



Supplement of

Impact of present aircraft NO_x and aerosol emissions on atmospheric composition and climate: results from a model intercomparison

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Supplementary material

S1. Chemical background in the UTLS

Table S1: Backgrounds expressed as global mass burdens, between 150 and 300 hPa, annually. The black carbon lifetime is written in brackets below the BC burden. It is worth noting that it is derived from the total BC burden, and not only that in the UTLS.

Model	EMAC-NO _x	LMDZ-INCA	MOZART3	OsloCTM3	GEOS-Chem
Period	2014–2018	2014–2018	2014–2018	2014–2017	2019
O ₃ (TgO ₃)	199	218	231	172	139
NO _y (TgN)	0.318	0.292	0.230	0.317	0.167
NO _x (TgN)	6.76 10 ⁻²	3.42 10 ⁻²	4.64 10 ⁻²	6.95 10 ⁻²	2.53 10 ⁻²
HNO ₃ (TgN)	0.152	0.152	0.125	0.224	0.107
OH (Tg)	8.47 10 ⁻⁵	7.02 10 ⁻⁵	7.31 10 ⁻⁵	8.26 10 ⁻⁵	5.88 10 ⁻⁵
CH ₄ (TgC)	641	744	651	614	546
NH ₃ (TgN)	3.06 10 ⁻²	7.31 10 ⁻³	-	3.09 10 ⁻⁴	1.22 10 ⁻³
SO ₂ (TgS)	2.33 10 ⁻²	4.91 10 ⁻²	-	7.53 10 ⁻³	1.95 10 ⁻²
Aerosols	EMAC-aer				
BC (Tg) [lifetime]	3.95 10 ⁻³ [7.7 days]	3.80 10 ⁻² [8.0 days]	-	2.93 10 ⁻³ [4.6 days]	1.55 10 ⁻³ [5.1 days]
SO ₄ (TgS)	0.116	0.473	-	0.384	5.96 10 ⁻²
NO ₃ (TgN)	5.62 10 ⁻²	0.239	-	0.226	3.36 10 ⁻²

