation. *Geoscientific Model Development*., 9: 4155-4167, doi:10.5194/gmd-9-4155-2016.

Masutomi, Y., Y. Kinose, T. Takimoto, T. Yonekura, H. Oue and K. Kobayashi (2019) Ozone changes the linear relationship between photosynthesis and stomatal conductance and decreases water use efficiency in rice. *Science of The Total Environment*., 655: 1009-1016, doi:10.1016/j.scitotenv.2018.11.132.

Masutomi, Y., Y. Sato, A. Higuchi, A. Takami and T. Nakajima (2019) The effects of citizen-driven urban forestry on summer high air temperatures over the Tokyo metropolitan area. *Journal of Agricultural Meteorology*, 75(3): 144-152. doi:10.2480/agrmet.D-18-00047.

Michibata, T., K. Suzuki, Y. Sato and T. Takemura (2016) The source of discrepancies in aerosol–cloud–precipitation interactions between GCM and A-Train retrievals. *Atmospheric Chemistry Physics*, 16: 15413-15424, doi:10.5194/acp-16-15413-2016.

Mittal, S., T. Hanaoka, P.R. Shukla and T. Masui (2015) Air pollution co-benefits of low carbon policies in road transport: a sub-national assessment for India. *Environmental Research Letters*, 10(8), doi: 10.1088/1748-9326/10/8/085006

Mittal, S., H. Dai, S. Fujimori and T. Masui (2016) Bridging greenhouse gas emissions and renewable energy deployment target: Comparative assessment of China and India. *Applied energy*, 166: 301-313, doi: 10.1016/j.apenergy.2015.12.124

Mittal, S., H. Dai, S. Fujimori, T. Hanaoka and R. Zhang (2017) Key factors influencing the global passenger transport dynamics using the AIM/Transport model. *Transport Research Part D,* 55: 373-388, doi: 10.1016/j.trd.2016.10.006

Morino, Y., K. Ueda, A. Takami, T. Nagashima, K. Tanabe, K. Sato, T. Noguchi, T. Ariga, K. Matsuhashi and T. Ohara (2017) Sensitivities of Simulated Source Contributions and Health Impacts of PM2.5 to Aerosol Models. *Environmental Science and Technology*, 51: 14273-14282. doi:10.1021/acs.est.7b04000.

Nakajima T., R. Imasu, A. Takami, D. Goto, H. Tsuruta, J. Uchida, T. Dai, S. Misawa, K. Ueda, C.F.S. Ng, C. Watanabe, S. Konishi, Y. Sato, A. Higuchi, Y. Masutomi, A. Murakami, K. Tsuchiya, H. Kondo, Y. Niwa, K. Yoshimura, T. Ohara, Y. Morino, N. Schutgens, K. Sudo, T. Takemura, T. Inoue, Y. Arai, R. Murata, R. Yonemoto, T.T.N. Trieu, M. Uematsu, M. Satoh, H. Tomita, H. Yashiro and M. Hara (2015) Development of Seamless Chemical Assimilation System and Its Application for Atmospheric Environmental Materials. *Simulation*, 34(2): 104-114 (In Japanese).

Nakajima, T., S. Misawa, Y. Morino, H. Tsuruta, D. Goto, J. Uchida, T. Takemura, T. Ohara, Y. Oura, M. Ebihara and M. Satoh (2017) Model depiction of the atmospheric flows of radioactive cesium emitted from the Fukushima Daiichi Nuclear Power Station accident, *Progress in Earth and Planetary Science*, 4: 2, doi:10.1186/s40645-017-0117-x.

Nitta, T., K. Yoshimura and A. Abe-Ouchi (2017) Impact of arctic wetlands on the climate system: Model sensitivity simulations with the MIROC5 AGCM and a wetland scheme. *Journal of Hydrometeorology*, 18: 11, doi:10.1175/JHM-D-16-0105.1.

Oikawa, E. T. Nakajima and D. Winker (2018) An evaluation of the shortwave direct aerosol radiative forcing using CALIOP and MODIS observations. *Journal of Geophysical Research: Atmosphere*, 123: 1211-1233. doi:10.1002/2017JD027247.

