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Atmospheric observations of CO_2, $^{14}CO_2$ and O_2 concentrations to capture fossil fuel CO_2 emissions from the Greater Tokyo Area

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Shigeyuki Ishidoya[2] (O_2 and CO_2 at YYG)
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Hirofumi Sugawara[3] (CO_2 flux at YYG, CO_2/CH_4/CO at NDA)
Naoki Kaneyasu[2] (aerosol component at YYG)
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Points:

- ✓ We have performed ground-based atmospheric observations for measuring concentrations of CO_2, $^{14}CO_2$ and O_2 in the Greater Tokyo Area.

- ✓ The $^{14}CO_2$ measurement was used for separating the fossil fuel CO_2 emissions from the biotic emissions. The O_2:CO_2 exchange ratio (oxidation ratio, OR) was used for the partitioning of CO_2 into emissions from gas fuels and gasoline.

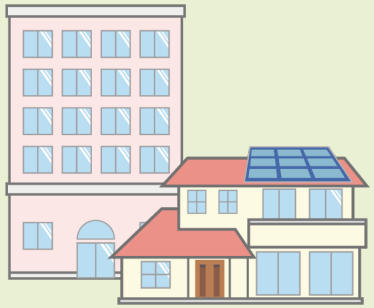
- ✓ Results from $^{14}CO_2$ measurements showed that a ratio of fossil fuel-derived CO_2 to the variation of CO_2 concentrations was 71% (TST) and 73% (YYG) in average for winter but varied from 44% to 92%, indicating significant contribution of biotic CO_2 in Tokyo.

- ✓ Results from OR showed larger OR in winter than in summer (due to both wintertime increases of fossil fuel combustion and summertime terrestrial biospheric activities) at TST and YYG and larger OR in the morning and late evening in winter due to increase of gas fuel combustion at YYG.

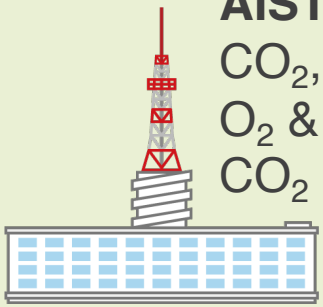
- ✓ Our colleague developed building/road-scale dynamic CO_2 mapping and grid-based high spatial resolution CO_2 emission inventory in Tokyo.

$^{14}CO_2$ and O_2 observations to capture fossil fuel CO_2 emissions

CO_2 from natural gas
$^{14}CO_2$ = zero, OR* = 1.97



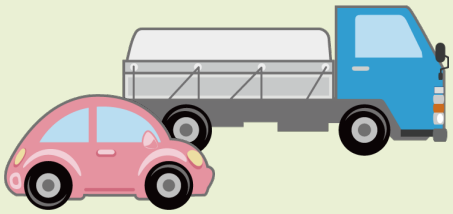
Yoyogi site (52m)
AIST, NDA, NIES
CO_2, CH_4, CO, …
O_2 & $^{14}CO_2$
CO_2 & heat flux