S2. Complementary figures

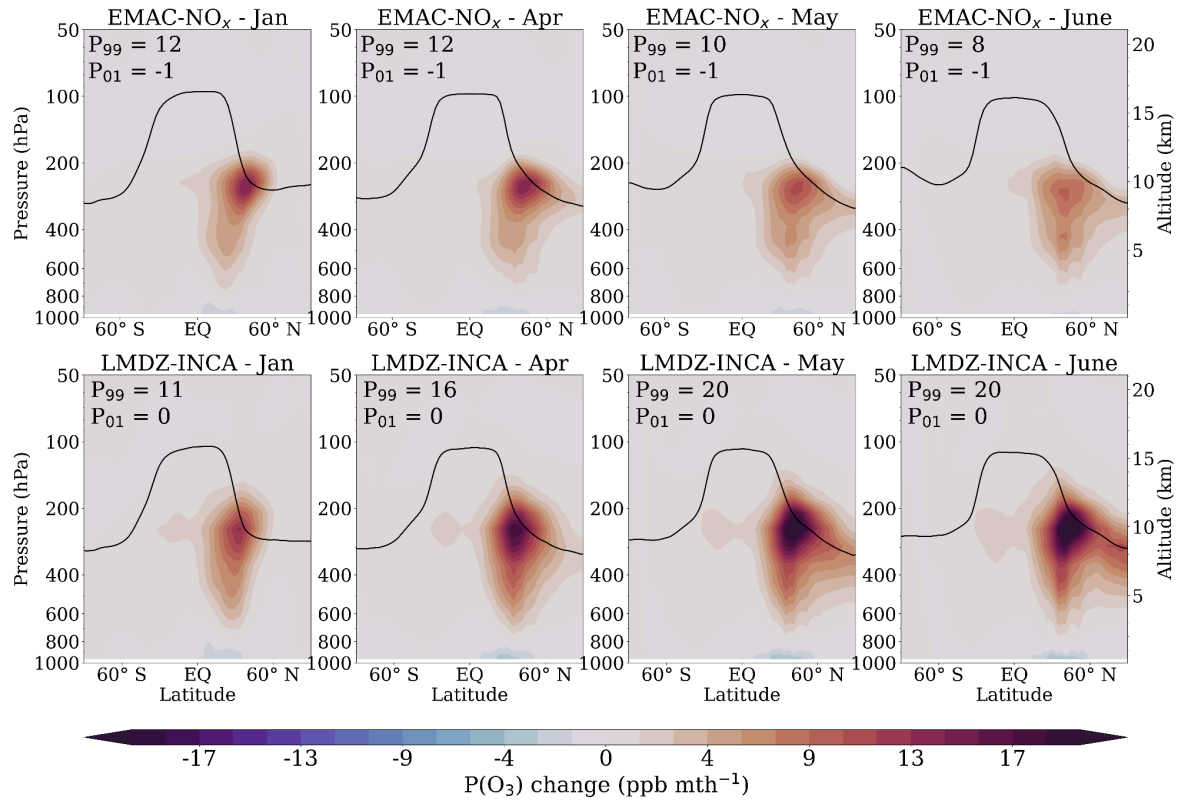


Figure S1: Zonal cross sections in the perturbation of ozone production $P(O_3)$, for the EMAC and LMDZ-INCA models (top and bottom), during January, April, May, and June (from left to right).