Okata, M., T. Nakajima, K. Suzuki, T. Inoue, T. Y. Nakajima and H. Okamoto (2017) A study on radiative transfer effects in 3D cloudy atmosphere using satellite data. *Journal of Geophysical Research: Atmosphere*, 122: 443-468, doi:10.1002/2016JD025441.

Park, C., T. Hanaoka, T. Masui, L. Dongkun, and J. Taeyong (2019) Impacts of Climate Change, Income Change and Mitigation Measures on CO_2 emission in the Korean Residential Sector in 2050, *Journal of Climate Change Research*, 10(1): 9-21, doi: 10.15531/ksccr.2019.10.1.9

Park, C., R. Xing, T. Hanaoka, Y. Kanamori and T. Masui (2017) Impact of Energy Efficient Technologies on Residential CO_2 Emissions: A Comparison of Korea and China. *Energy Procedia*, 111: 689-698(2017). doi:10.1016/j.egypro.2017.03.231.

Park, S., T. Takemura and S. -W. Kim (2018) Comparison of aerosol optical depth between observation and simulation from MIROC-SPRINTARS: Effects of temporal inhomogeneous sampling. *Atmospheric Environment*, 186: 56-73, doi:10.1016/j.atmosenv.2018.05.021.

Sahu, S., T. Ohara, G. Beig, J. Kurokawa and T. Nagashima (2015) Rising critical emission of air pollutants from renewable biomass based cogeneration from the sugar industry in India. *Environmental Research Letters*, 10, doi:10.1088/1748-9326/10/9/095002.

Sato, Y., H. Miura, H. Yashiro, D. Goto, T. Takemura, H. Tomita and T. Nakajima (2016) Unrealistically pristine air in the Arctic produced by current global scale models, *Scientific Reports*, 6: 26561, doi:10.1038/srep26561.

Sato, Y., D. Goto, T. Michibata, K. Suzuki, T. Takemura, H. Tomita and T. Nakajima (2018) Aerosol effects on cloud water amounts were successfully simulated by a global cloud-system resolving model. *Nature Communications*, 9: 985, doi:10.1038/s41467-018-03379-6.

Saya, A., K. Yoshimura, T. Yoshikane, E.-C. Chang and T. Oki (2018) Precipitation redistribution method for regional simulations of radioactive material transport during the Fukushima Daiichi nuclear power plant accident, *Journal of Geophysical Research: Atmosphere*, 123. doi:10.1029/2018JD028531.

Sekiya, T., K. Sudo and T. Nagai (2016) Evolution of stratospheric sulfate aerosol from the 1991 Pinatubo eruption: Roles of aerosol microphysical processes. *Journal of Geophysical Research: Atmosphere*, 121: 2911-2938, doi:10.1002/2015JD024313.

Sekiya, T., K. Miyazaki, K. Ogochi, K. Sudo and M. Takigawa (2018) Global high-resolution simulations of tropospheric nitrogen dioxide using CHASER V4.0. *Geoscientific Model Development*, 11: 959-988, doi:10.5194/gmd-11-959-2018.

Seposo, X., M. Kond, K. Ueda, T. Michikawa, S. Yamazaki and H. Nitta (2018) Health impact assessment of PM2.5-related mitigation scenarios using local risk coefficient estimates in 9 Japanese cities. *Environmental International*, 120: 525-534. doi:10.1016/j.envint.2018.08.037.

Shi, C., T. Nakajima and M. Hashimoto (2016) Simultaneous retrieval of aerosol optical thickness and chlorophyll concentration from multi-wavelength measurement over East China Sea. *Journal of Geophysical Research: Atmosphere* 121: 14084-14101. doi:10.1002/2016JD025790.

Sudo, K. (2017) Investigating Global Changes in Atmospheric Trace Constituents with a Chemistry Climate Model, *Atmospheric Chemistry Research*, 36: 036A03 (In Japanese).

Suzuki, K., and T. Takemura (2019) Perturbations to global energy budget due to absorbing and scattering aerosols. *Journal of Geophysical Research: Atmosphere*, 124, doi:10.1029/2018JD029808.

Takahashi, H. G., S. Watanabe, M. Nakata and T. Takemura (2018) Response of the atmospheric hydrological cycle over the tropical Asian monsoon regions to anthropogenic aerosols and its seasonality. *Progress in Earth and Planetary Science*, 5: 44, doi:10.1186/s40645-018-0197-2.