NIES Tokyo Skytree observatory (250m)
CO_2, CH_4, CO, …
O_2 & $^{14}CO_2$

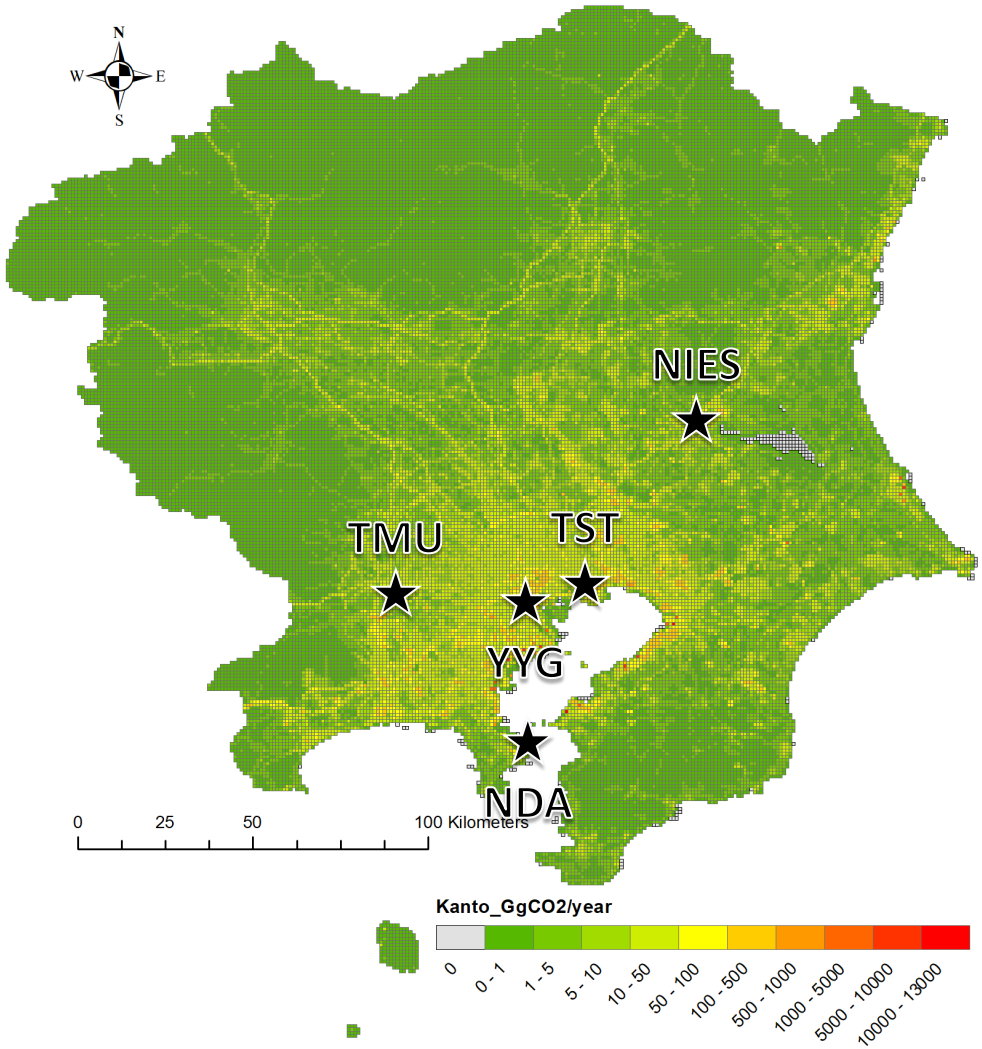
Biospheric CO_2
$^{14}CO_2$ included, OR = 1.1 (plants) & 1.25 (human)

CO_2 from gasoline
$^{14}CO_2$ = zero, OR = 1.5



*Oxidative Ratio; $-O_2/CO_2$ (mol/mol)

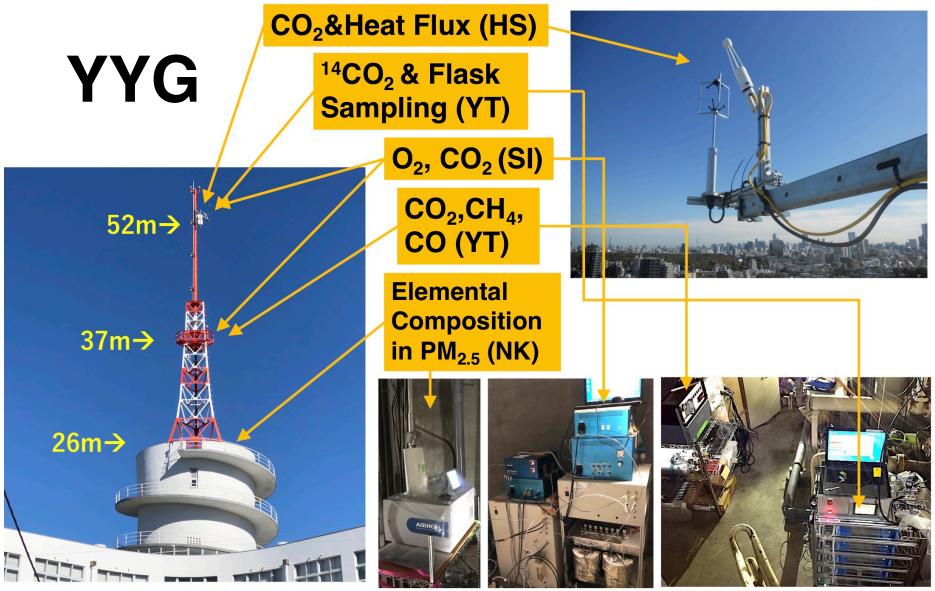
Atmospheric Observations in the Greater Tokyo Area



