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Competing effects of nitrogen deposition and ozone exposure on northern hemispheric terrestrial carbon uptake and storage, 1850–2099

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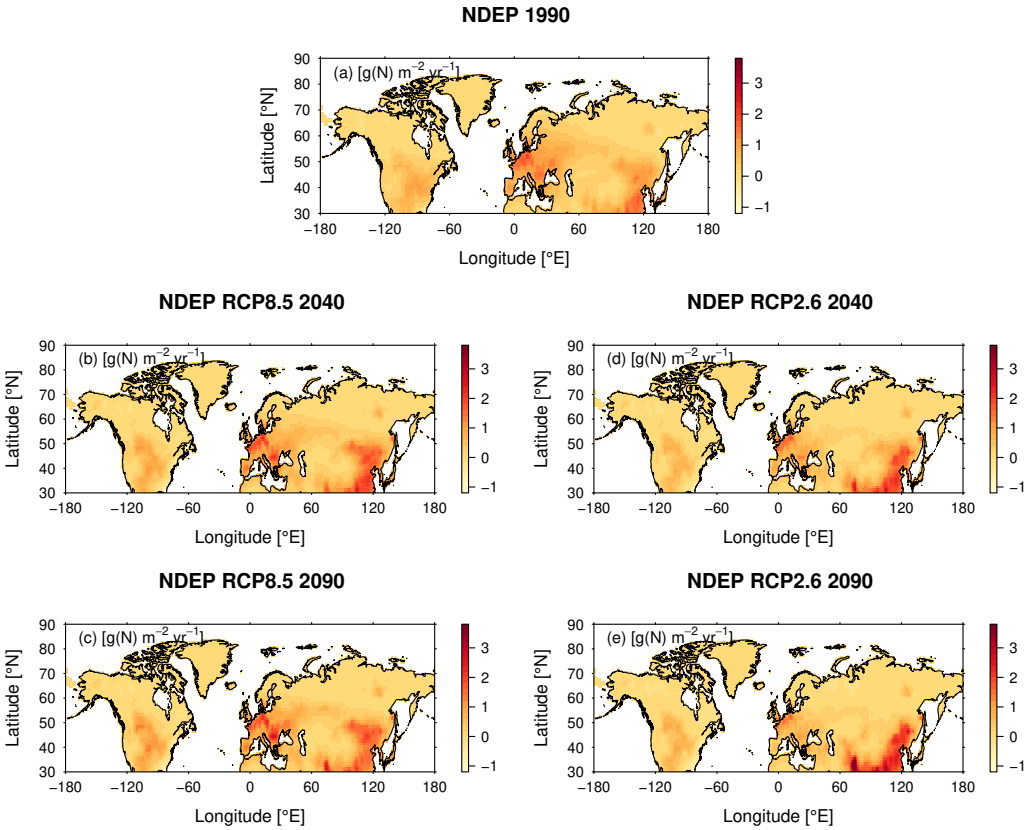

Figure S1. Mean simulated change in nitrogen deposition rates for the temperate and boreal Northern Hemisphere ($\geq 30°$N) in the decades of the years of 1990, 2040 and 2090 compared to the decade of the year 1850, each according to the RCP2.6 and RCP8.5 emission scenario.

