

Long-term historical trends in air pollutant emissions in Asia: Regional Emission inventory in ASia (REAS) version 3

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Supplementary figures

Figures S1, S3, S5, S7, S9, and S11 show emissions of (a) SO₂, (b) NO_x, (c) CO, (d) CO₂, (e) PM₁₀, (f) PM_{2.5}, (g) BC, (h) OC, (i) NMVOC, and (j) NH₃ from major sectors during 1950-2015 in China, India, Japan, Southeast Asia (SEA), East Asia other than China and Japan (OEA), and South Asia other than India (OSA), respectively. See Fig. 1 for the definitions of SEA, OEA, and OSA. (Sectors for (a)-(h): PP = Power plants, IND = Industry, ROAD = Road transport, OTRA = Other transport, RESI = Residential, and ODOM = Other domestic; Sectors for (i): CMB = Combustion, ROAD = Road transport (including both tail pipe and evaporative emissions), INDPRC = Industrial processes, EXT = Extraction processes, PAINT = Paint use, SLV = Solvent use, and WST = Waste treatment; Sectors for (j): CMB = Combustion, MM = Manure management, FER = Fertilizer application, HUMAN = Human perspiration and respiration, LTRN = Latrines, and INDPRC = Industrial processes.)

Figures S2, S4, S6, S8, S10, and S12 provide emissions of (a) SO₂, (b) NO_x, (c) CO, (d) CO₂, (e) PM₁₀, (f) PM_{2.5}, (g) BC, (h) OC, (i) NMVOC, and (j) NH₃ from each fuel type during 1950-2015 in China, India, Japan, SEA, OEA, and OSA, respectively. See Fig. 1 for the definitions of SEA, OEA, and OSA. Note that emissions from non-combustion sources are not included in (i) NMVOC and (j) NH₃ to show contributions from fuel types clearly because majority of their emissions are from non-combustion sources. (Fuel types: COAL = Primary coal, DC = Secondary coal, NGAS = Natural gas, OGAS = Other gas fuels, LF = Light oil fuels, MD = Diesel oil, HF = Heavy oil fuels, BF = Biofuels, OTH = Other fuels, NCMB = Non-combustion sources, and CEMK = combustion emissions from cement kilns (only for Japan). Notes: For CO emissions from pig iron, crude steel, and sinter production for all countries, those from brick production except for China, Japan, Republic of Korea, and Taiwan, emissions of PM species from sinter and pig iron production for China, and those from brick production for all countries and regions estimated based on their production amounts, both combustion and non-combustion emissions are included in NCMB here. In Japan, emissions from cement production were estimated not by fuel consumption, but based on production amounts of cement in each kiln type. Therefore, contributions from total emissions from cement kiln combustion are included in CEMK.)

30 **Figure S13** illustrates grid maps of annual emissions of CO₂ and PM₁₀ in 1965 and 2015.

Figures S14 and S15 compare CO, NMVOC, NH₃, PM₁₀, PM_{2.5}, and OC emissions in REASv3 with other published estimates for China and India, respectively. Note that IM means estimates by inverse modeling and [A][B][C] of Jiang et al. (2017) are estimates based on A: MOPITT Column, B: MOPITT Profile, and C: MOPITT Lower Profile, respectively.

35 **Figures S16-S19** compare emissions of SO₂, NO_x, BC, CO, NMVOC, NH₃, PM₁₀, PM_{2.5}, and OC in REASv3 with other published estimates for Japan, SEA, OEA, and OSA, respectively. See Fig. 1 for the definitions of SEA, OEA, and OSA. Note that IM means estimates by inverse modeling and [A][B][C] of Jiang et al. (2017) are estimates based on A: MOPITT Column, B: MOPITT Profile, and C: MOPITT Lower Profile, respectively.

40 **Figures S20** compares Asia total emissions and relative ratios of those from China, India, Japan, SEA, OEA, and OSA for CO, NMVOC, NH₃, PM₁₀, PM_{2.5}, and OC among REASv3, CEDS, and EDGARv4.3.2. See Fig. 1 for definitions of SEA, OEA, and OSA.

China Sector

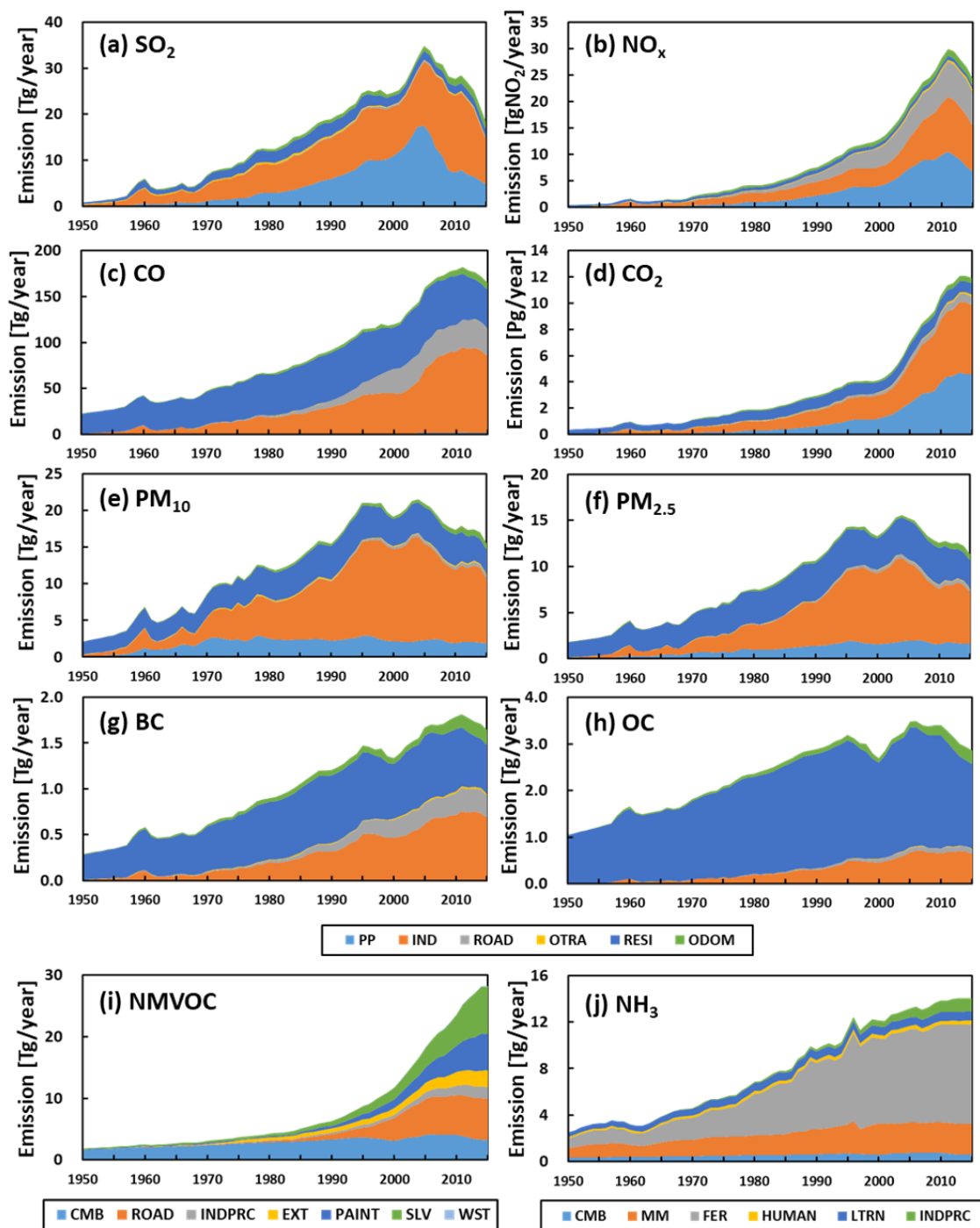


Figure S1. Emissions of (a) SO₂, (b) NO_x, (c) CO, (d) CO₂, (e) PM₁₀, (f) PM_{2.5}, (g) BC, (h) OC, (i) NMVOC, and (j) NH₃ from major sectors in China from 1950 to 2015.

China Fuel

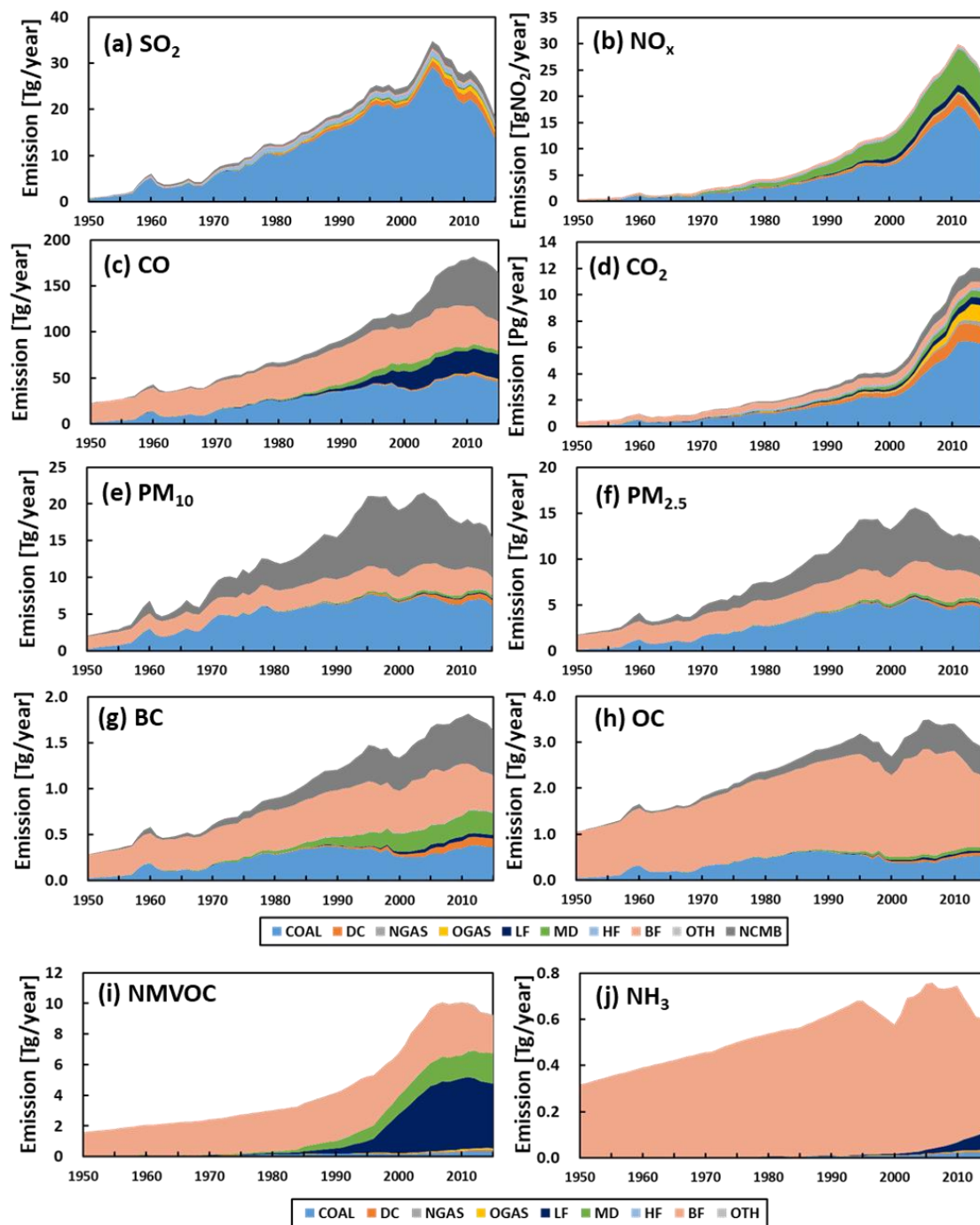


Figure S2. Emissions of (a) SO_2 , (b) NO_x , (c) CO , (d) CO_2 , (e) PM_{10} , (f) $\text{PM}_{2.5}$, (g) BC , (h) OC , (i) NMVOC , and (j) NH_3 from each fuel type in China from 1950 to 2015.

India Sector

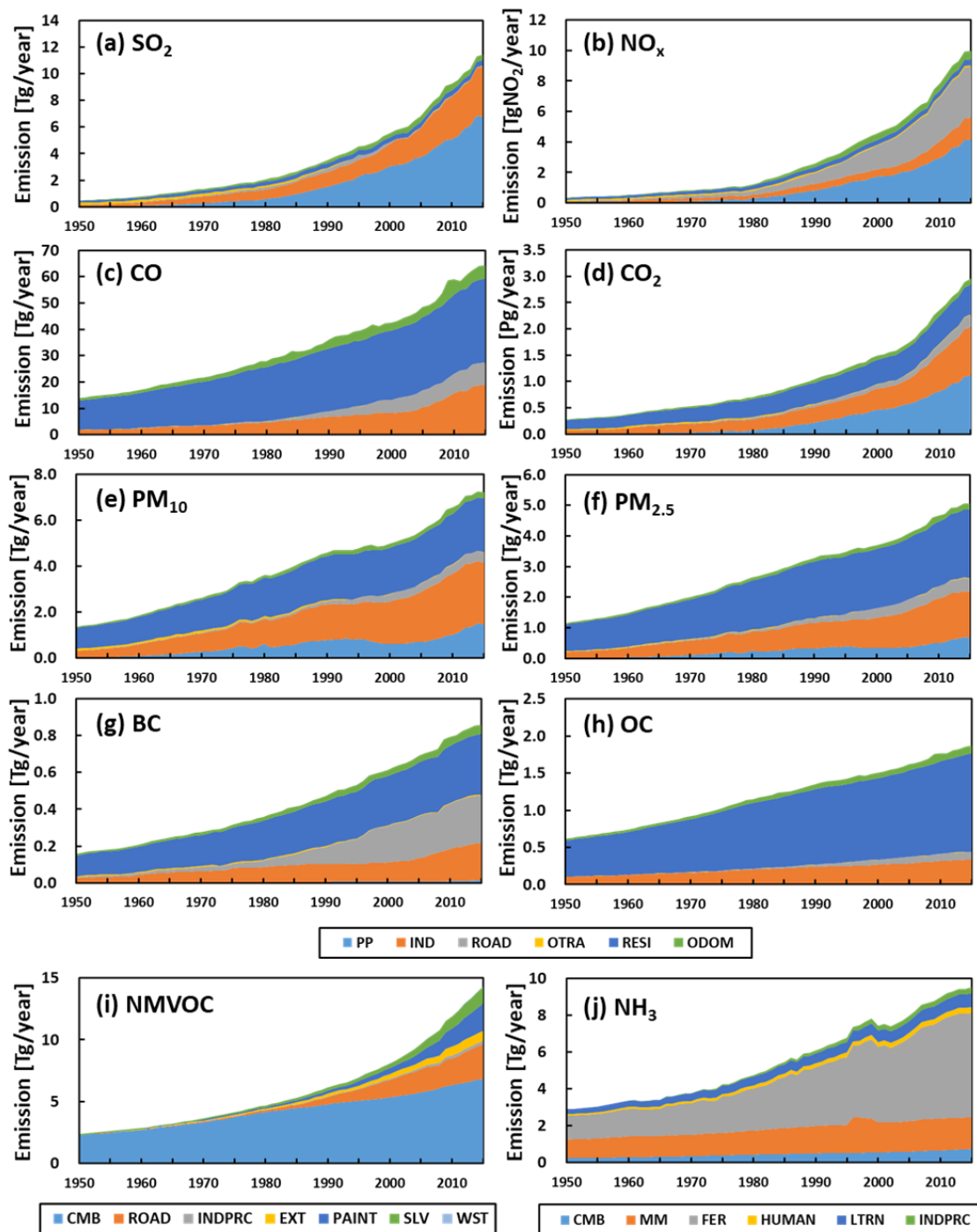


Figure S3. Emissions of (a) SO₂, (b) NO_x, (c) CO, (d) CO₂, (e) PM₁₀, (f) PM_{2.5}, (g) BC, (h) OC, (i) NMVOC, and (j) NH₃ from major sectors in India from 1950 to 2015.