Tokyo SkyTree (TST)	Sumida, Tokyo	Continuous CO_2, CH_4, CO and O_2 Flask ($^{14}CO_2$)
Yoyogi (YYG)	Shibuya, Tokyo	Continuous CO_2, CH_4, CO and O_2 Flask ($^{14}CO_2$) CO_2 flux, aerosol
NDA	Yokosuka, Kanagawa	Continuous CO_2, CH_4, CO
NIES	Tsukuba, Ibaraki	Continuous CO_2, CH_4, CO and O_2 Flask ($^{14}CO_2$)
Tokyo Metropolitan Univ. (TMU)	Hachioji, Tokyo	Continuous CO_2

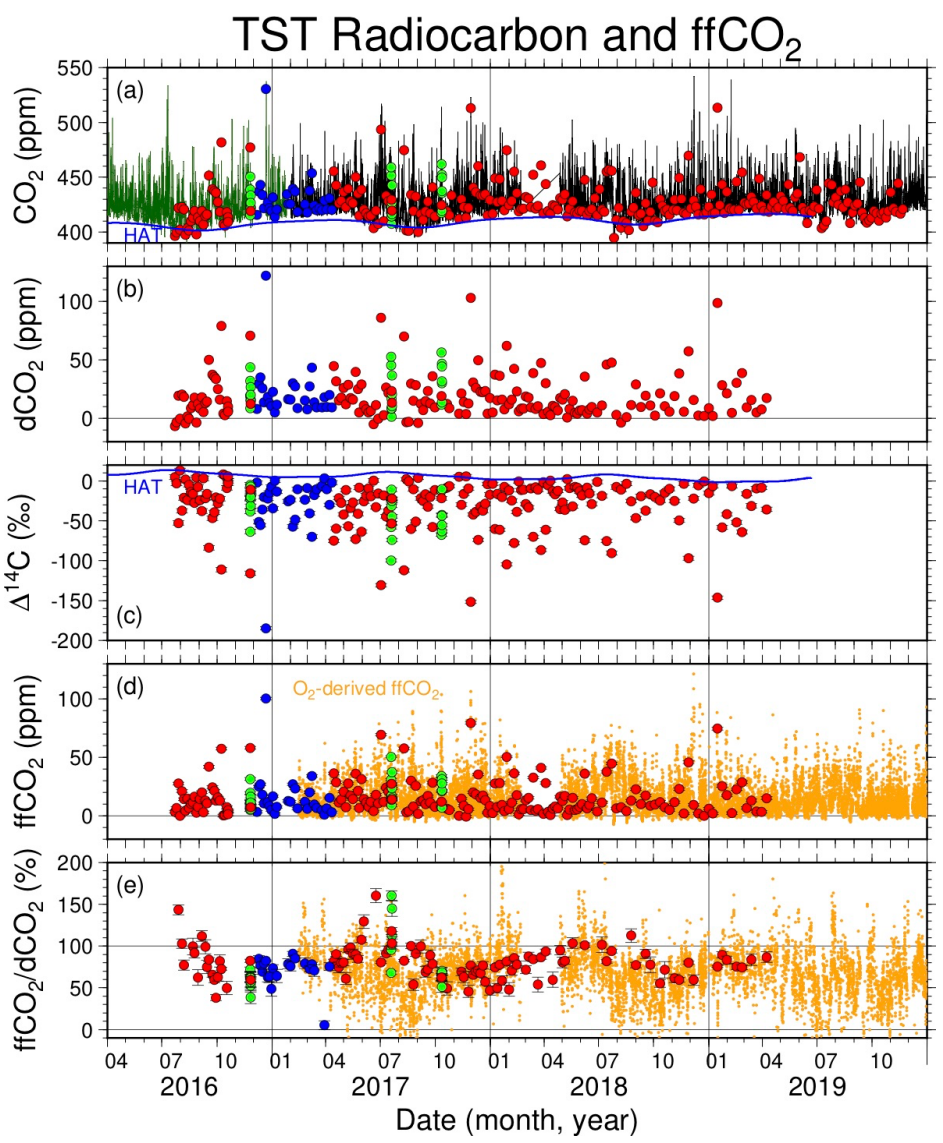
Location of atmospheric observation sites in the Greater Tokyo Area. Color map shows a 1km mesh CO_2 emission data in 2005 (updated from Cong et al., CBM, in review).