Takemura, T., and K. Suzuki (2019) Weak global warming mitigation by reducing black carbon emissions. *Scientific Reports*, 9: 4419, doi:10.1038/s41598-019-41181-6.

Trieu, T. T. N., D. Goto, H. Yashiro, R. Murata, K. Sudo, H. Tomita, M. Satoh and T. Nakajima (2017) Evaluation of summertime surface ozone in Kanto area of Japan using a semi-regional model and observation, *Atmospheric Environment*, 153: 163-181, doi:10.1016/j.atmosenv.2017.01.030.

Uchida, J., M. Mori, M. Hara, M. Satoh, D. Goto, T. Kataoka, K. Suzuki and T. Nakajima (2017) Impact of lateral boundary errors on simulations of convective systems with a non-hydrostatic regional climate model. *Monthly Weather Review*, 145: 5059-5082, doi:10.1175/MWR-D-17-0158.1.

Uchida, J., M. Mori, H. Nakamura, M. Satoh, K. Suzuki and T. Nakajima (2016) Error and energy budget analysis of a non-hydrostatic stretched-grid global atmospheric model. *Monthly Weather Review*, 144: 1423-1447, doi:10.1175/MWR-D-15-0271.1.

Ueda K., S. Tasmin, A. Takami, D. Goto, M. Oishi, V.L.H. Phung, S. Yasukochi and P. H. Chowdhury (2016) Effects of Long-term Exposure to Fine Particulate Matter on Mortality: Systematic Review and Meta-analysis on Assessment of Exposure and Health Effects in Epidemiological Studies. *Journal of Japan Society for Atmospheric Environment*, 51(6): 245-256 (in Japanese).

Ueda, K., M. Yamagami, F. Ikemori, K. Hisatsune and H. Nitta (2016) Associations between fine particulate matter components and daily mortality in Nagoya, Japan. *Journal of Epidemiology*, 26: 249-257, doi:10.2188/jea.JE20150039.

Wei, Z. K. Yoshimura, L. Wang, D. Miralles, S. Jasechko and X. Lee (2017) Revisiting the contribution of transpiration to global terrestrial evapotranspiration. *Geophysical Research Letter*, doi:10.1002/2016GL072235.

Wu R., H. Dai, Y. Geng, Y. Xie, T. Masui and T. Xu (2016) Achieving China's INDC through carbon cap-and-trade: Insights from Shanghai. *Applied Energy*, 184: 1114–1122, doi: 10.1016/j.apenergy.2016.06.011

Wu R., H. Dai, Y. Geng, Y. Xie, T. Masui, Z. Liu and Y. Qian (2017) Economic Impacts from PM2.5 Pollution-Related Health Effects: A Case Study in Shanghai. *Environmental Science & Technology*, 51 (9): 5035-5042, doi: 10.1021/acs.est.7b00026

Xie, Y., H. Dai, H. Dong, T. Hanaoka and T. Masui (2016) Economic impacts from $PM_{2.5}$ pollution-related health effects in China: A provincial-level analysis. *Environmental Science and Technology*, 50 (9): 4836-4843. doi:10.1016/j.envint.2018.03.030.

Xie, Y., H. Dai, Y. Zhang, Y. Wu, T. Hanaoka and T. Masui (2019) Comparison of health and economic impacts of $PM_{2.5}$ and ozone pollution in China, *Environmental International*, 30: 104881, doi: 10.1016/j.envint.2019.05.075

Xing, R., T. Hanaoka, Y. Kanamori and T. Masui (2015) An Impact Assessment of Sustainable Technologies for the Chinese Urban Residential Sector at Provincial Level. *Environmental Research Letters*, 10(6), doi: 10.1088/1748-9326/10/6/065001

Xing, R., T. Hanaoka, Y. Kanamori and T. Masui (2015) Energy Service Demand Projections and CO2 Reduction Potentials in Rural Households in 31 Chinese Provinces. *Sustainability*, 7: 15833-15846, doi: 10.3390/su71215789

Xing, R., T. Hanaoka, Y. Kanamori and T. Masui (2017) Greenhouse Gas and Air Pollutant Emissions of China's Residential Sector: The Importance of Considering Energy Transition. *Sustainability*, 9: 614, doi: 10.3390/su9040614

Xing, R., T. Hanaoka, Y. Kanamori and T. Masui (2018) Achieving Chinas Intended Nationally Determined Contribution and its co-benefits: Effects of the residential sector. *Journal of Cleaner Production*, 172 (20): 2964-2977. doi:10.1016/j.jclepro.2017.11.114.