India Fuel

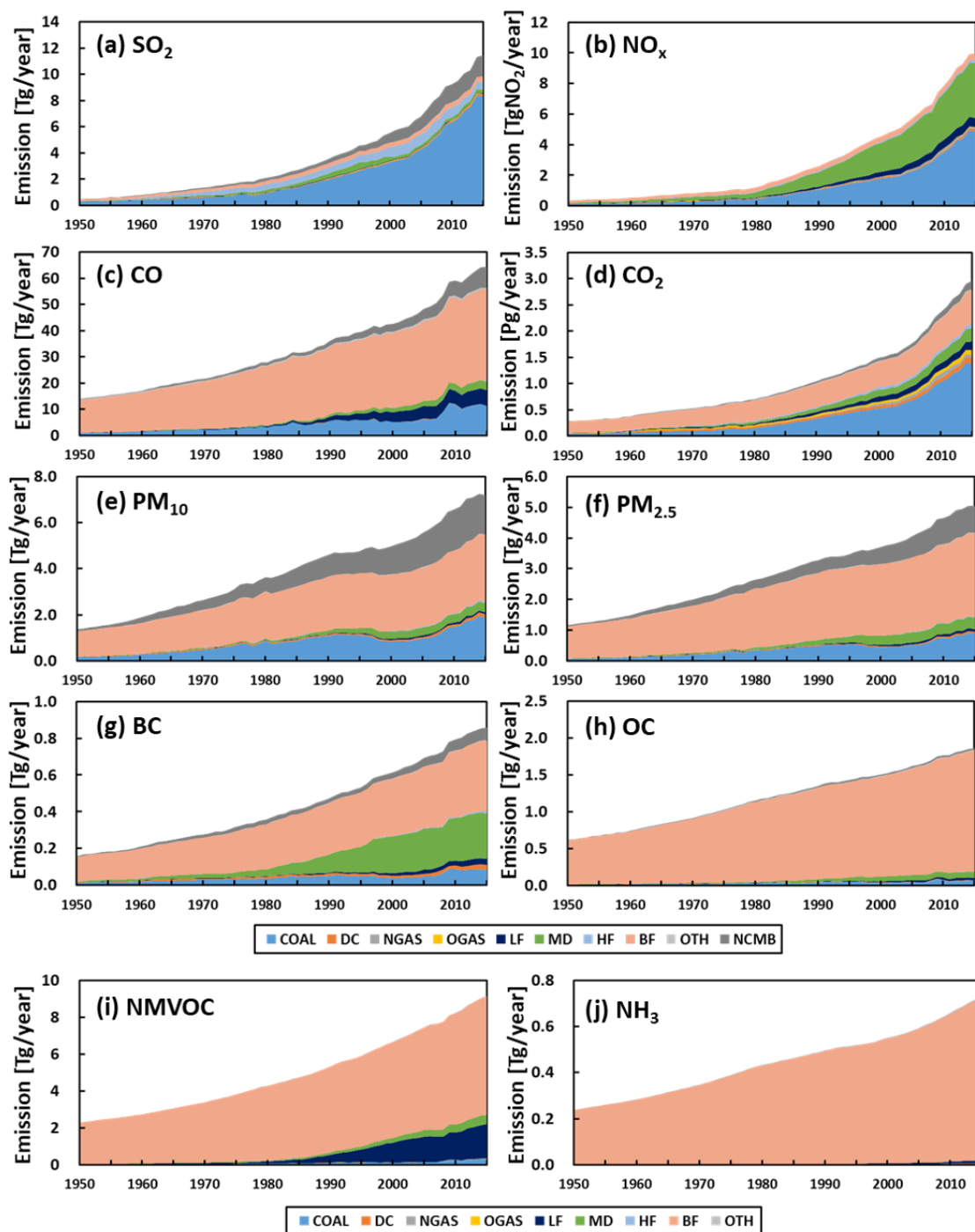
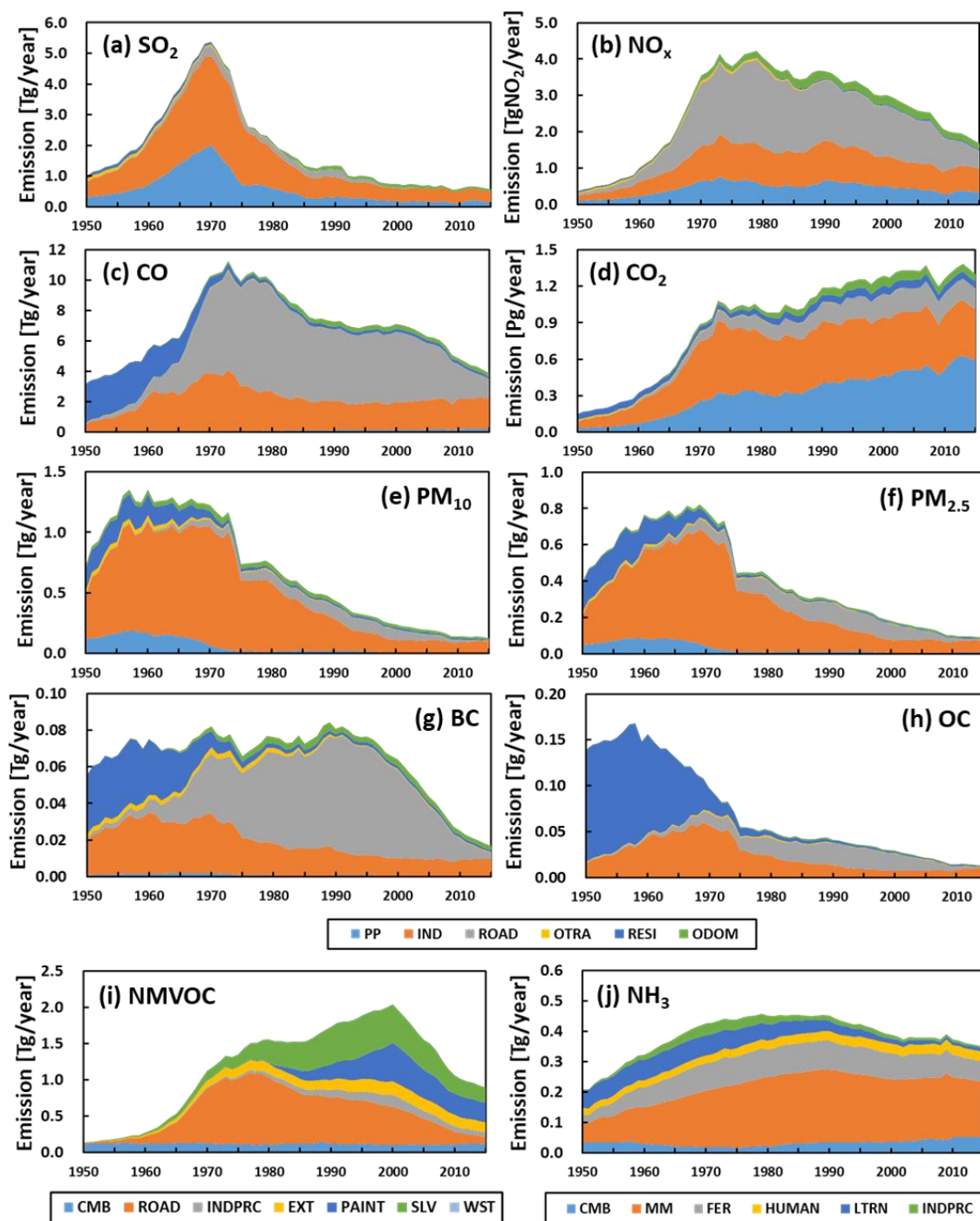


Figure S4. Emissions of (a) SO_2 , (b) NO_x , (c) CO, (d) CO_2 , (e) PM_{10} , (f) $\text{PM}_{2.5}$, (g) BC, (h) OC, (i) NMVOC, and (j) NH_3 from each fuel type in India from 1950 to 2015.

Japan Sector



55 **Figure S5.** Emissions of (a) SO_2 , (b) NO_x , (c) CO , (d) CO_2 , (e) PM_{10} , (f) $\text{PM}_{2.5}$, (g) BC , (h) OC , (i) NMVOC , and (j) NH_3 from major sectors in Japan from 1950 to 2015.

Japan Fuel

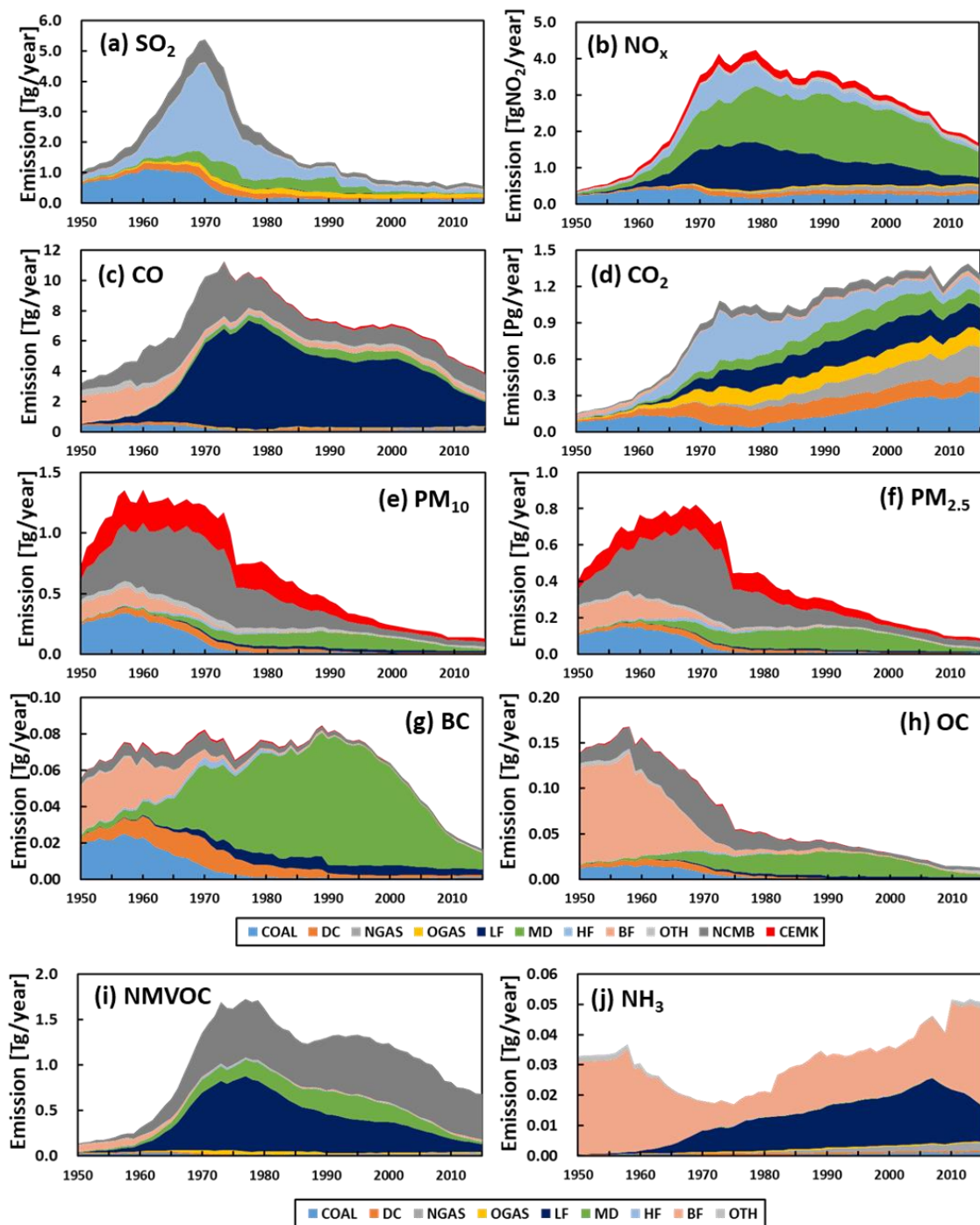


Figure S6. Emissions of (a) SO₂, (b) NO_x, (c) CO, (d) CO₂, (e) PM₁₀, (f) PM_{2.5}, (g) BC, (h) OC, (i) NMVOC, and (j) NH₃ from each fuel type in Japan from 1950 to 2015.

SEA Sector

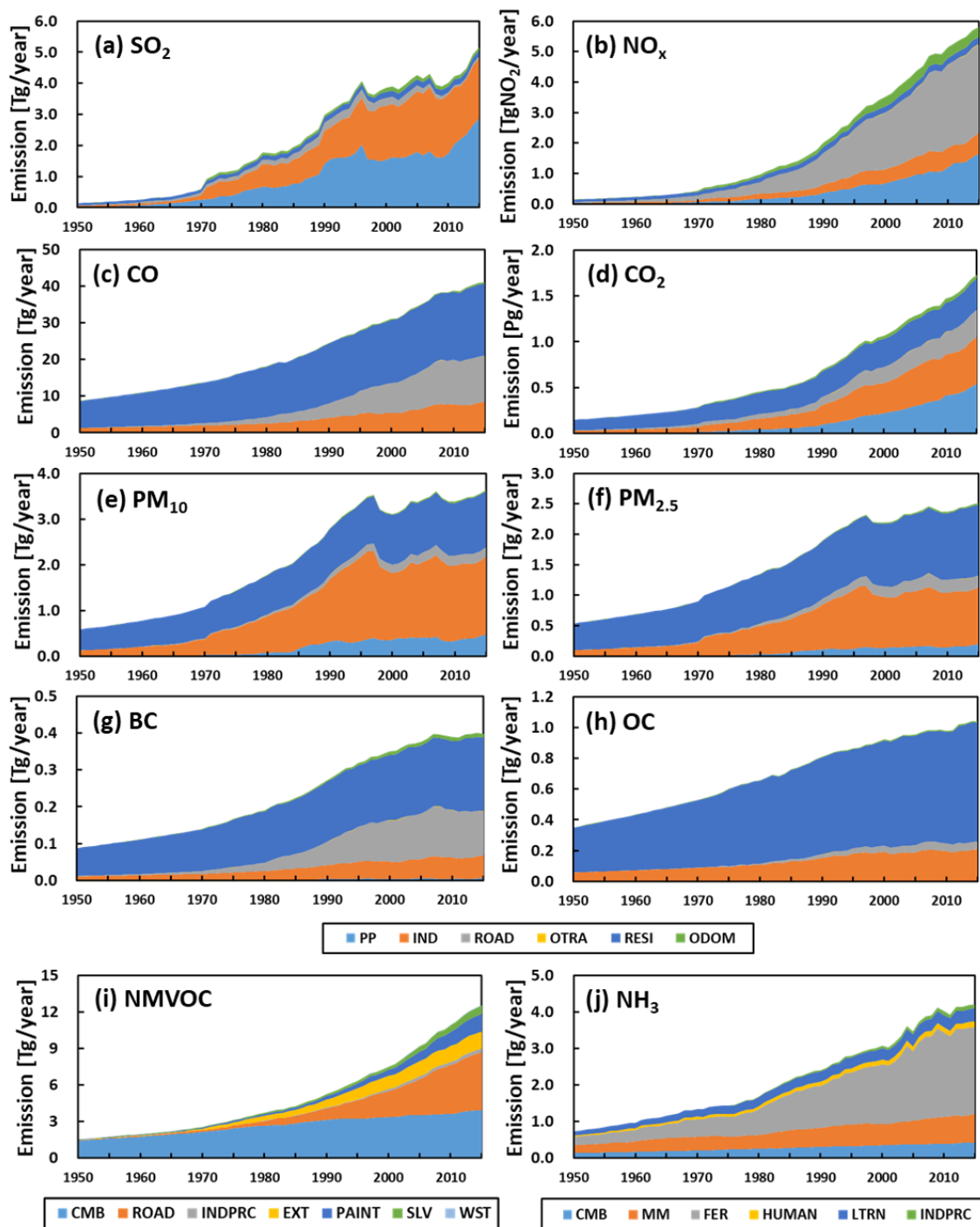


Figure S7. Emissions of (a) SO_2 , (b) NO_x , (c) CO, (d) CO_2 , (e) PM_{10} , (f) $\text{PM}_{2.5}$, (g) BC, (h) OC, (i) NMVOC, and (j) NH_3 from major sectors in SEA from 1950 to 2015. See Fig. 1 for the definitions of SEA.