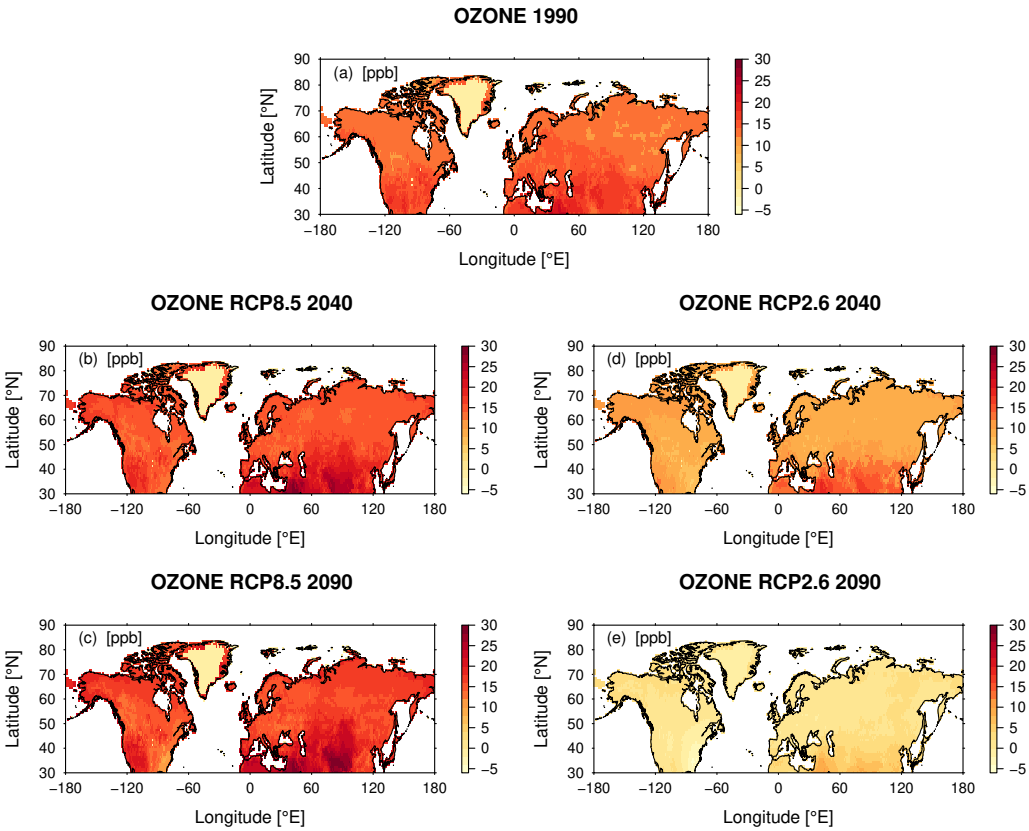

Figure S2. Mean simulated change in canopy level O_3 concentration for the temperate and boreal Northern Hemisphere ($\geq 30°$N) in the decades of the years of 1850, 1990, 2040 and 2090 compared to the decade of the year 1850, each according to the RCP2.6 and RCP8.5 emission scenario.

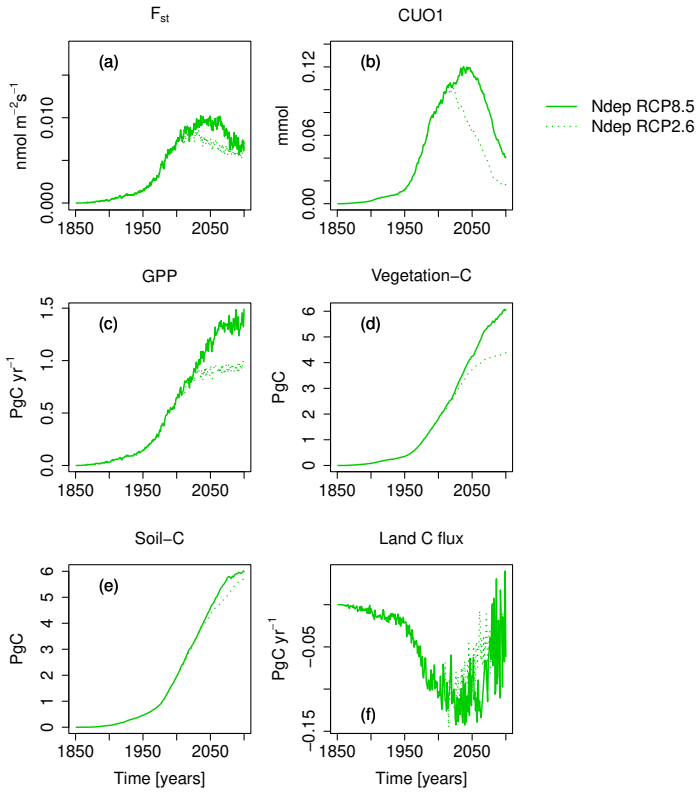

Figure S3. Nitrogen deposition induced absolute change in regional mean O_3 uptake (F_{st}), mean cumulative O_3 uptake above a flux threshold of $1\ \mathrm{nmol\,m^{-2}\,s^{-1}}$ (CUO1), summed GPP, total carbon biomass in vegetation (vegetation-C), summed carbon soil organic matter (soil-C), and summed land carbon flux (land C flux) compared to pre-industrial values in the simulation region. The nitrogen deposition induced change is calculated from the simulation runs S3 and S5 (see Tab. 2). Solid lines indicate results from simulations based on RCP8.5, dotted lines results from simulations based on RCP2.6. The effect of the seasonal cycle is smoothed by the application of a moving average of 12 months (a,b).