Atmospheric Observations at TST and YYG



	Tokyo SkyTree (TST)	Tokai University, Yoyogi (YYG)
CO_2,CH_4,CO	CRDS (Picarro G2401)	
O_2 & CO_2	Fuel cell O_2 analyzer (Oxzilla II) and NDIR (LI-840A) (Hoshina et al., 2018)	Paramagnetic O_2 analyzer (POM-6E) and NDIR (LI-820) (Ishidoya et al., 2017)
$^{14}CO_2$	Flask sampling of whole air (every 4-day). ^{14}C analysis by NIES-CAMS.	
CO_2 flux	N/A	Sonic anemometer (WindMasterPro) and open-path NDIR (LI-7500) (Hirano et al., 2015)
Aerosol	N/A	XRF analyzer (PX-375) (Kaneyasu et al., 2020)

Fossil fuel CO_2 estimated from $^{14}CO_2$ and O_2 at TST



(a) CO_2 mole fraction
Continuous (line) and flask (circles) measurements (14 p.m. or 20 p.m. LT)
Background (Hateruma Island) (curve)

(b) CO_2 increase from background (ΔCO_2)

(c) $\Delta^{14}C$ in CO_2

$\Delta^{14}C = \delta^{14}C - 2(\delta^{13}C + 25)(1 + \delta^{14}C/1000)$

(d) CO_2 from fossil fuel combustion (CO_2^{ff})
derived from $\Delta^{14}C$ (red/blue circles)

$CO_2^{ff} = CO_2^{obs} (\Delta^{14}C^{bg} - \Delta^{14}C^{obs}) / (\Delta^{14}C^{bg} + 1000)$

and from O_2 (orange dots)

$CO_2^{ff} = (\Delta O_2 + \alpha_{bio} \cdot \Delta CO_2)/(\alpha_{bio} - \alpha_{ff})$

ΔO_2 and ΔCO_2: change from baseline

α_{bio}: Oxidative ratio for biosphere (1.05 ± 0.05)

α_{ff}: Oxidative ratio for fossil fuel combustion from inventory (1.68 ± 0.03)