SEA Fuel

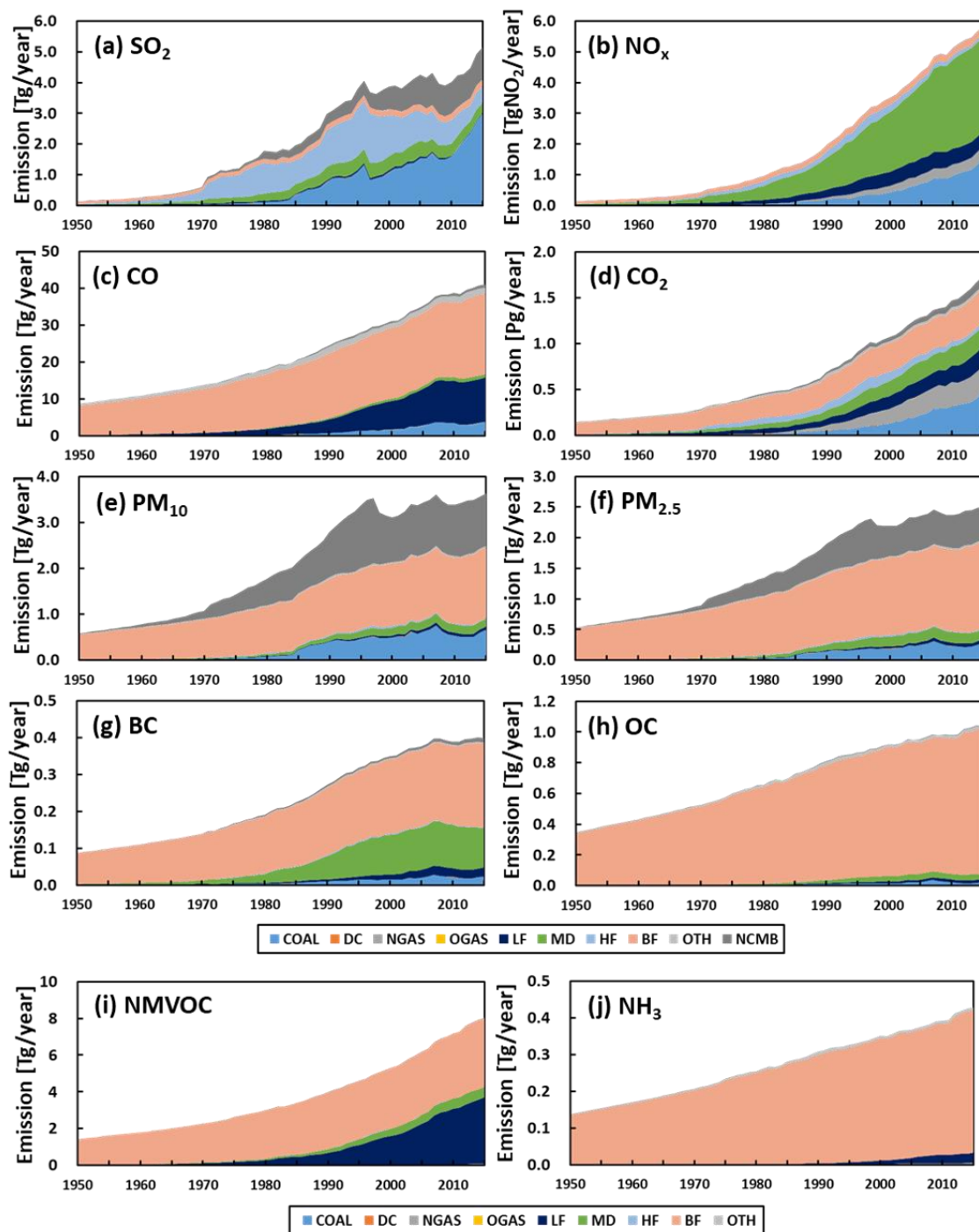


Figure S8. Emissions of (a) SO_2 , (b) NO_x , (c) CO , (d) CO_2 , (e) PM_{10} , (f) $\text{PM}_{2.5}$, (g) BC , (h) OC , (i) NMVOC , and (j) NH_3 from each fuel type in SEA from 1950 to 2015. See Fig. 1 for the definitions of SEA.

OEA Sector

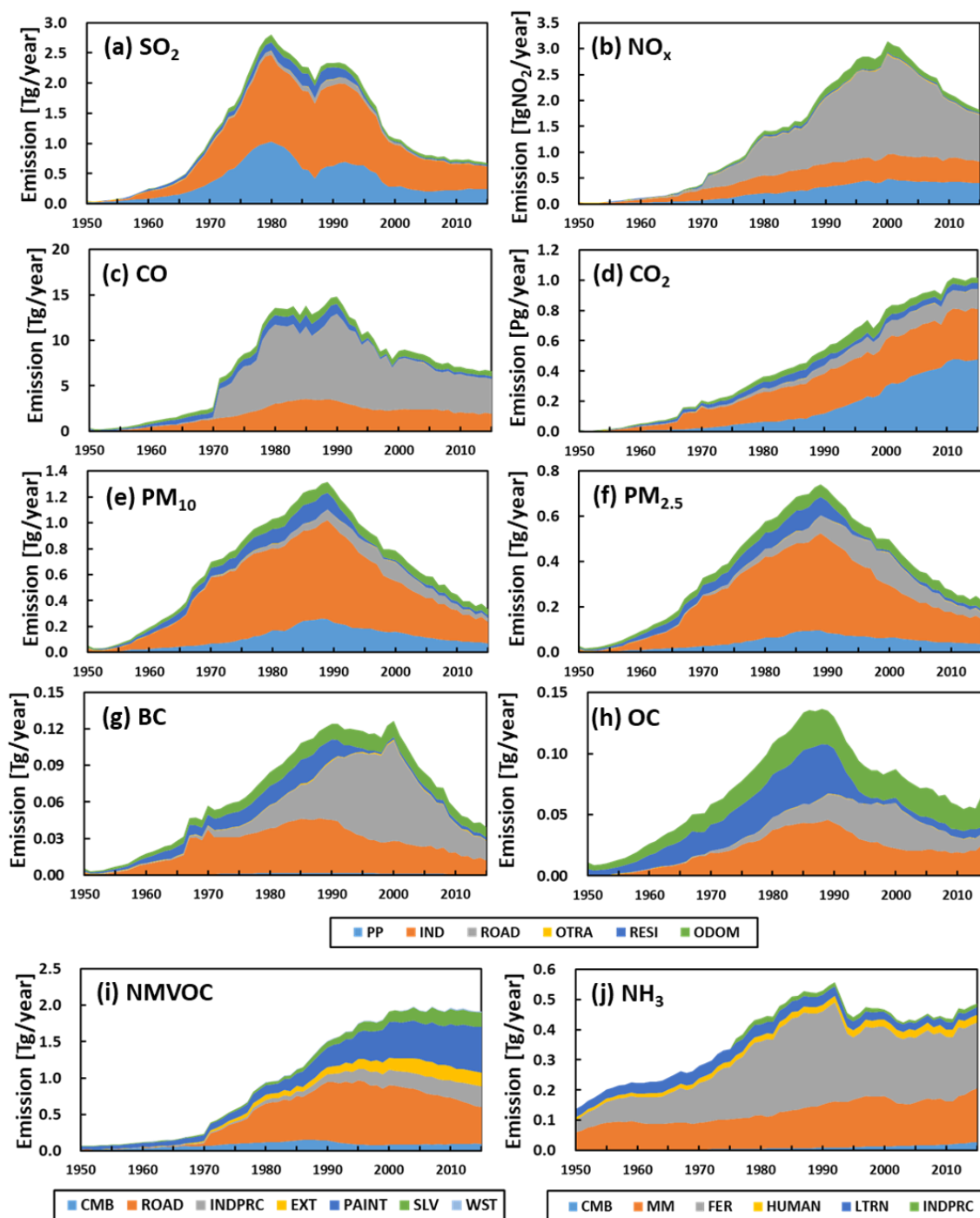
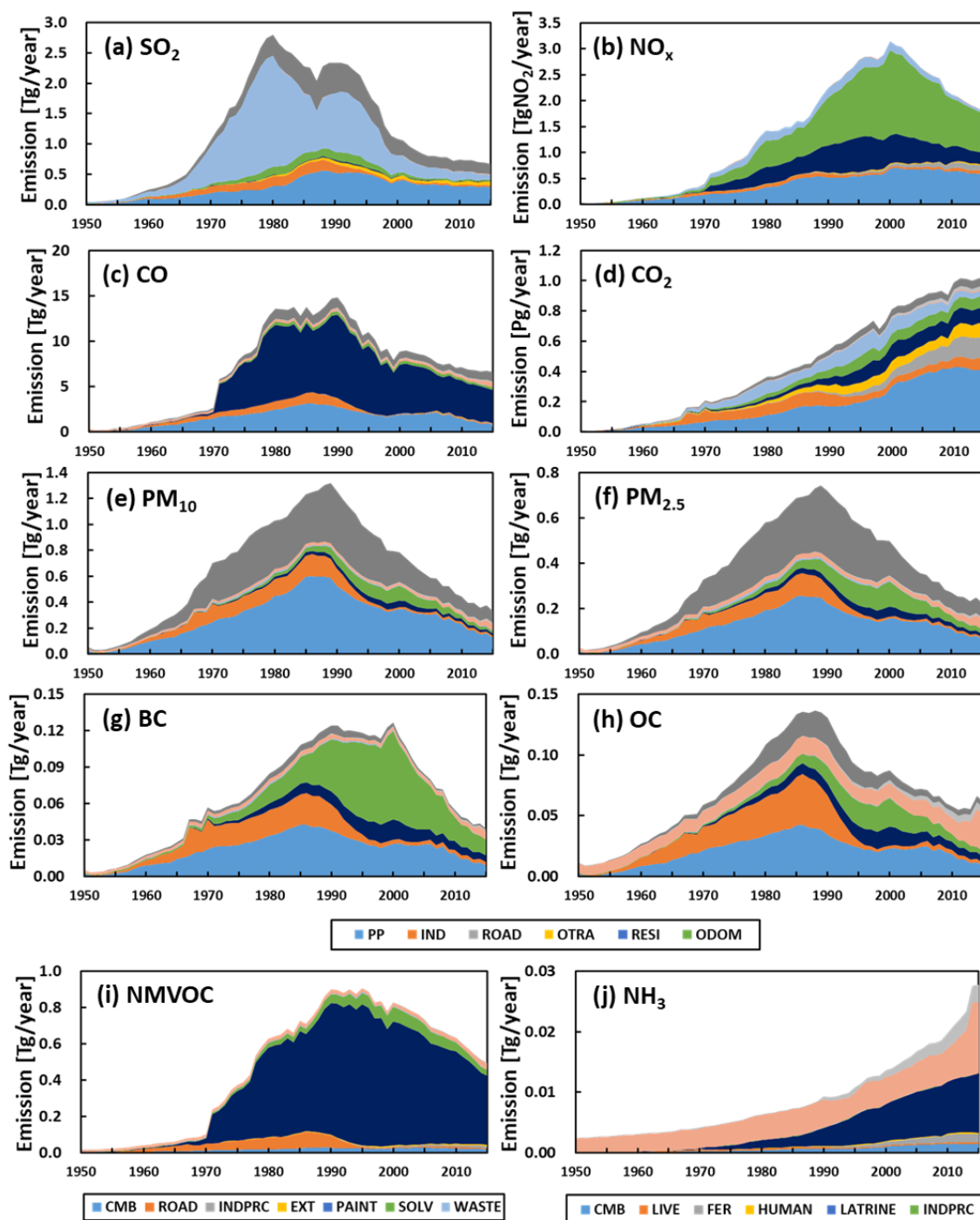


Figure S9. Emissions of (a) SO_2 , (b) NO_x , (c) CO , (d) CO_2 , (e) PM_{10} , (f) $\text{PM}_{2.5}$, (g) BC , (h) OC , (i) NMVOC , and (j) NH_3 from major sectors in OEA from 1950 to 2015. See Fig. 1 for the definitions of OEA.

OEA Fuel



70 **Figure S10.** Emissions of (a) SO_2 , (b) NO_x , (c) CO , (d) CO_2 , (e) PM_{10} , (f) $\text{PM}_{2.5}$, (g) BC , (h) OC , (i) NMVOC , and (j) NH_3 from each fuel type in OEA from 1950 to 2015. See Fig. 1 for the definitions of OEA.

OSA Sector

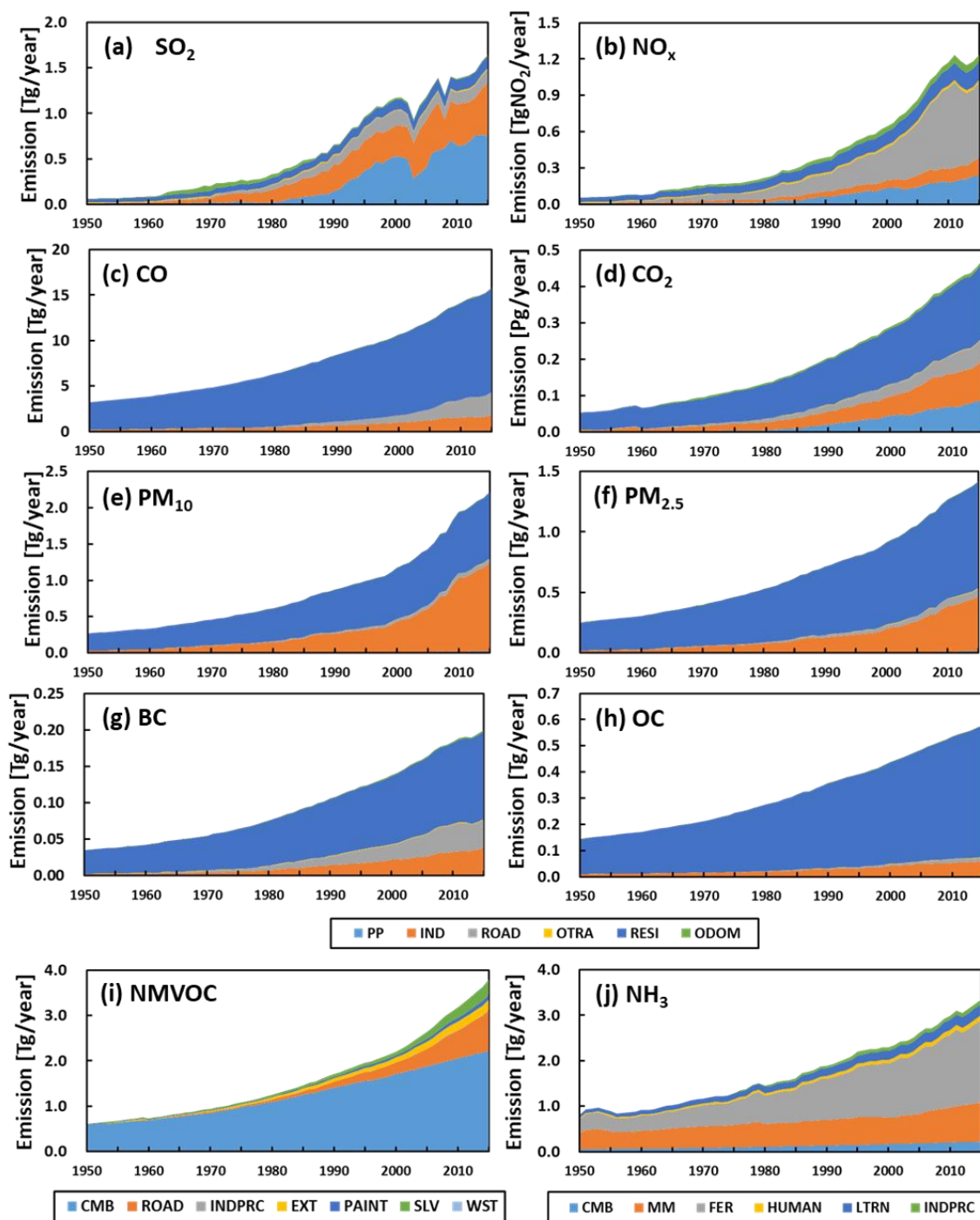


Figure S11. Emissions of (a) SO_2 , (b) NO_x , (c) CO, (d) CO_2 , (e) PM_{10} , (f) $\text{PM}_{2.5}$, (g) BC, (h) OC, (i) NMVOC, and (j) NH_3 from major sectors in OSA from 1950 to 2015. See Fig. 1 for the definitions of OSA.