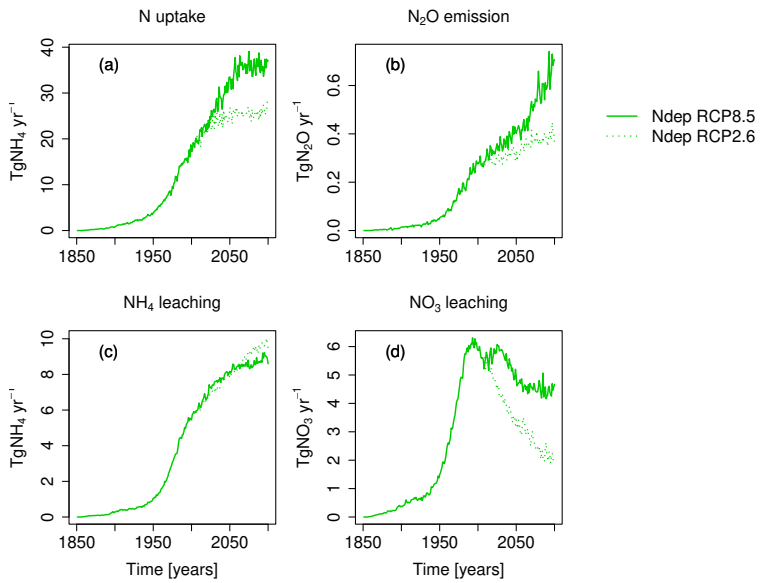

Figure S4. Nitrogen deposition induced absolute change in total N uptake by region, N_2O emission, NH_4 leaching and N_2O leaching compared to pre-industrial values in the simulation region. The nitrogen deposition induced absolute change is calculated from the simulation runs S3 and S5 (see Tab. 2). Solid lines indicate results from simulations based on RCP8.5, dotted lines results from simulations based on RCP2.6.

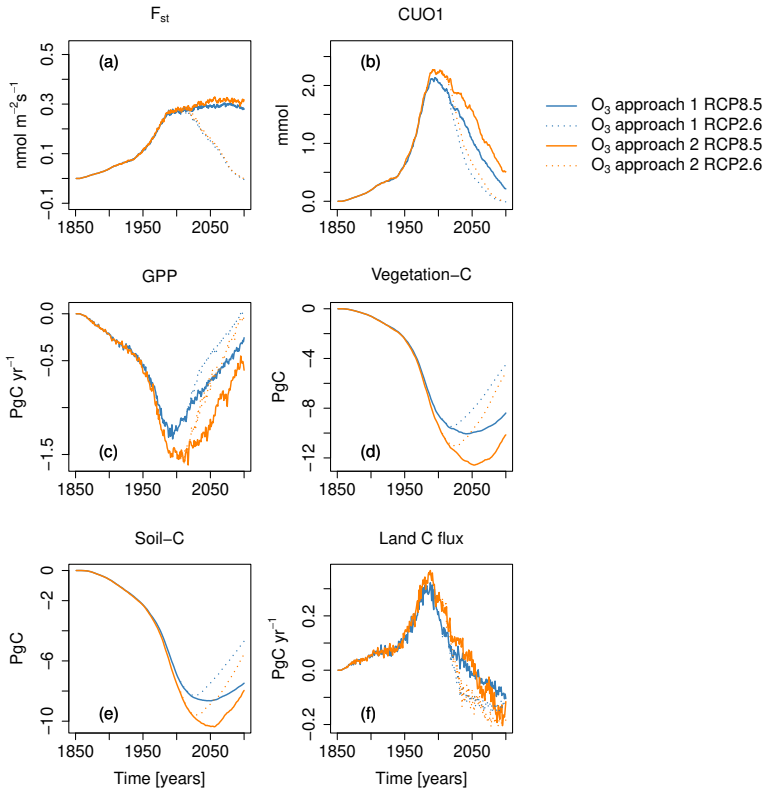

Figure S5. Ozone induced absolute change in regional mean O_3 uptake (F_{st}), mean cumulative O_3 uptake above a flux threshold of 1 $\mathrm{nmol\,m^{-2}\,s^{-1}}$ (CUO1), summed GPP, total carbon biomass in vegetation (vegetation-C) and summed carbon soil organic matter (soil-C) compared to pre-industrial values in the simulation region. Different colors indicate different approaches to calculate the O_3 induced change from the factorial runs. Orange lines represent approach 1: (S2-S1)/S1, blue lines approach 2:(S5-S4)/S4. Solid lines indicate results from simulations based on RCP8.5, dotted lines results from simulations based on RCP2.6. The effect of the seasonal cycle is smoothed by the application of a moving average of 12 months.