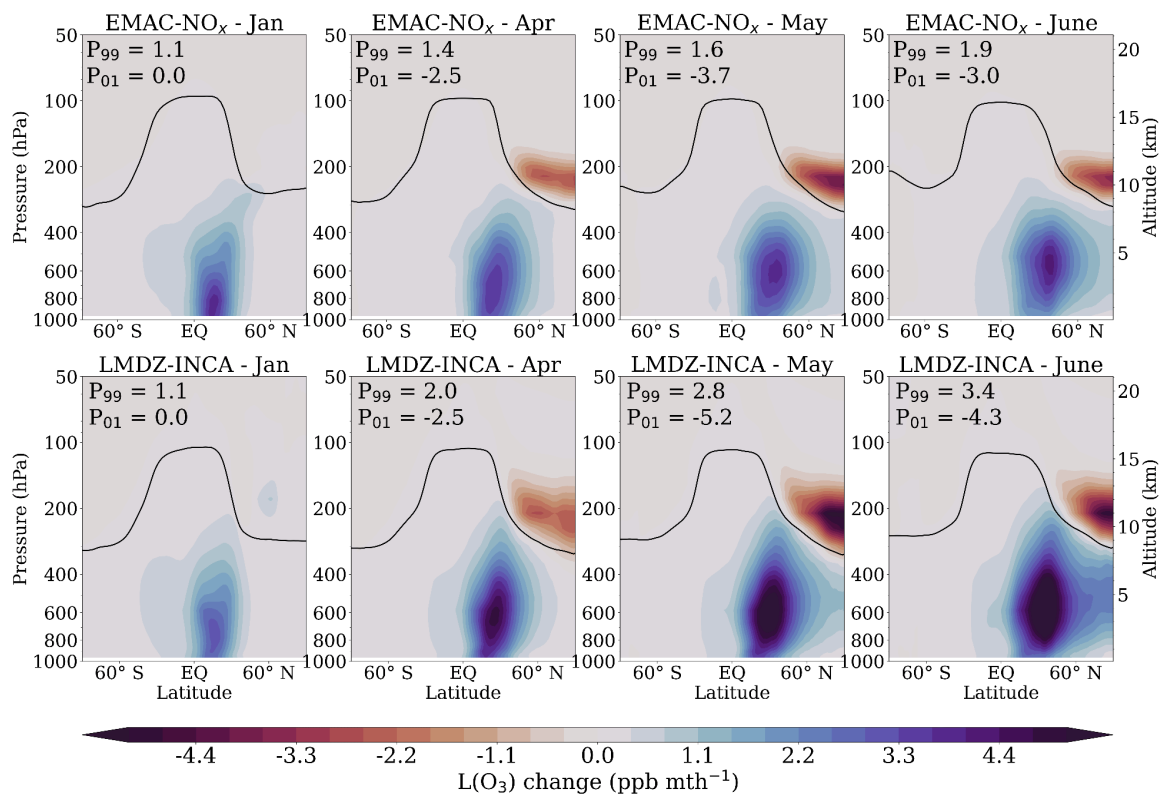


Figure S2: Same as Fig. S1 for ozone chemical loss $L(O_3)$. Note that the colors are reversed, in order to keep showing in red the variations that lead to an increase in ozone lifetime.

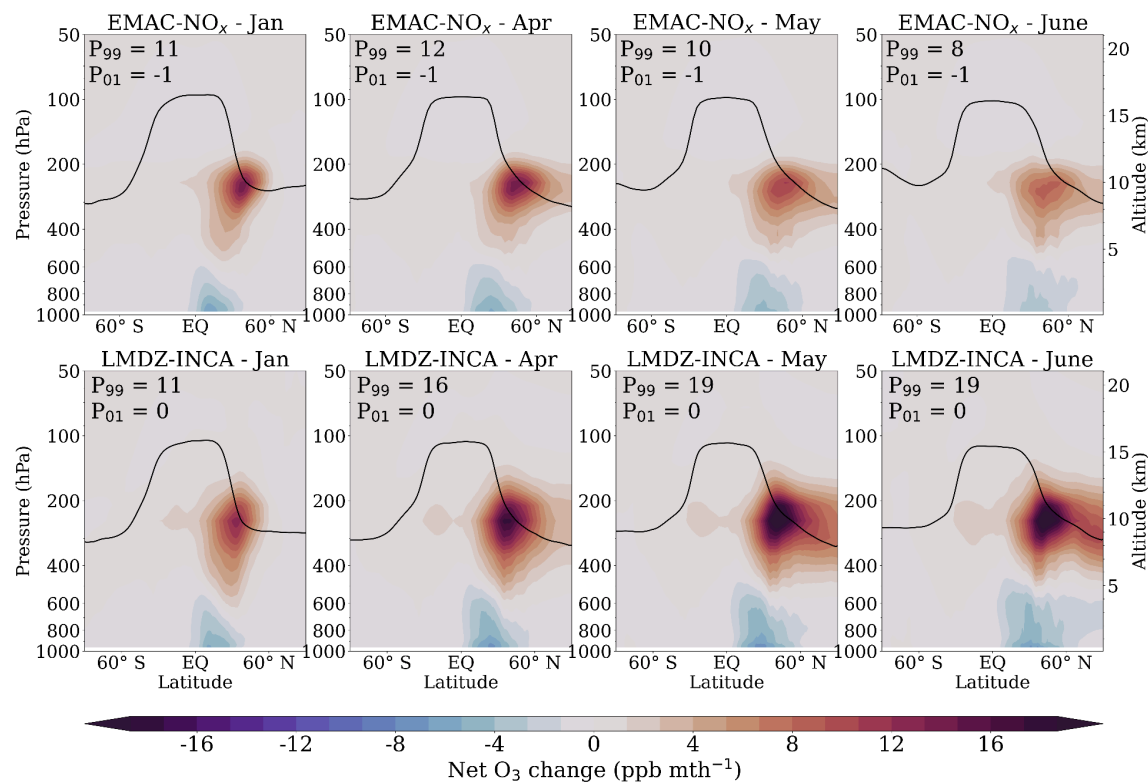


Figure S3: Same as Fig. S1 for net ozone production $P(O_3) - L(O_3)$.