Xing, R., T. Hanaoka, Y. Kanamori and T. Masui (2018) Estimating energy service demand and CO_2 emissions in the Chinese service sector at provincial level up to 2030, *Resources, conservation and recycling*, 134: 347-360, doi: 10.1016/j.resconrec.2018.02.030

Xing, R., T. Hanaoka, Y. Kanamori and T. Masui (2018) Achieving zero emission in China's urban building sector: Opportunities and barriers, *Current Option in Environmental Sustainability*, 30: 115-122, doi: 10.1016/j.cosust.2018.05.005

Xu T., Y. Geng, H. Dai, T. Fujita, R. Wu, Z. Liu, T. Masui and Y. Xie (2016) The effects of household consumption pattern on regional development: A case study of Shanghai. *Energy*, 103: 49-60, doi: 10.1016/j.energy.2016.02.140

Yoshikane, T. and K. Yoshimura (2018) Dispersion characteristics of radioactive materials estimated by using wind patterns. *Scientific Reports*, 8: 9926. doi:10.1038/s41598-018-27955-4.

Yoshimura, K., T. Nitta, Y. Ishitsuka, M. Tada, K. Suzuki and T. Takemura (2018) Impact of short-lived climate pollutants on terrestrial water circulation. *Journal of Japan Society of Civil Engineers. Ser. B1, Hydraulic Engineering*, 74: 4, I_217-I_222. doi:10.2208/jscejhe.74.I-217.

Yumimoto, K., M. Kajino, T. Y. Tanaka, and I. Uno (2019) Dust vortex in the Taklimakan Desert by Himawari-8 high frequency and resolution observation, Scientific Reports, 9: 1209, doi:10.1038/s41598-018-3786104.

Yumimoto, K., T. Y. Tanaka, M. Yoshida, M. Kikuchi, T. M. Nagao, H. Murakami and T. Maki (2018) Assimilation and forecasting experiment for heavy Siberian wildfire smoke in May 2016 with himawari-8 aerosol optical thickness. *Journal of the Meteorological Society of Japan*. 96B: 133-149. doi:10.2151/jmsj.2018-035.

Yumimoto, K. and T. Takemura (2015) Long-Term Inverse Modeling of Asian Dust: Inter-Annual Variations of Its Emission, Transport, Deposition and Radiative Forcing. *Journal of Geophysical Research: Atmosphere*, 120: 1582-1607, doi:10.1002/2014JD022390.

Yumimoto, K., I. Uno, S. Itahashi, M. Kuribayashi and K. Miyazaki (2015) Application of Inversion Technique to Quick Update of Anthropogenic NOx Emission with Satellite Observations and Chemical Transport Model. *Journal of Japan Society for Atmospheric Environment*, 5:199-206. doi:10.11298/taiki.50.199.

Zhang, R., S. Fujimori and T. Hanaoka (2018) Contribution of the transport sector to climate change mitigation: Insights from a global passenger transport model coupled with a computable general equilibrium model. *Applied Energy*, 211(1): 76-88, doi: 10.1016/j.apenergy.2017.10.103

Zhang, R., S. Fujimori and T. Hanaoka (2018) The contribution of transport policies to the mitigation potential and cost of 2°C and 1.5°C goals. *Environmental Research Letters*, 13(5): 054008, doi: 10.1088/1748-9326/aabb0d

Zhao, S., and K. Suzuki (2019) Differing impacts of black carbon and sulfate aerosols on global precipitation and the ITCZ location via atmosphere and ocean energy perturbations. *J. Climate*, 32: 5567-5582, doi:10.1175/JCLI-D-18-0616.1.

Websites:

S-12 HP < http://157.82.240.167/~S12/moej-s12/index.html>