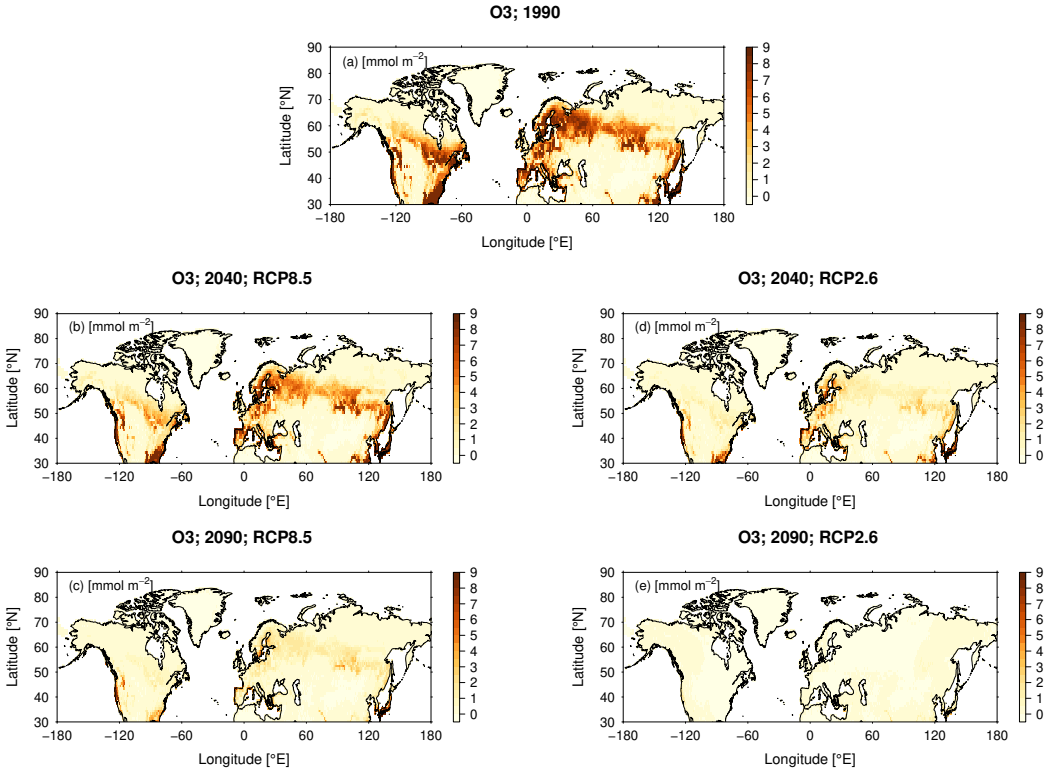

Figure S6. Absolute change in CUO1 compared to pre-industrial values induced by O_3, calculated according to approach 2. Displayed are the decade 1990 (mean of the years 1990-1999), 2040 (mean of the years 2040-2049) and of 2090 (mean of the years 2090-2099). For the decades 2040 and 2090 results from simulations based on RCP8.5 and RCP2.6 are displayed. See Tab. 2 for details on the calculation of the O_3 impact.