OSA Fuel

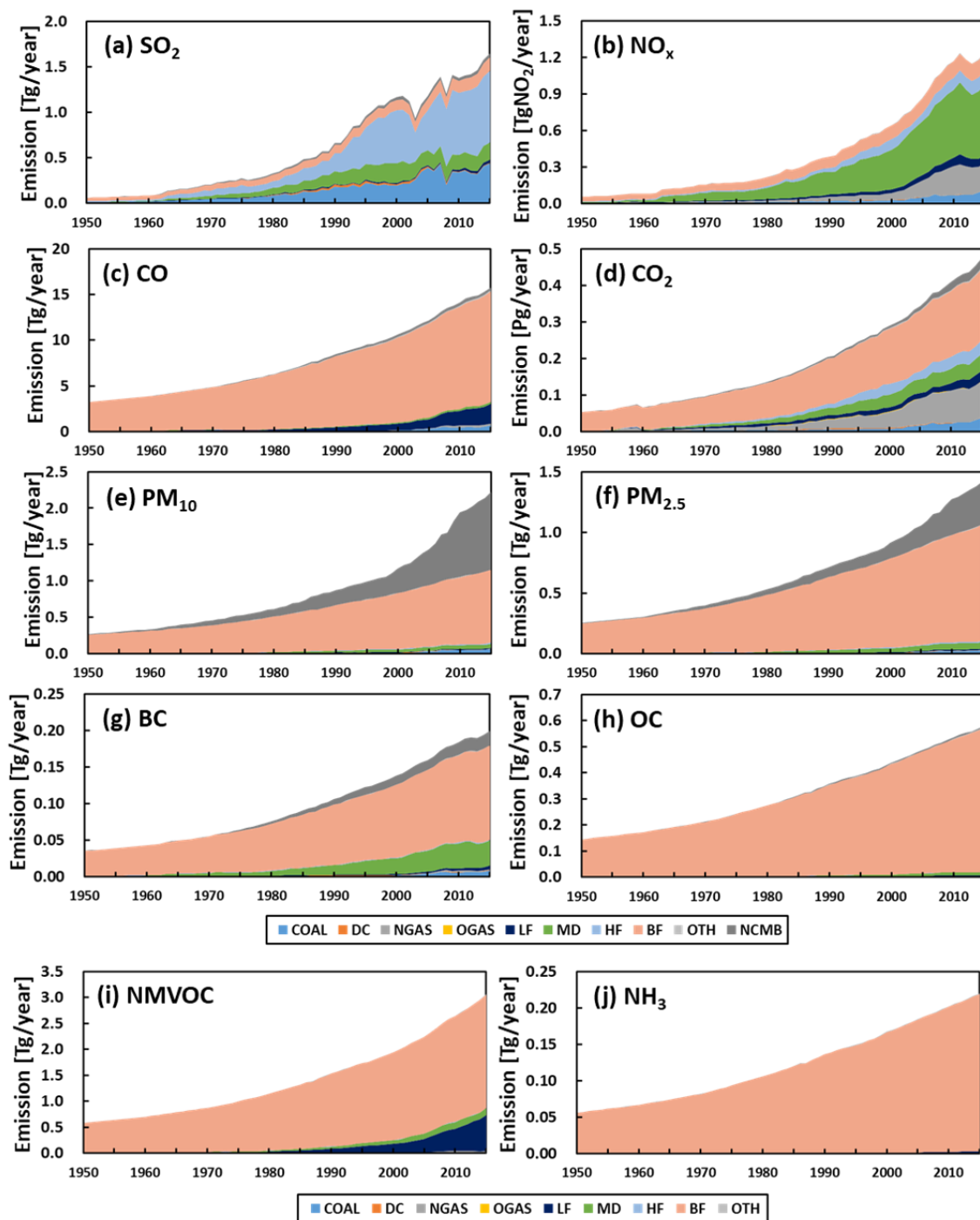


Figure S12. Emissions of (a) SO₂, (b) NO_x, (c) CO, (d) CO₂, (e) PM₁₀, (f) PM_{2.5}, (g) BC, (h) OC, (i) NMVOC, and (j) NH₃ from each fuel type in OSA from 1950 to 2015. See Fig. 1 for the definitions of OSA.

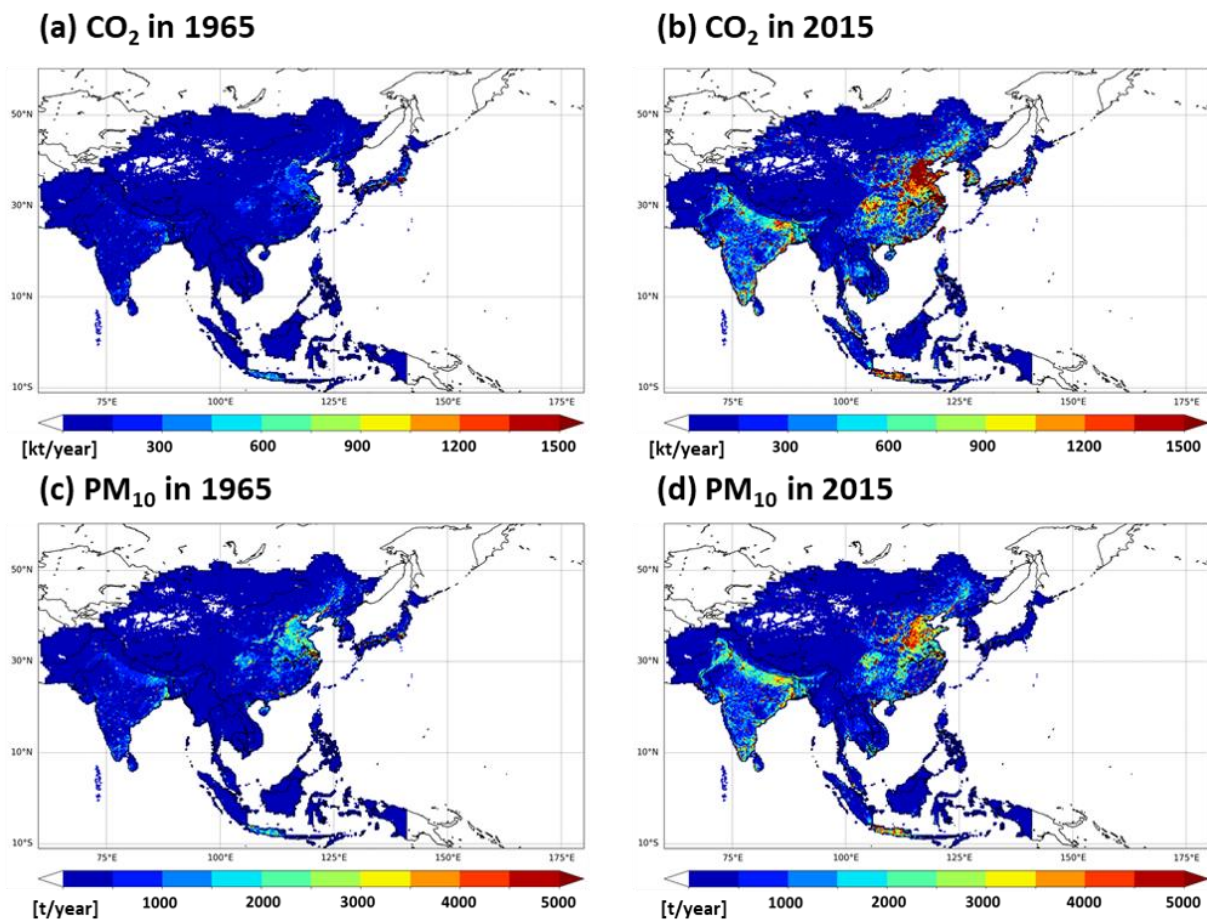


Figure S13. Grid maps of annual emissions of (a, b) CO₂ (kt year⁻¹ per grid cell) and (c, d) PM₁₀ (t year⁻¹ per grid cell) in 1965 (left) and 2015 (right).

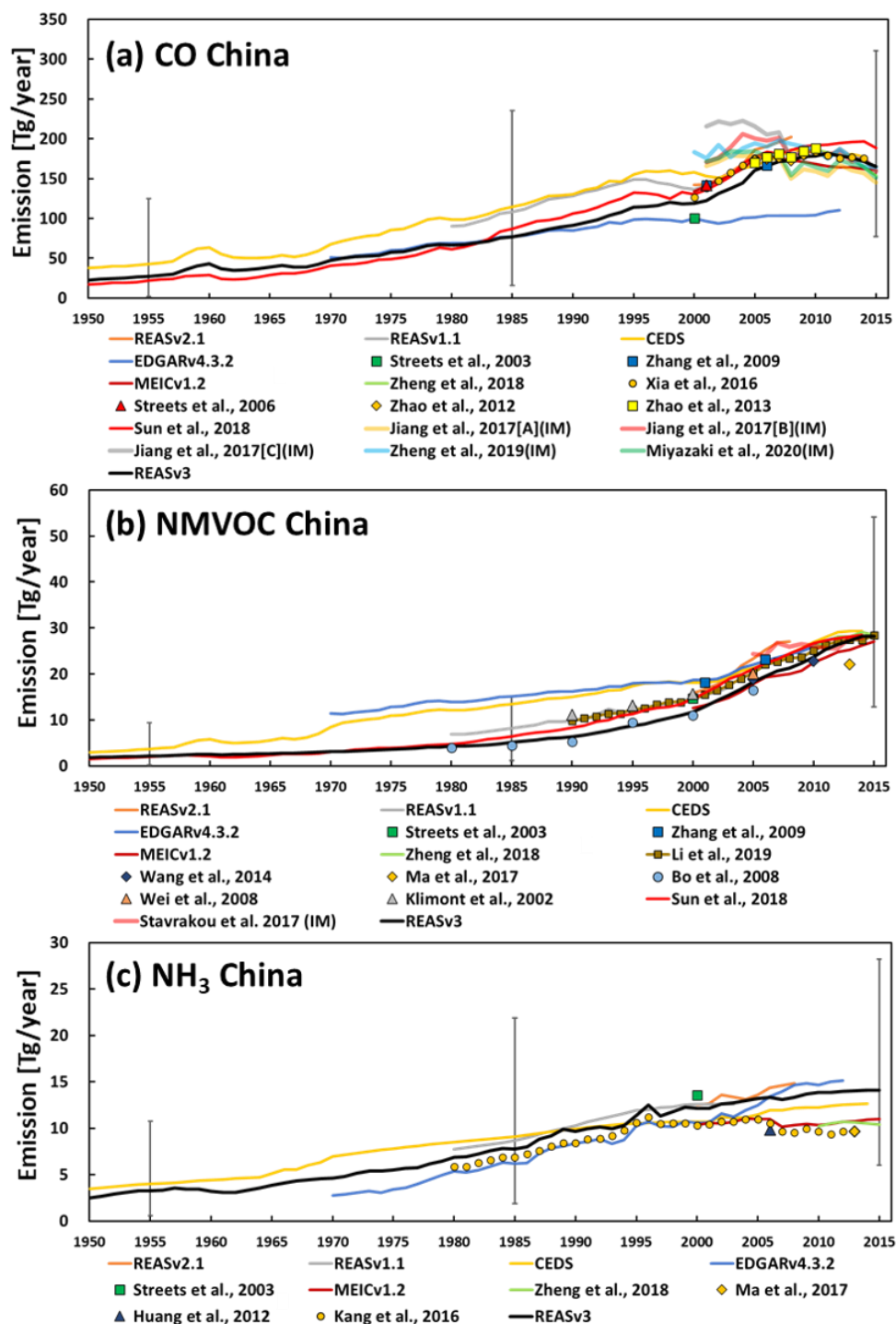


Figure S14. Comparison of (a) CO, (b) NMVOC, (c) NH₃, (d) PM₁₀, (e) PM_{2.5} and (f) OC emissions in China between REASv3 and other studies. Emissions from domestic and fishing ships were excluded from REAS series, CEDS, and EDGARv4.3.2. Error bars indicate the uncertainty range of REASv3 in 1955, 1985, and 2015.