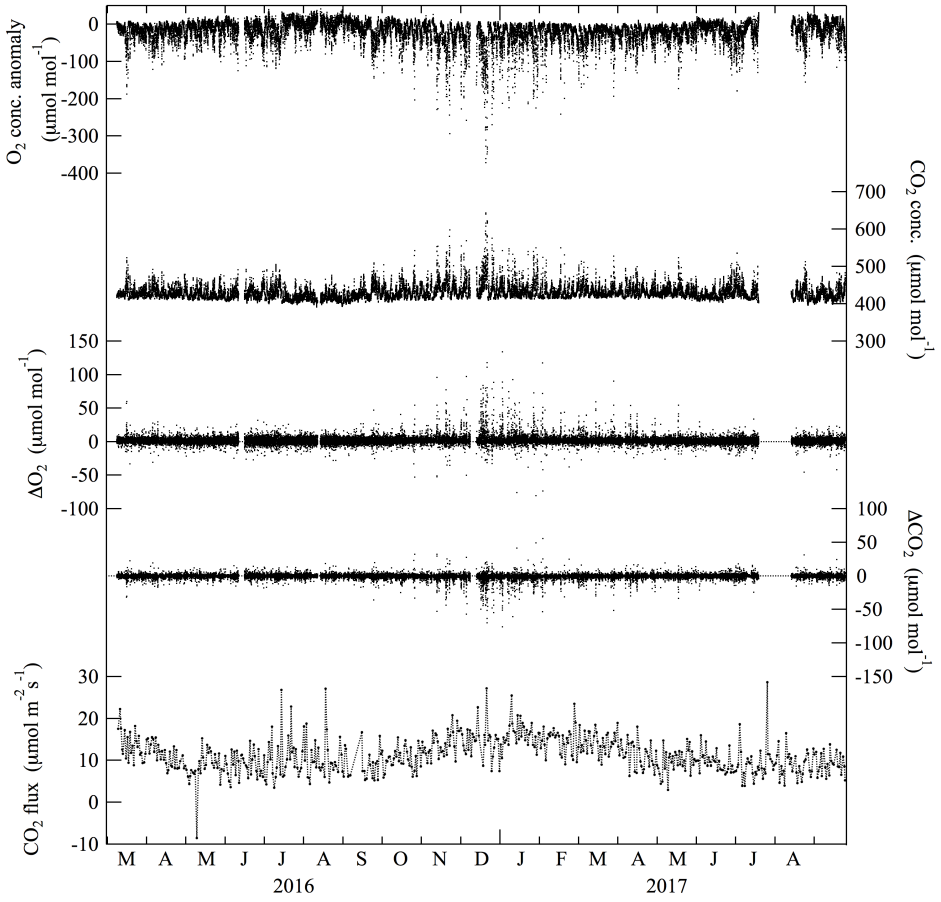
(e) $CO_2^{ff}/\Delta CO_2$

$\Delta^{14}C$-derived CO_2^{ff} was 71% in ΔCO2 for winter, indicating significant contribution of biotic CO_2 in Tokyo. ($\Delta^{14}C$ method doesn't work well in summer)

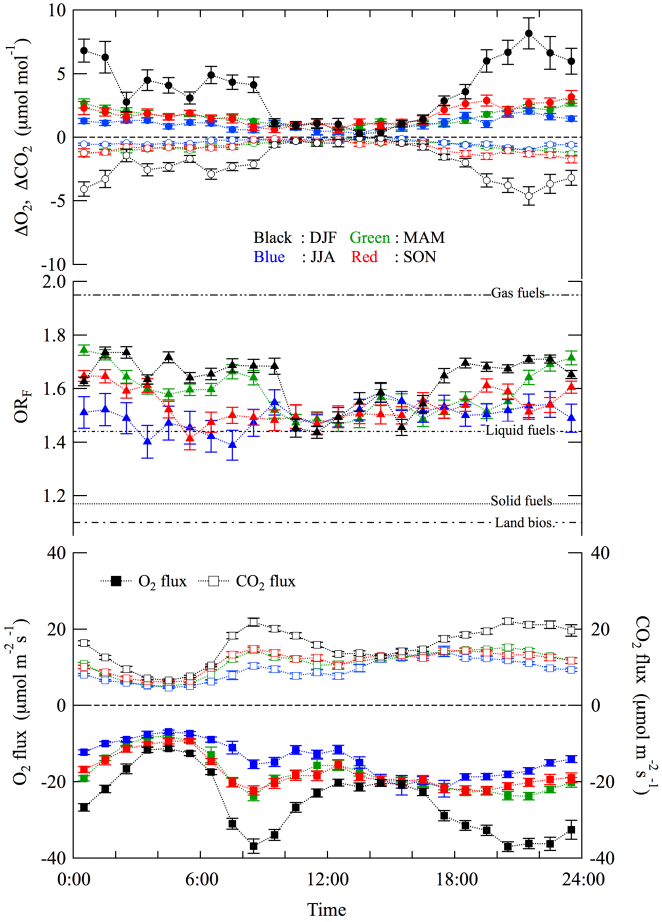
O_2 might be used as a proxy for continuous monitoring of fossil fuel CO_2 content by assuming typical ratio of gas fuels and gasoline combustions.

Oxidative Ratio for net turbulent flux observed at YYG

(Ishidoya et al., ACPD, 2019)