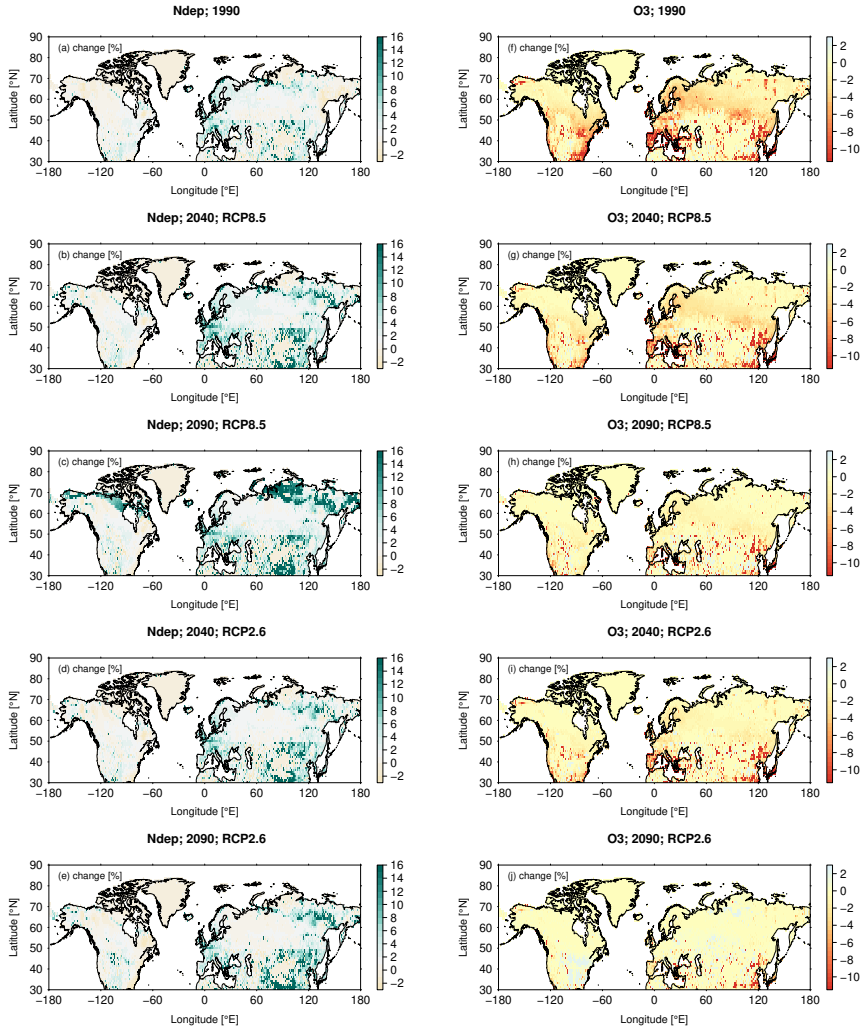

Figure S7. Relative change in GPP compared to pre-industrial values induced by nitrogen deposition (left column) and O_3 calculated according to approach 2 (right column). The induced change in GPP is displayed for the decades 1990 (mean of the years 1990-1999), 2040 (mean of the years 2040-2049) and 2090 (mean of the years 2090-2099). For the decades 2040 and 2090 results from simulations based on RCP8.5 and RCP2.6 are displayed. See Tab. 2 for details on the calculation of the single drivers.