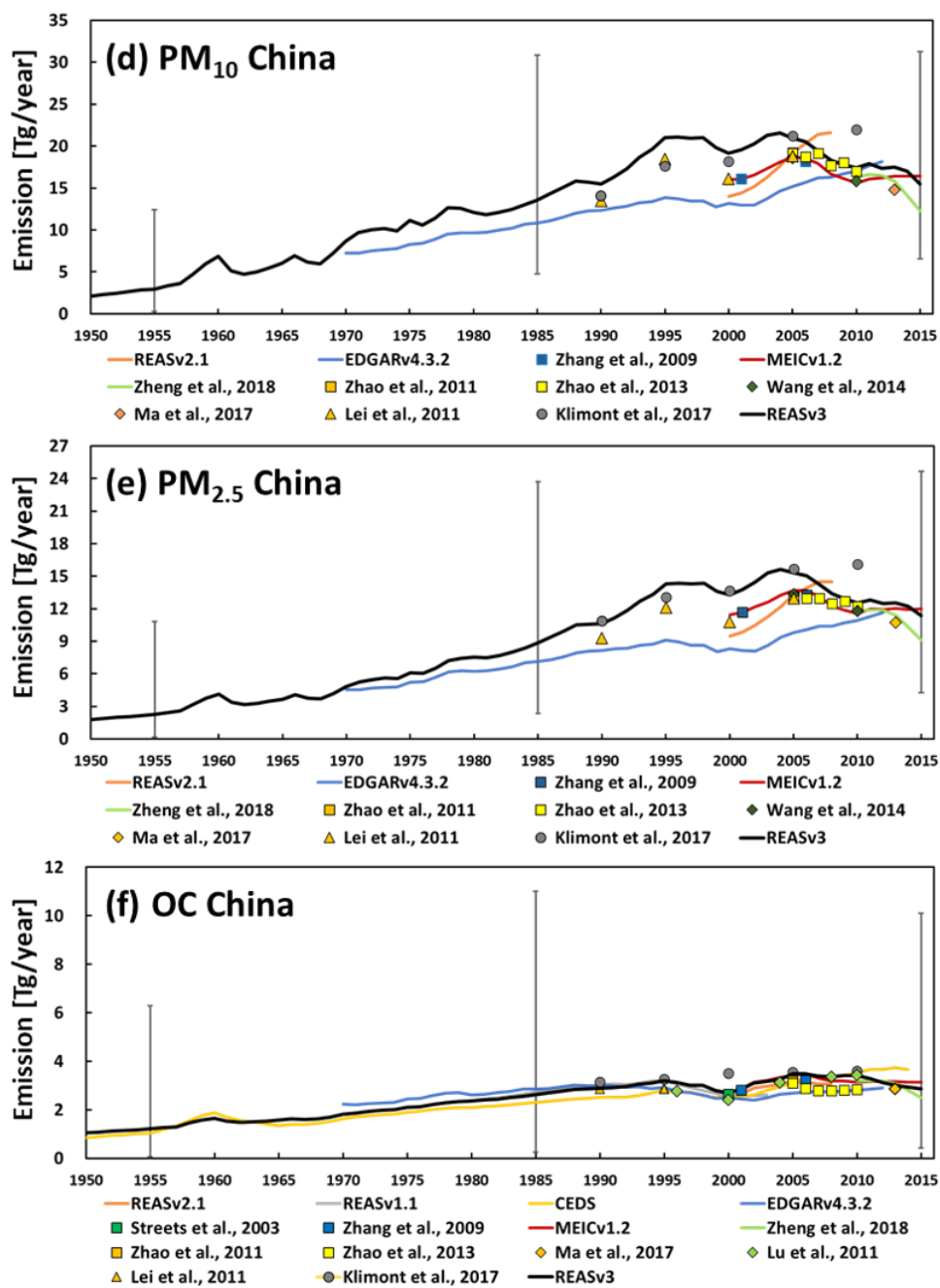
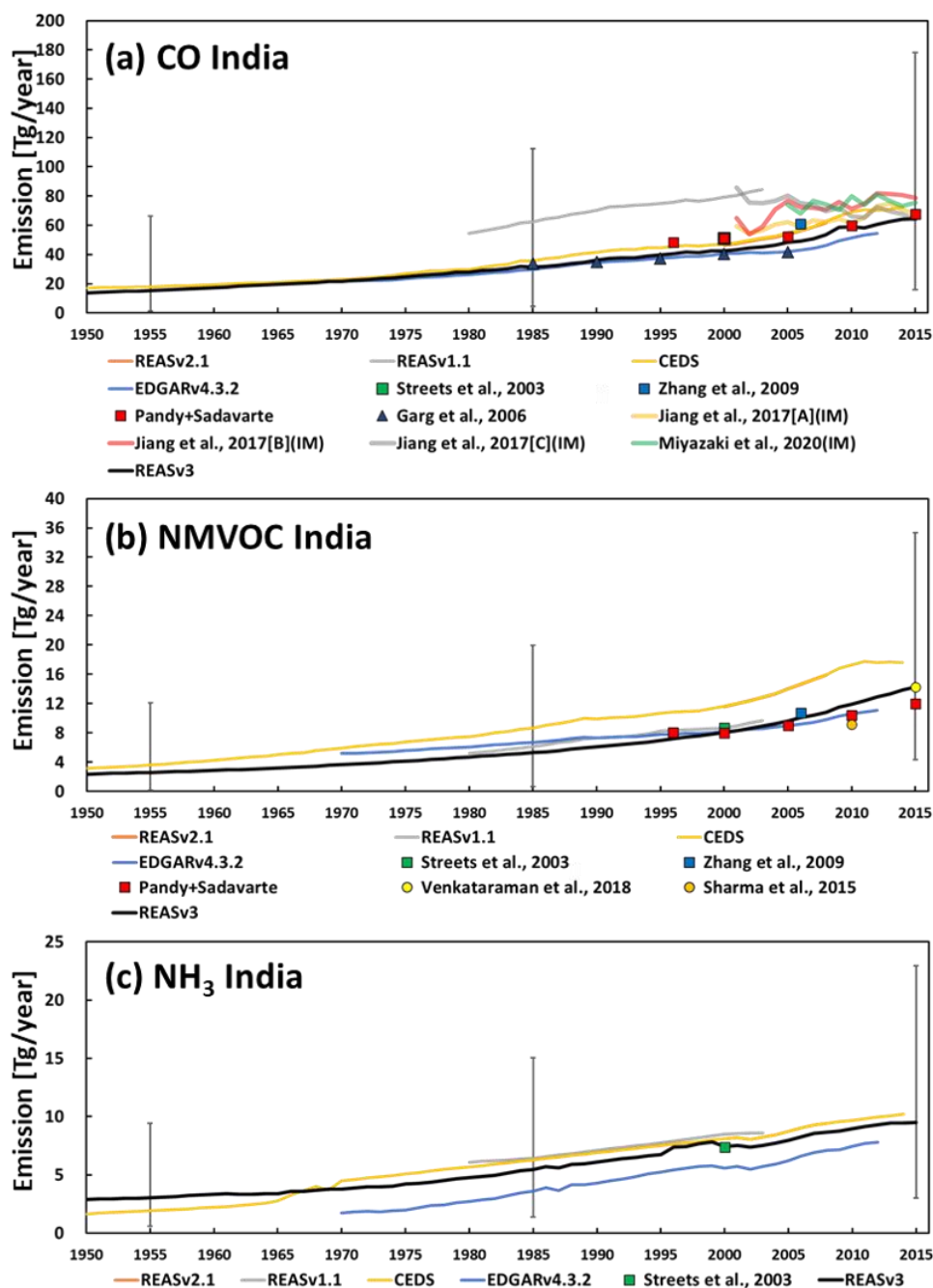
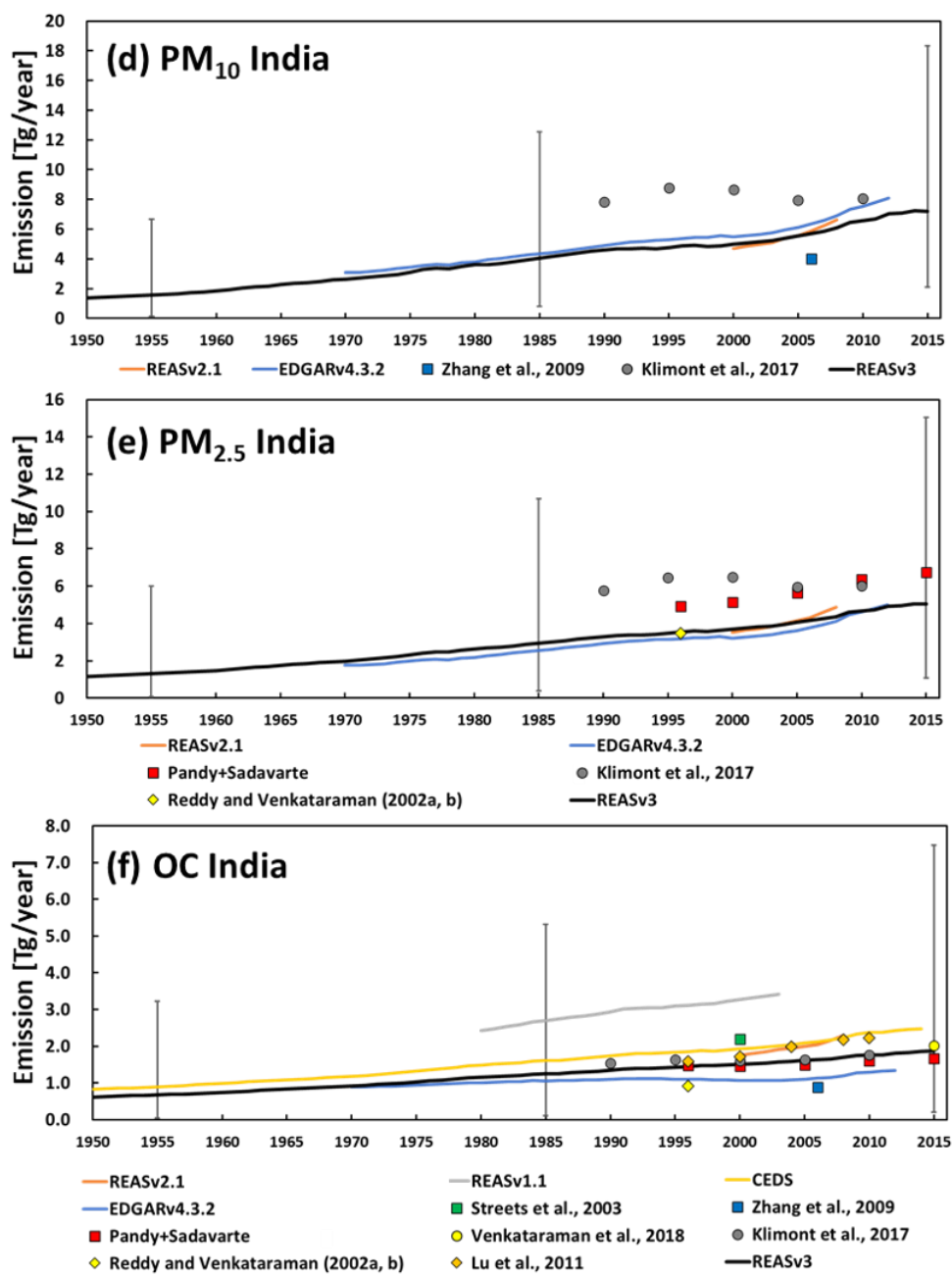


Figure S14. Continued.



90 **Figure S15.** Comparison of (a) CO, (b) NMVOC, (c) NH₃, (d) PM₁₀, (e) PM_{2.5} and (f) OC emissions in India between REASv3 and other studies. Emissions from domestic and fishing ships were excluded from REAS series, CEDS, and EDGARv4.3.2. Note that values of "Pandey+Sadavarte" are calculated from Pandey et al. (2014) and Sadavarte and Venkataraman (2014). Error bars indicate the uncertainty range of REASv3 in 1955, 1985, and 2015.



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Figure S15. Continued.

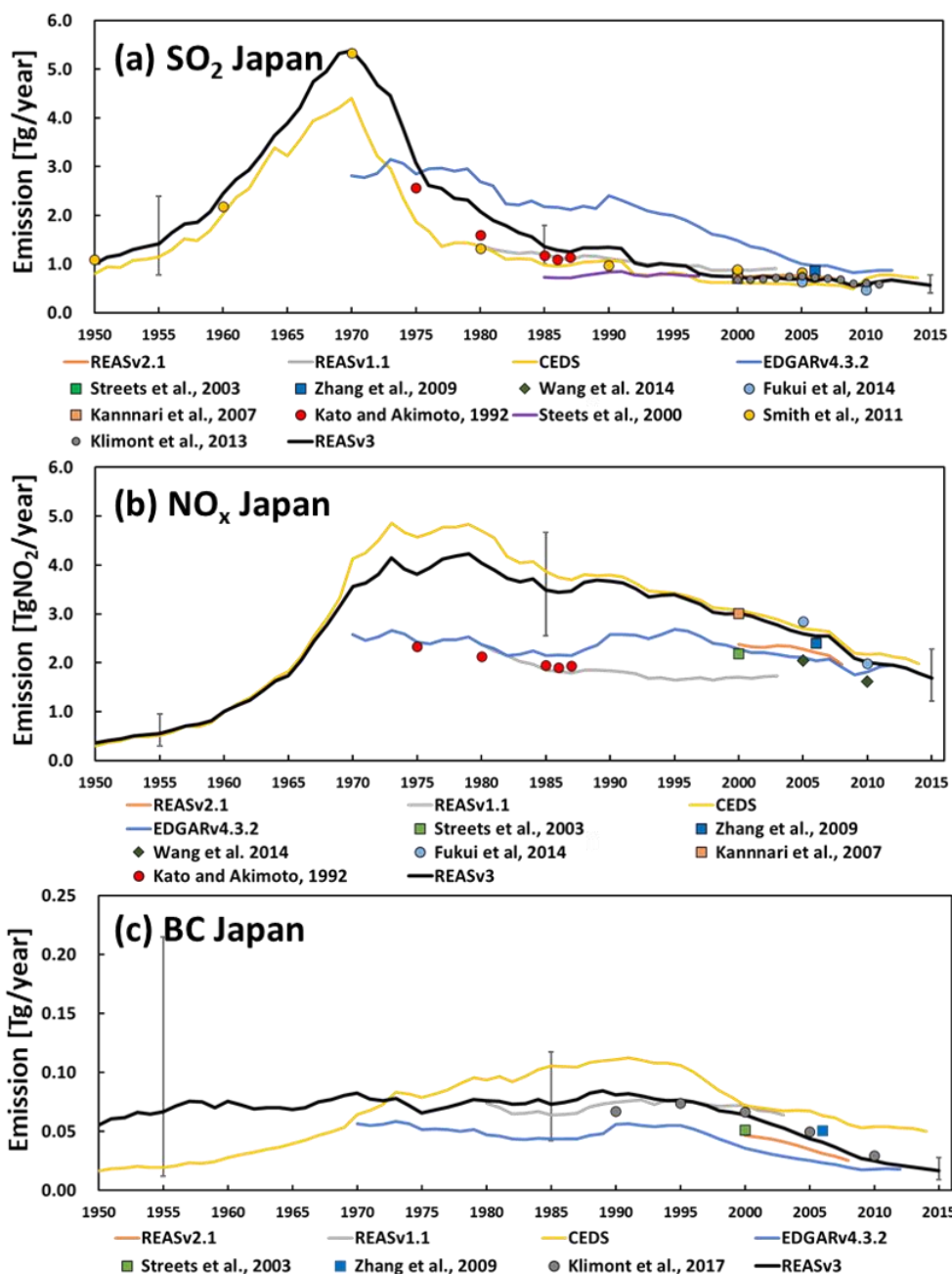


Figure S16. Comparison of (a) SO₂, (b) NO_x, (c) BC, (d) CO, (e) NMVOC, (f) NH₃, (g) PM₁₀, (h) PM_{2.5} and (i) OC emissions in Japan between REASv3 and other studies. Emissions from domestic and fishing ships were excluded from REAS series, CEDS, EDGARv4.3.2, Kannari et al. (2007), and Fukui et al. (2013). Error bars indicate the uncertainty range of REASv3 in 1955, 1985, and 2015.