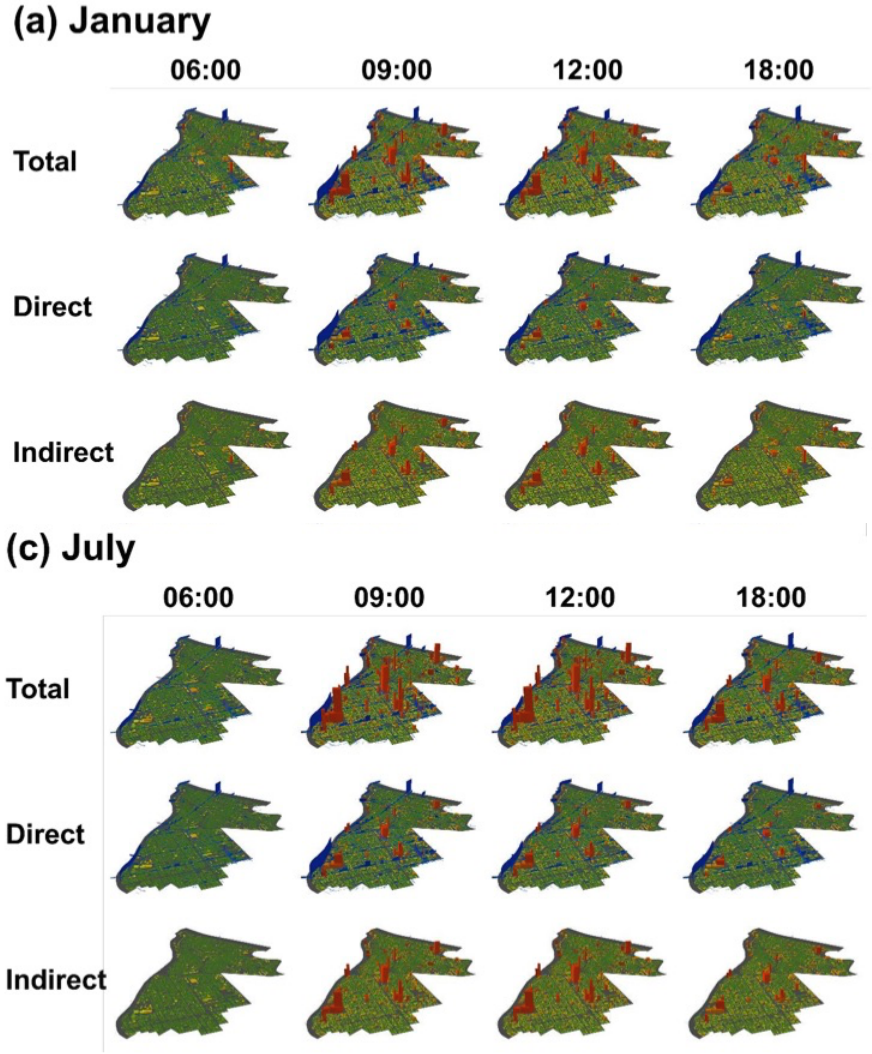


Time series of O_2 and CO_2 concentrations observed at 52 m, ΔO_2 and ΔCO_2 (52 m minus 37 m), and daily mean CO_2 fluxes observed using the eddy correlation method at YYG.



Average diurnal cycles of ΔO_2 and ΔCO_2 for each season: December to February (back), March to May (green), June to August (blue) and September to November (red).

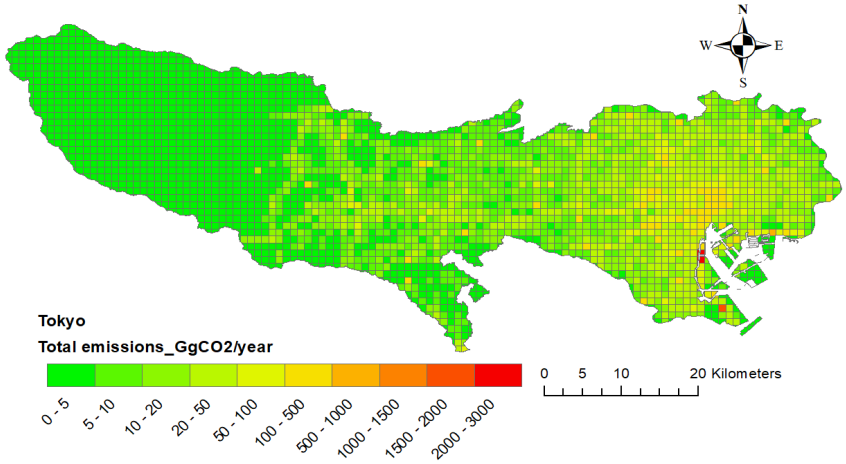
Development of emission inventory in Tokyo



Carbon mapping in Sumida, Tokyo (Yamagata et al., Sustainability, 2018).

← Building/road-scale dynamic CO_2 mapping developed by Y. Yamagata, T. Yoshida and D. Murakami (NIES)

↓ Grid-based high spatial resolution CO_2 emission inventory developed by R. Cong, M. Saito, A. Ito (NIES) and T. Oda (NASA)



CO_2 emission data (1 km mesh) in Tokyo in 2005 (Cong et al., CBM, in review).