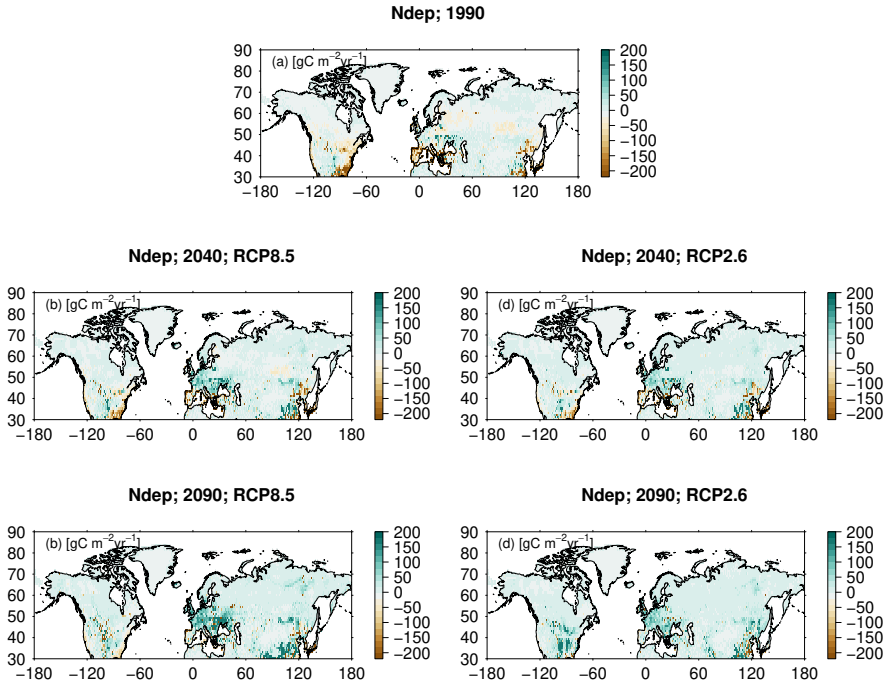

Figure S8. Combined absolute impact of nitrogen deposition and O_3 calculated according to approach 2 on GPP compared to pre-industrial values. The induced change in GPP is displayed for the decades 1990 (mean of the years 1990-1999), 2040 (mean of the years 2040-2049) and 2090 (mean of the years 2090-2099). For the decades 2040 and 2090 results from simulations based on RCP8.5 and RCP2.6 are displayed. See Tab. 2 for details on the calculation of the single drivers.