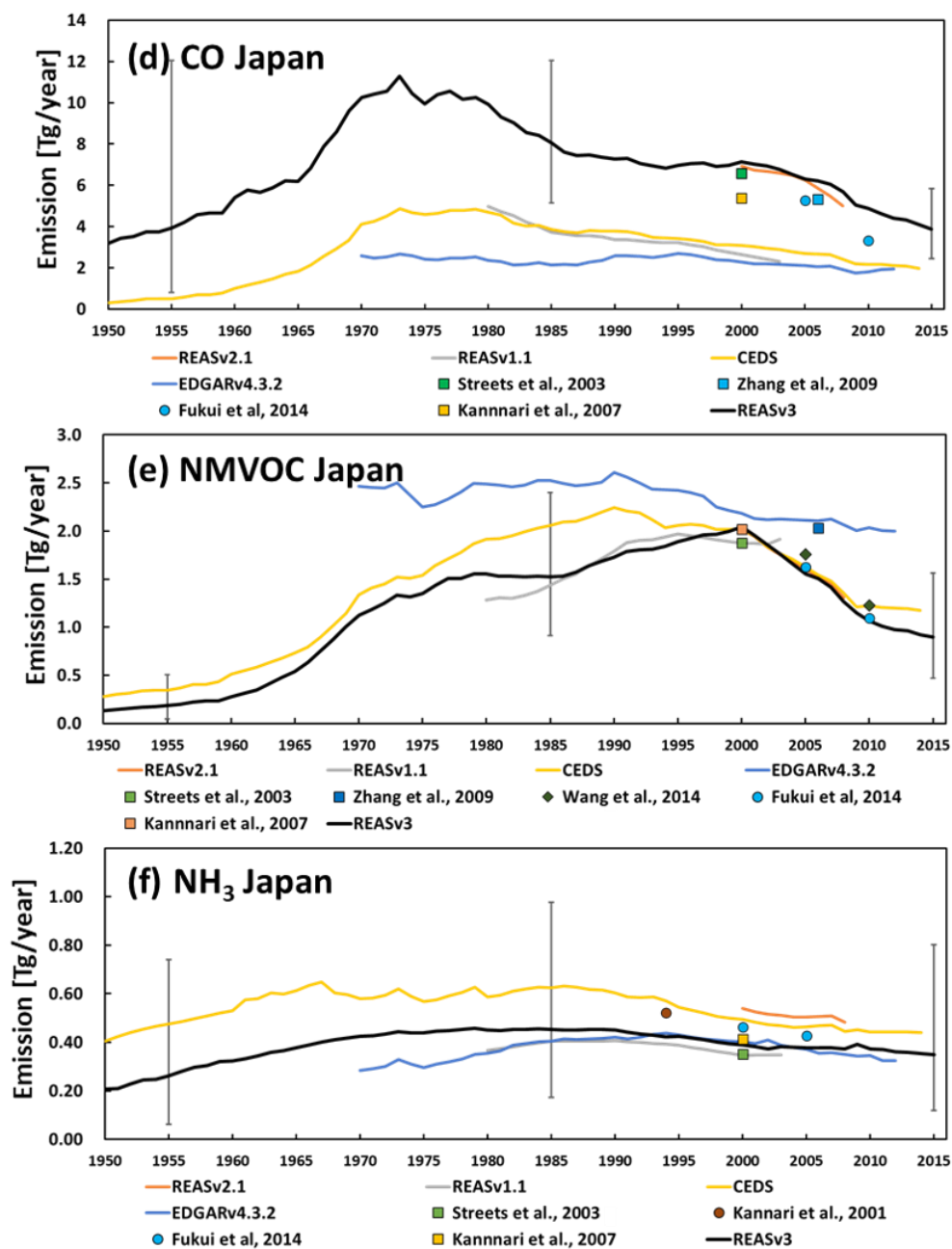
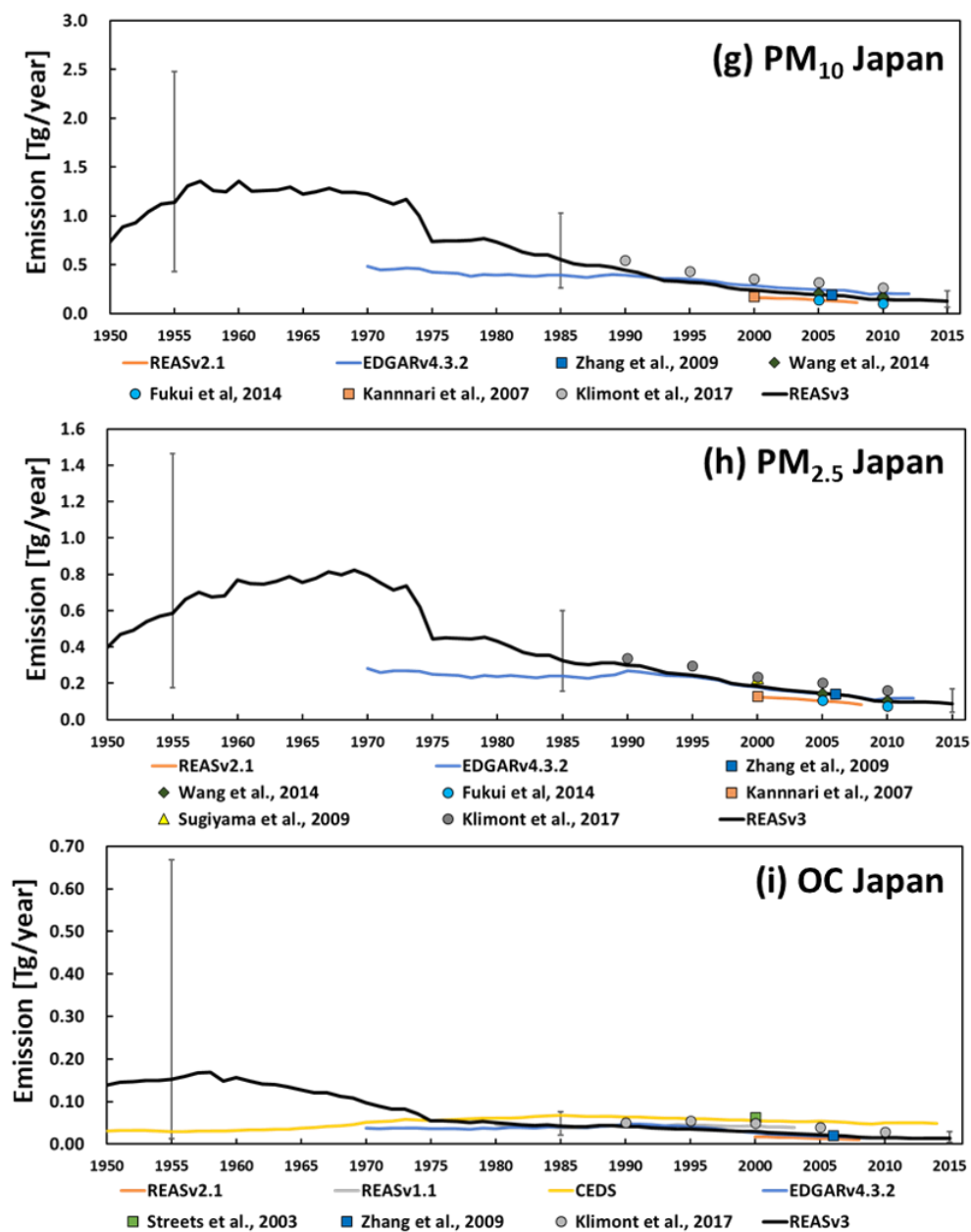


Figure S16. Continued.



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Figure S16. Continued.

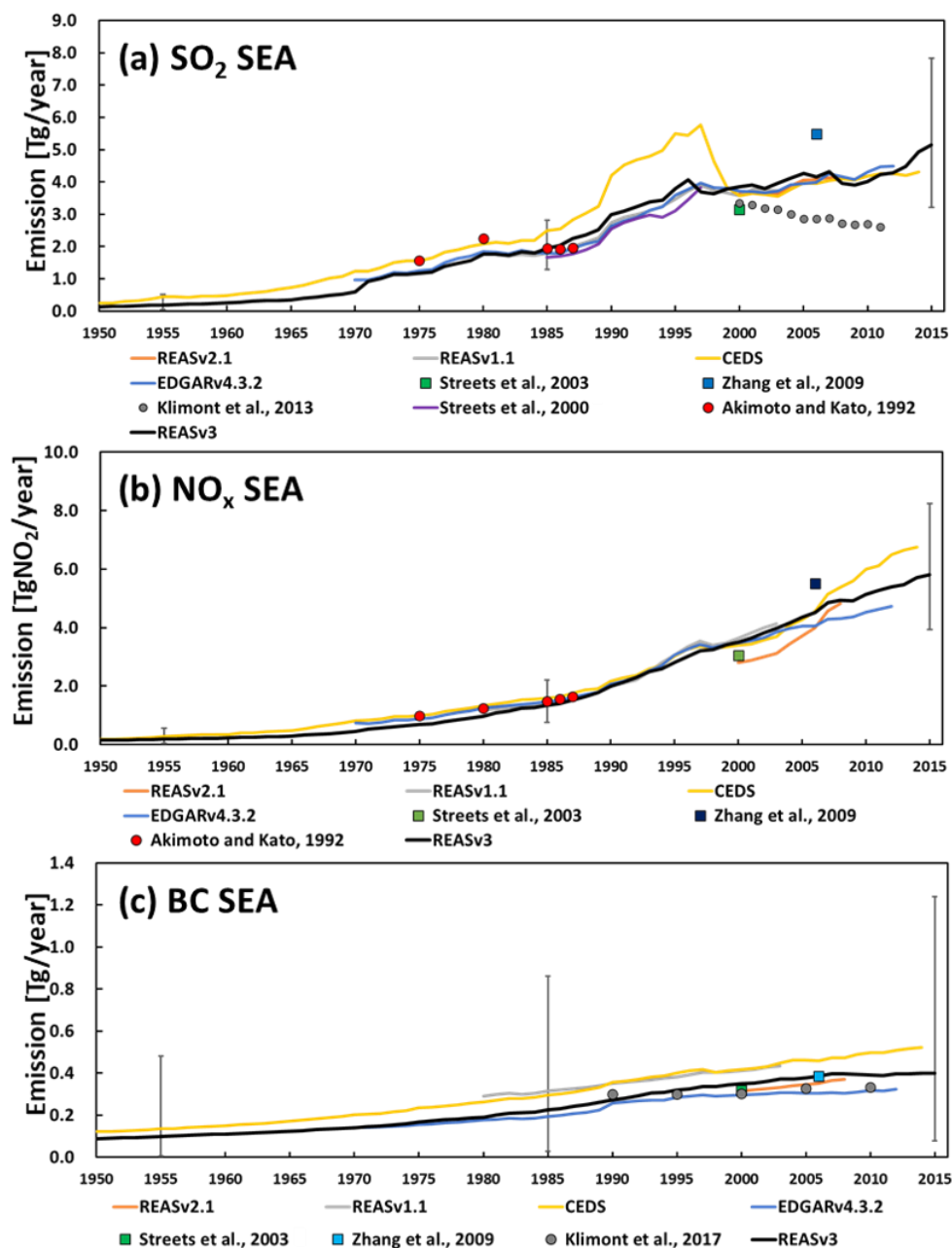


Figure S17. Comparison of (a) SO₂, (b) NO_x, (c) BC, (d) CO, (e) NMVOC, (f) NH₃, (g) PM₁₀, (h) PM_{2.5} and (i) OC emissions in SEA between REASv3 and other studies. Emissions from domestic and fishing ships were excluded from REAS series, CEDS, and EDGARv4.3.2. See Fig. 1 for the definitions of SEA. Error bars indicate the uncertainty range of REASv3 in 1955, 1985, and 2015.