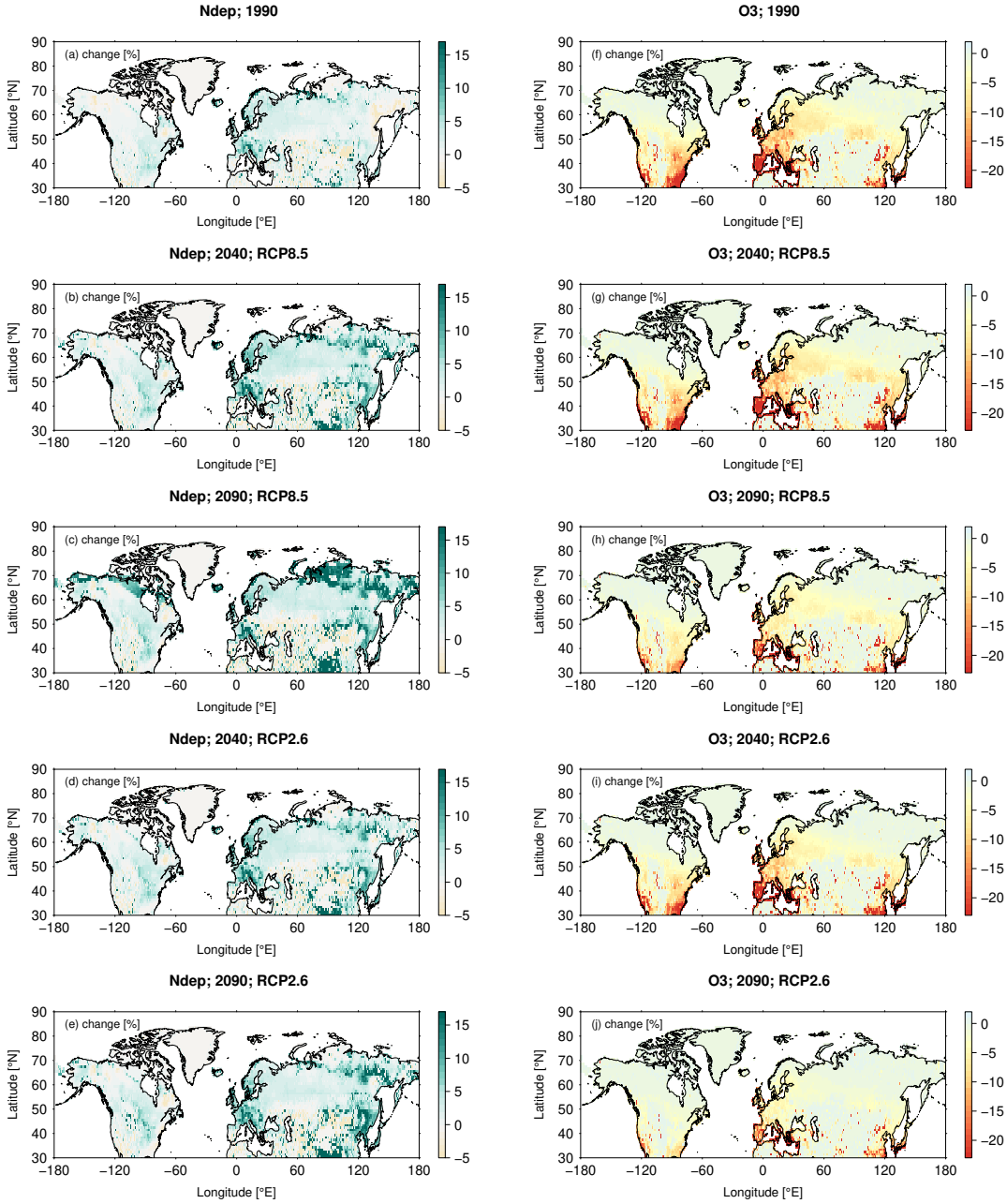

Figure S9. Relative change in the total carbon biomass in vegetation (vegetation-C) compared to pre-industrial values induced by nitrogen deposition (left column) and O_3 calculated according to approach 2 (right column). The induced change in vegetation-C is displayed for the decades 1990 (mean of the years 1990-1999), 2040 (mean of the years 2040-2049) and 2090 (mean of the years 2090-2099). For the decades 2040 and 2090 results from simulations based on RCP8.5 and RCP2.6 are displayed. See Tab. 2 for details on the calculation of the single drivers.

Table S1. The spread in the mean percent change displayed in Tab. 4 due to inter-annual variability, derived from error propagation of the yearly estimates in GPP, total carbon biomass in vegetation (vegetation-C), and land carbon flux (land C flux) induced by O_3 during the decades of 1990 (1990–1999), 2040 (2040–2049) and 2090 (2090–2099). For O_3 two values are displayed which refer to the two approaches to calculate the O_3 impact.

Region	Pollutant	1990	2040 RCP8.5	2040 RCP2.6	2090 RCP8.5	2090 RCP2.6
GPP						
NH30	O_3	±0.17;±0.14	±0.11;±0.19	±0.09;±0.22	±0.10;±0.10	±0.10;±0.08
NH30	Ndep	±0.13	±0.18	±0.11	±0.20	±0.12
Europe	O_3	±0.25;±0.33	±0.14;±0.19	±0.14;±0.24	±0.11;±0.13	±0.04;±0.08
Europe	Ndep	±0.26	±0.30	±0.21	±0.21	±0.12
USA	O_3	±0.41;±0.39	±0.19;±0.26	±0.17;±0.30	±0.05;±0.23	±0.20;±0.17
USA	Ndep	±0.23	±0.19	±0.23	±0.30	±0.13
China	O_3	±0.95;±0.76	±0.67;±1.31	±0.45;±1.02	±0.41;±0.40	±0.43;±0.44
China	Ndep	±0.23	±0.53	±0.23	±0.40	±0.59
Vegetation-C						
NH30	O_3	±0.38;±0.40	±0.14;±0.27	±0.15;±0.17	±0.17;±0.12	±0.19;±0.18
NH30	Ndep	±0.13	±0.15	±0.09	±0.08	±0.04
Europe	O_3	±0.34;±0.42	±0.13;±0.33	±0.19;±0.21	±0.22;±0.15	±0.18;±0.24
Europe	Ndep	±0.15	±0.20	±0.11	±0.09	±0.05
USA	O_3	±0.62;±0.50	±0.26;±0.27	±0.27;±0.29	±0.16;±0.24	±0.28;±0.25
USA	Ndep	±0.10	±0.07	±0.03	±06	±0.04
China	O_3	±1.63;±1.86	±0.43;±0.60	±0.23;±0.32	±0.45;±0.44	±0.44;±0.48
China	Ndep	±0.13	±0.22	±0.19	±0.24	±0.21
Land C flux						
NH30	O_3	±4.28;±4.48	±0.78;±0.98	±2.45;±2.07	±0.88;±2.15	±3.87;±7.86
NH30	Ndep	±2.20	±1.42	±1.46	±2.04	±1.51
Europe	O_3	±12.48;±14.84	±1.19;±1.31	±3.57;±4.70	±1.45;±12.10	±8.66;±11.30
Europe	Ndep	±13.34	±2.06	±1.69	±5.06	±2.10
USA	O_3	±8.60;±12.22	±1.17;±3.20	±2.13;±6.93	±0.72;±6.25	±5.30;±12.86
USA	Ndep	±4.50	±3.85	±3.33	±4.95	±2.95
China	O_3	±13.23;±25.46	±6.35;±13.3	±6.85;±11.77	±6.64;±13.77	±16.81;±14.57
China	Ndep	±15.81	±7.00	±4.89	±6.46	±8.29