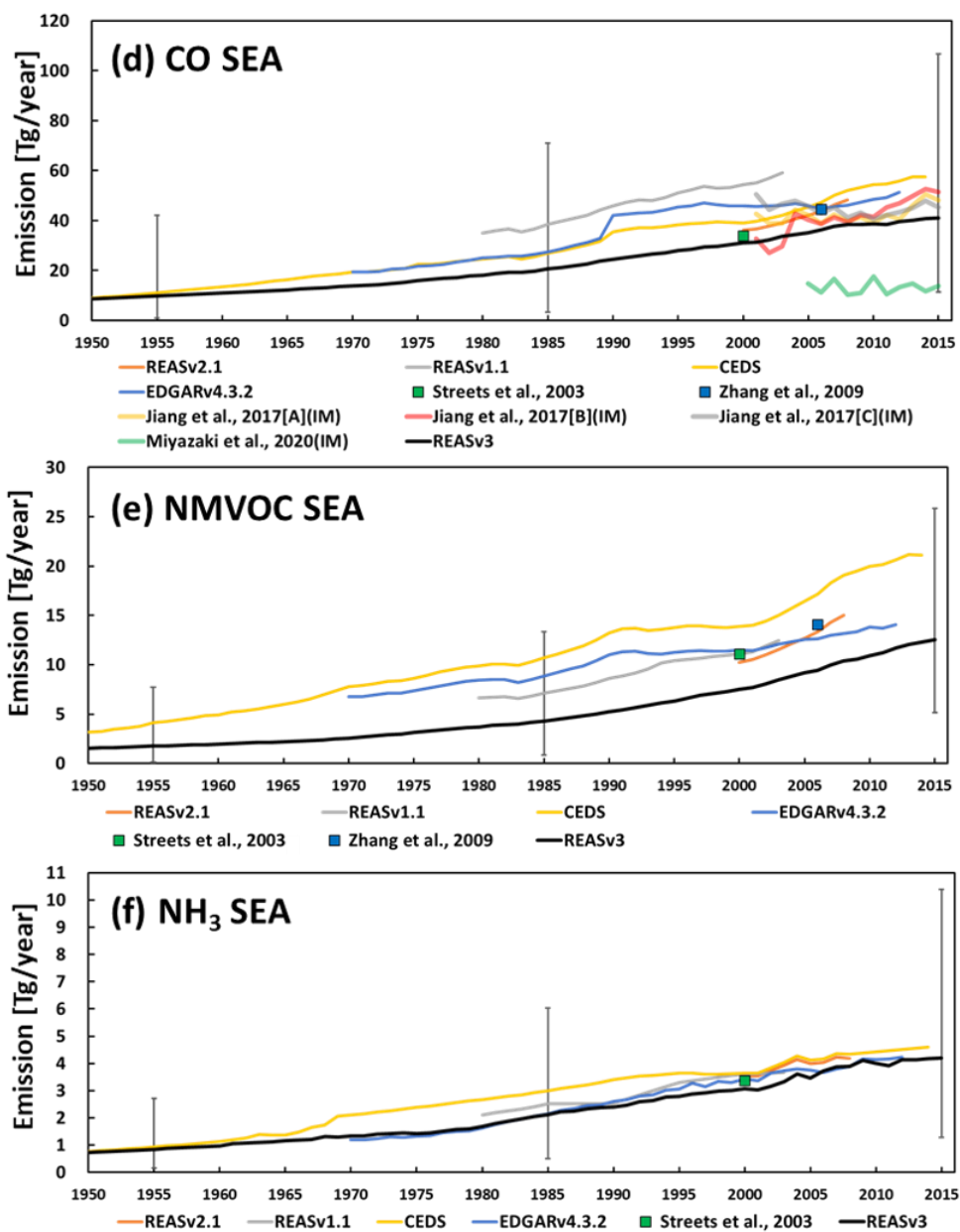


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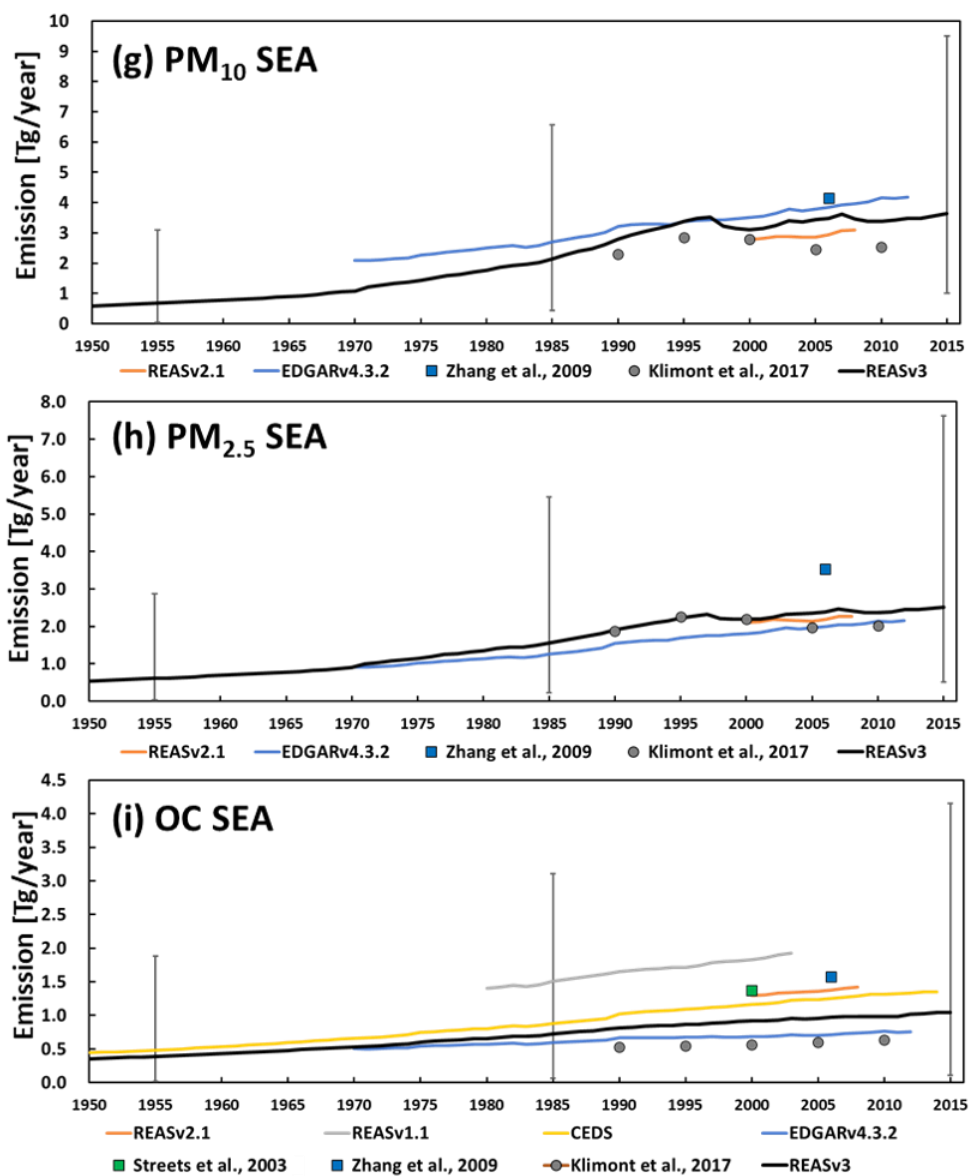
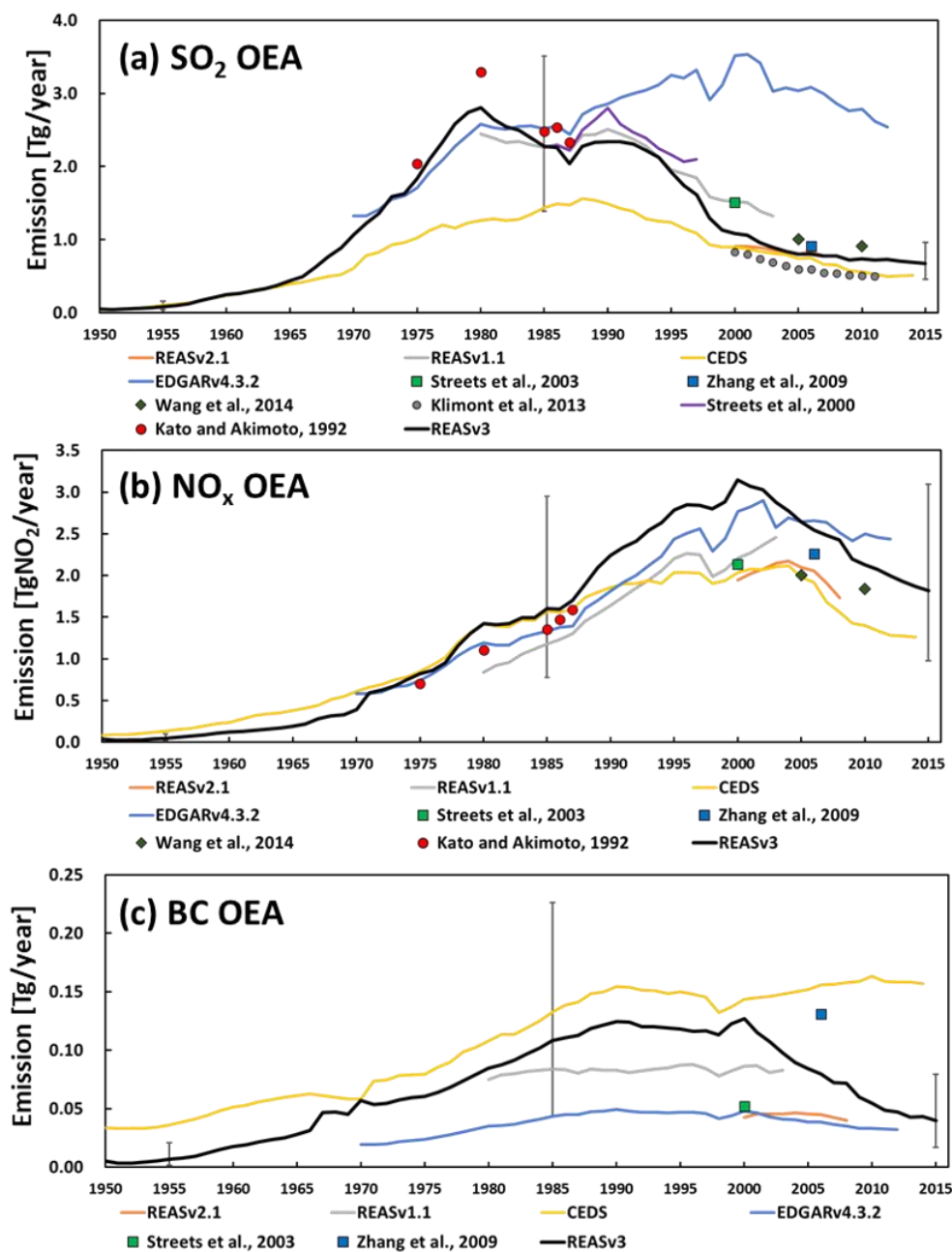
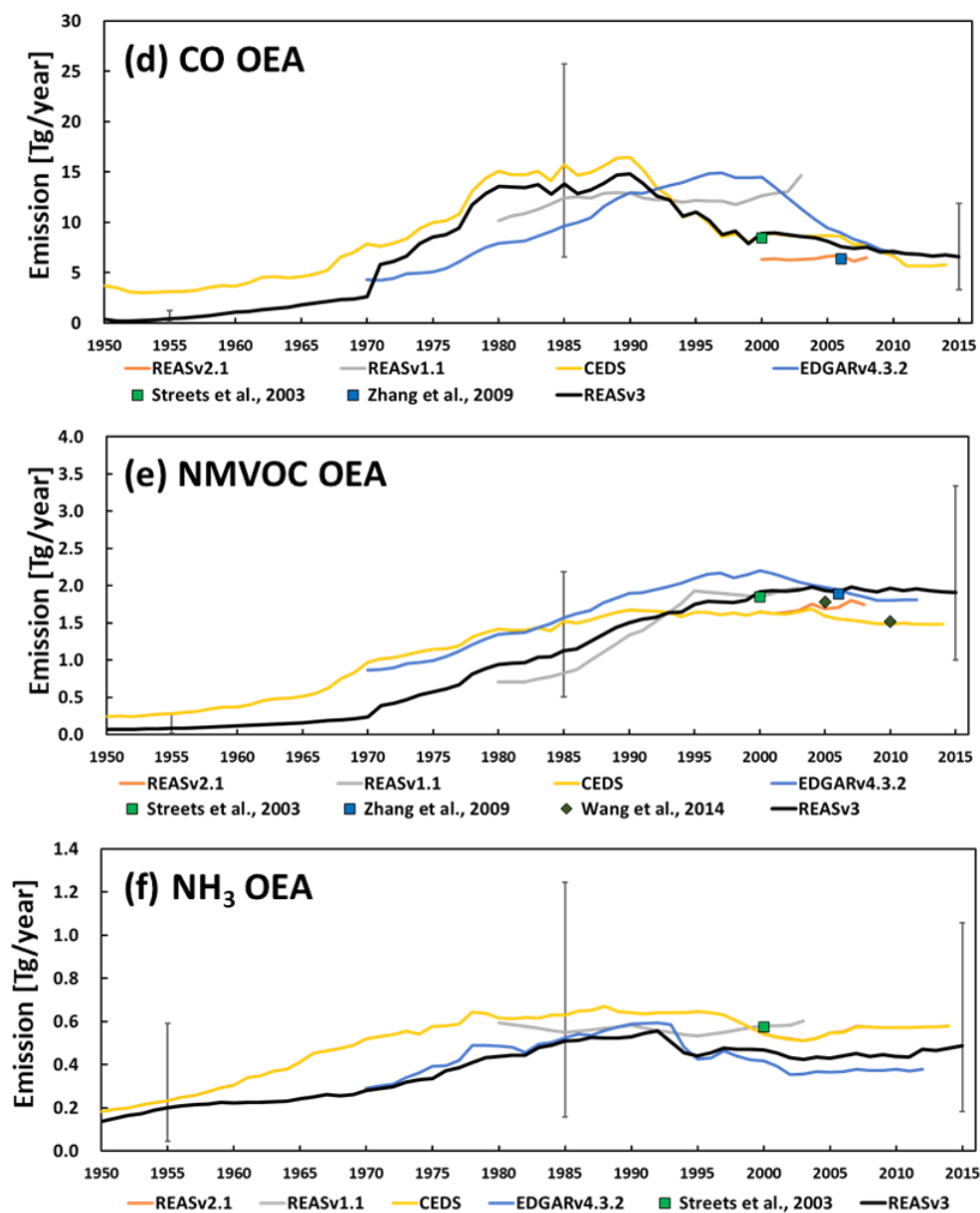


Figure S17. Continued.



120 **Figure S18.** Comparison of (a) SO₂, (b) NO_x, (c) BC, (d) CO, (e) NMVOC, (f) NH₃, (g) PM₁₀, (h) PM_{2.5} and (i) OC emissions in OEA between REASv3 and other studies. Emissions from domestic and fishing ships were excluded from REAS series, CEDS, and EDGARv4.3.2. See Fig. 1 for the definitions of OEA. Error bars indicate the uncertainty range of REASv3 in 1955, 1985, and 2015.



125 Figure S18. Continued.

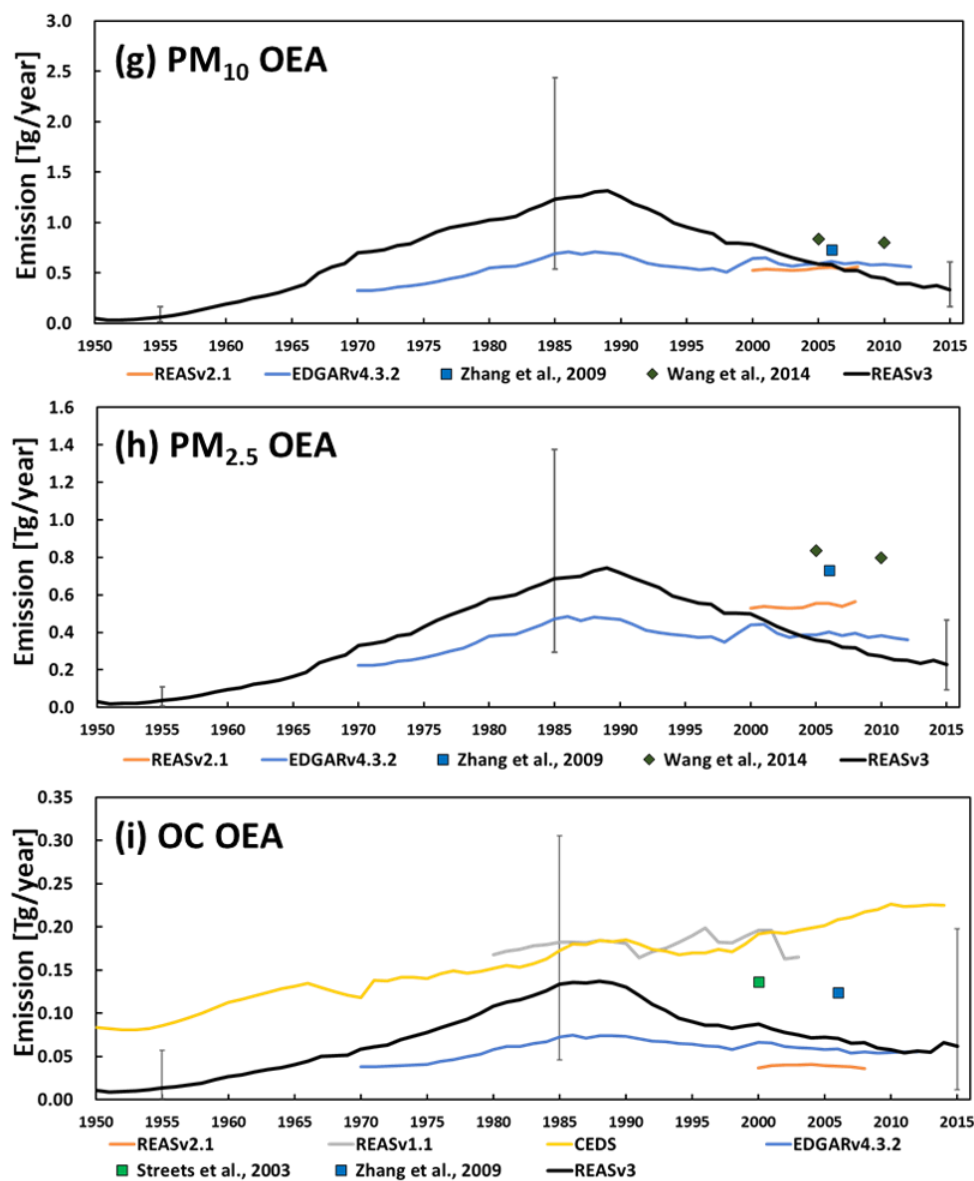


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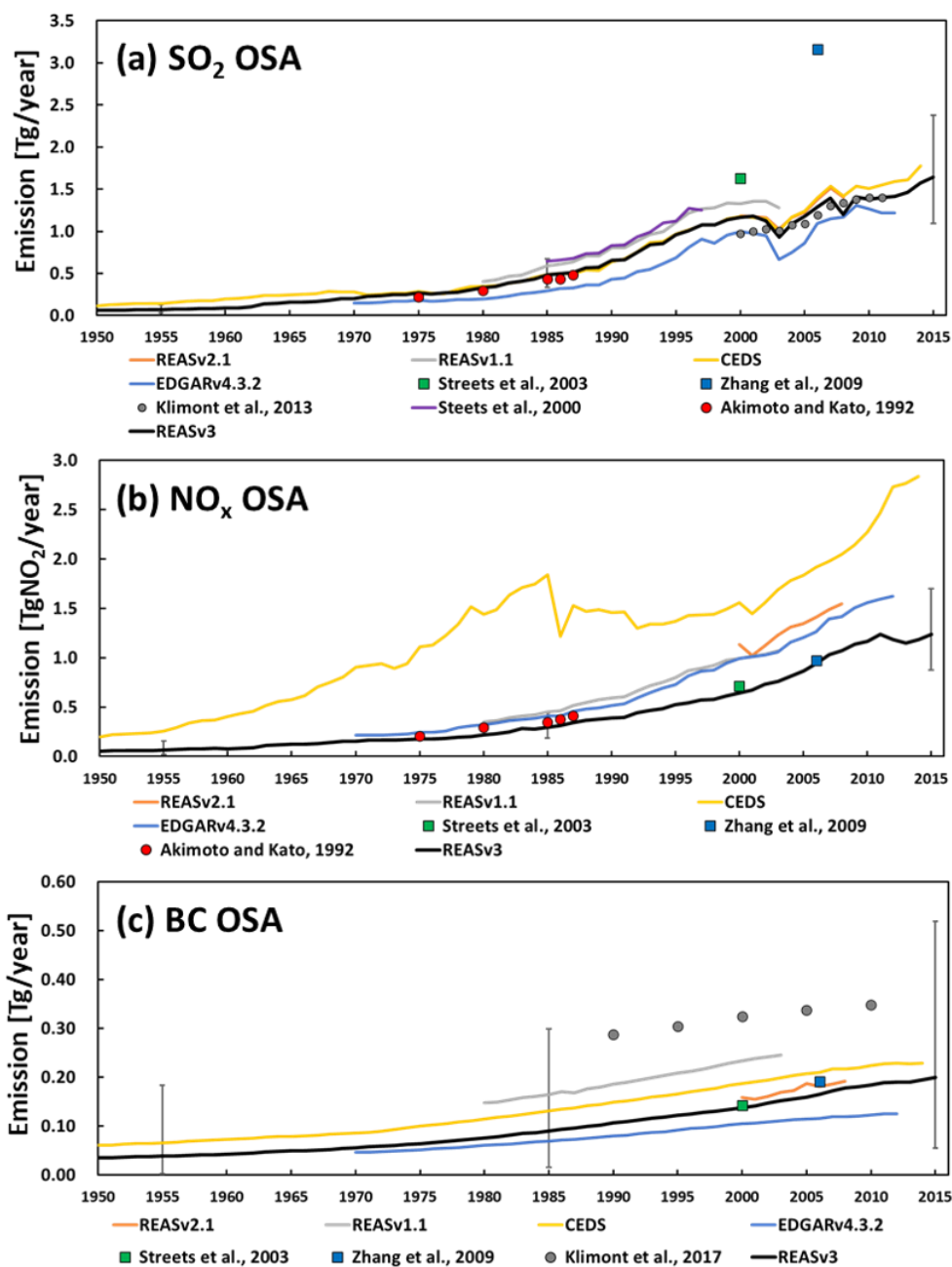


Figure S19. Comparison of (a) SO₂, (b) NO_x, (c) BC, (d) CO, (e) NMVOC, (f) NH₃, (g) PM₁₀, (h) PM_{2.5} and (i) OC emissions in OSA between REASv3 and other studies. Emissions from domestic and fishing ships were excluded from REAS series, CEDS, and EDGARv4.3.2. See Fig. 1 for the definitions of OSA. Error bars indicate the uncertainty range of REASv3 in 1955, 1985, and 2015.

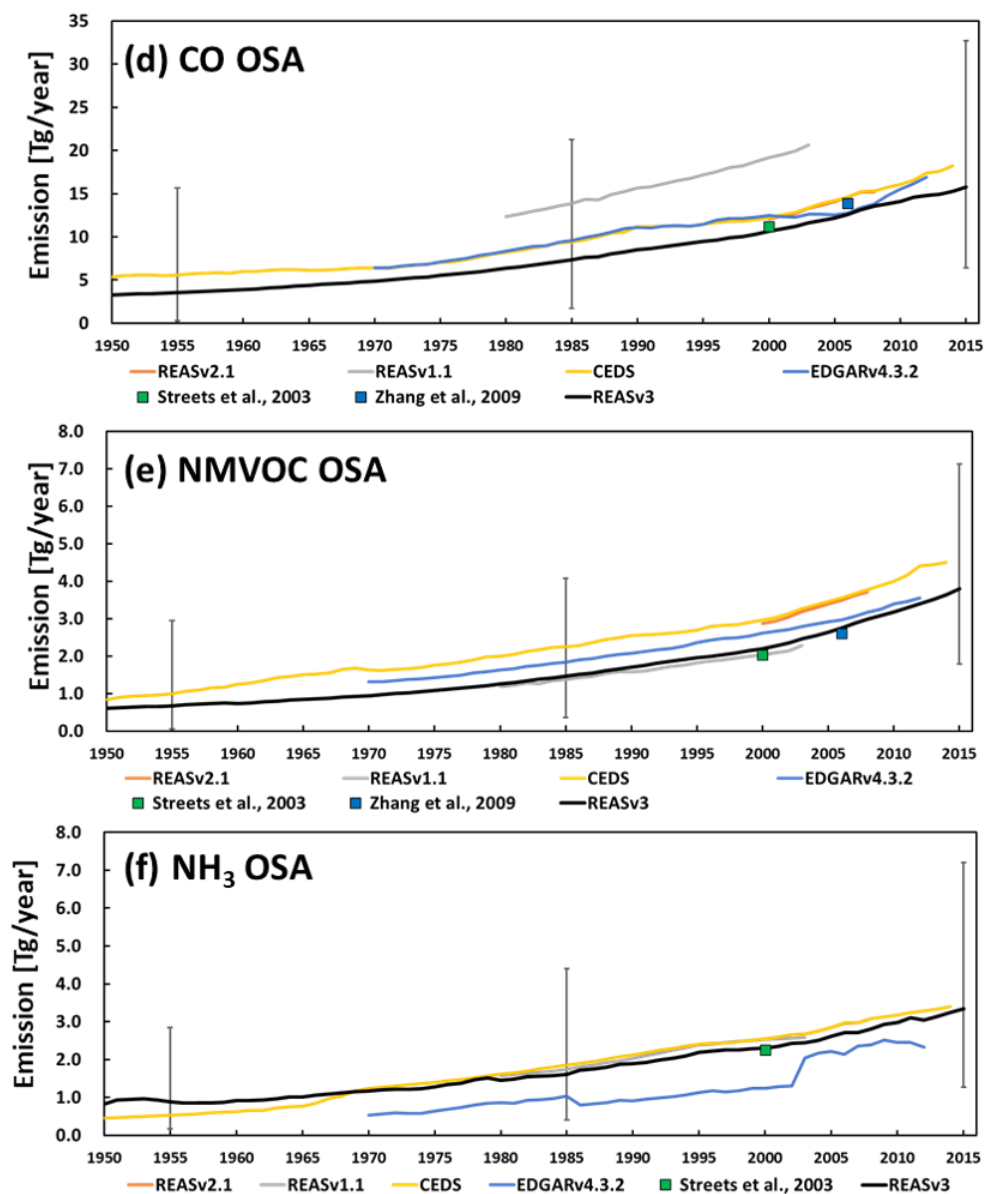


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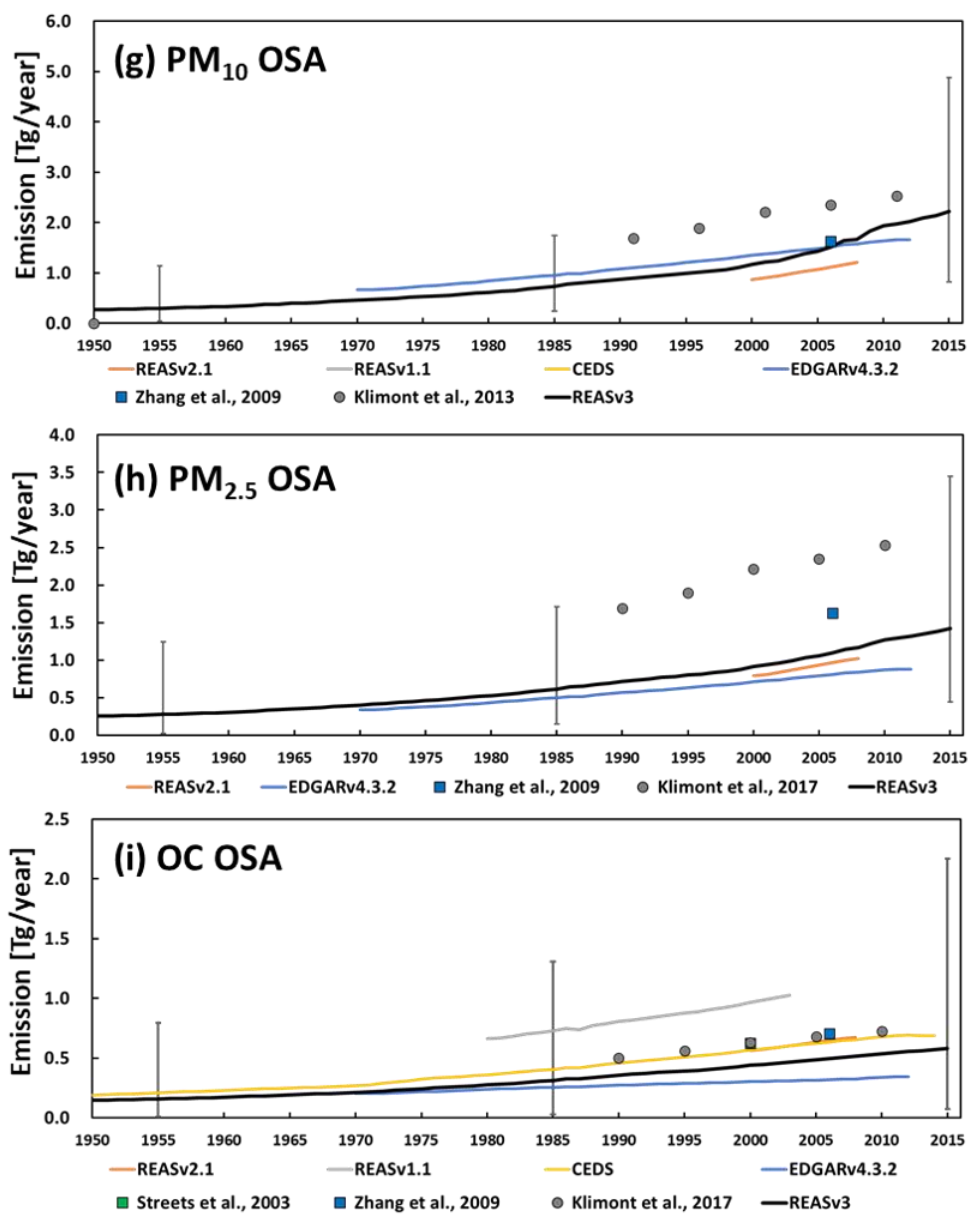


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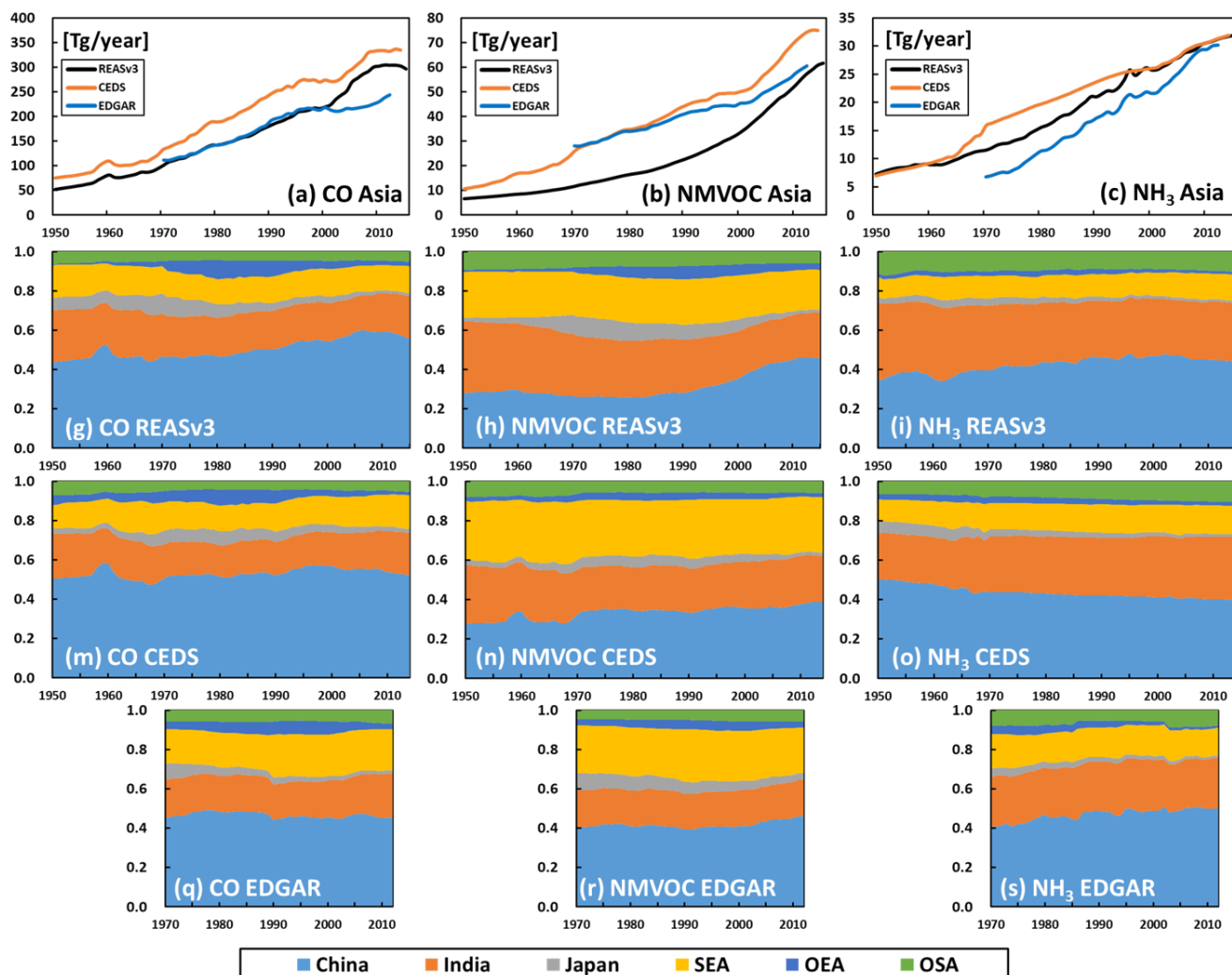


Figure S20. Comparison of trends of (a) CO, (b) NMVOC, (c) NH₃, (d) PM₁₀, (e) PM_{2.5}, and (f) OC emissions in Asia and relative ratios of emissions from China, India, Japan, SEA, OEA, and OSA for (g, m, q) CO, (h, n, r) NMVOC, (i, o, s) NH₃, (j, t) PM₁₀, (k, u) PM_{2.5}, and (l, p, v) OC among (g, h, i, j, k, l) REASv3, (m, n, o, p) CEDS, and (q, r, s, t, u, v) EDGARv4.3.2. See Fig. 1 for the definitions of SEA, OEA, and OSA.

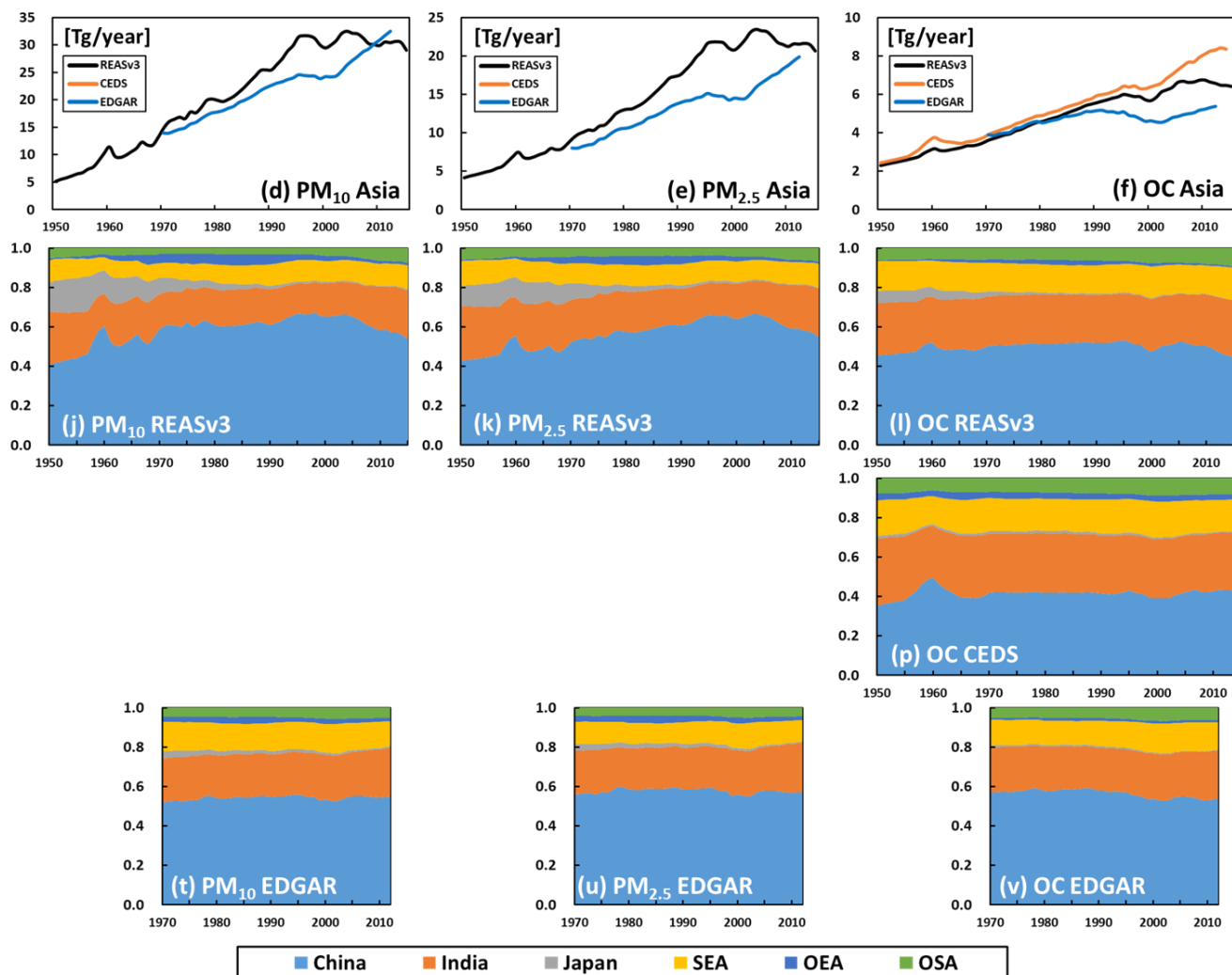


Figure S20. Continued.

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