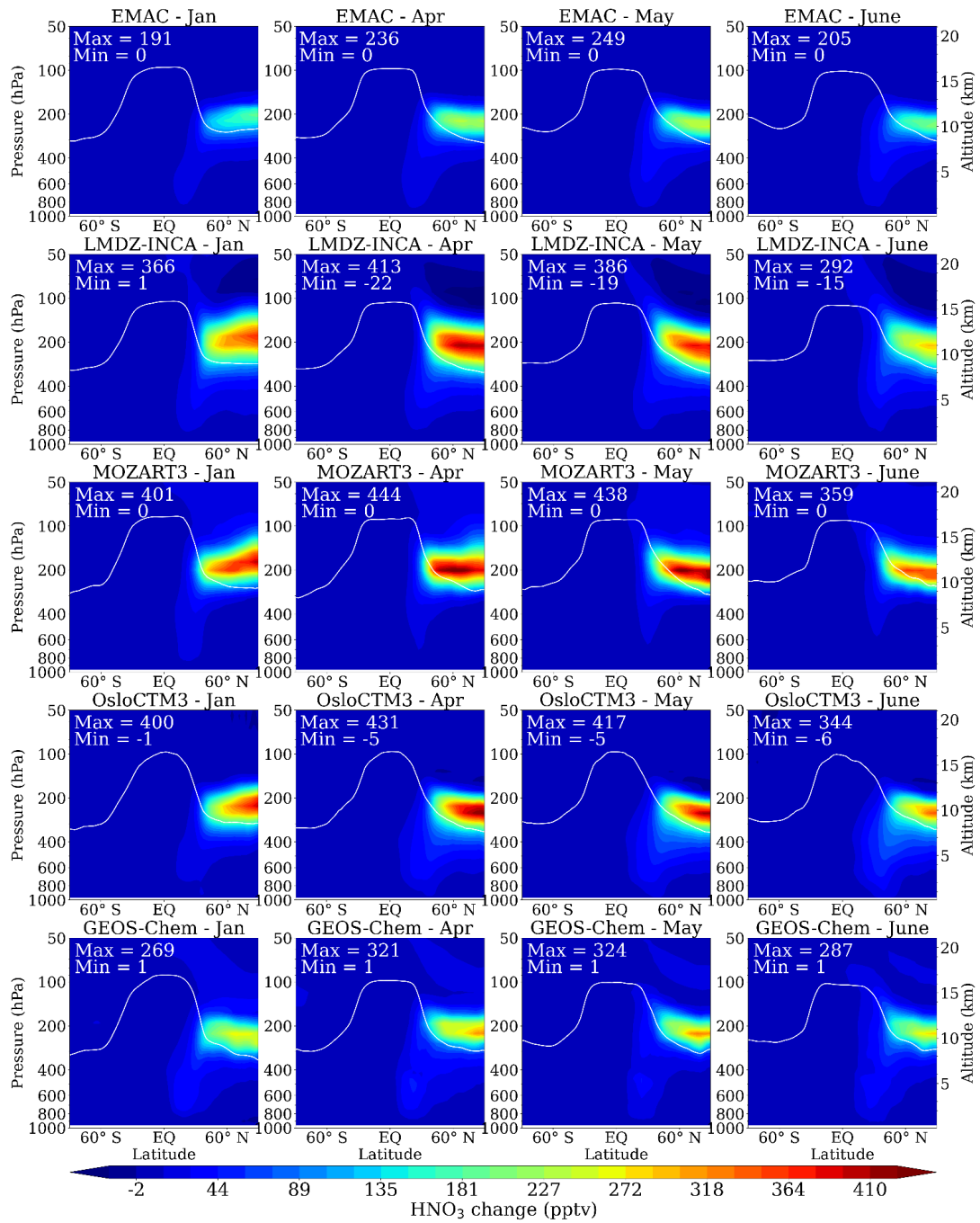


Figure S4: Zonal cross sections in the perturbation in nitric acid (HNO_3), for the EMAC and LMDZ-INCA models (top and bottom), during January, April, May, and June (from left to right).

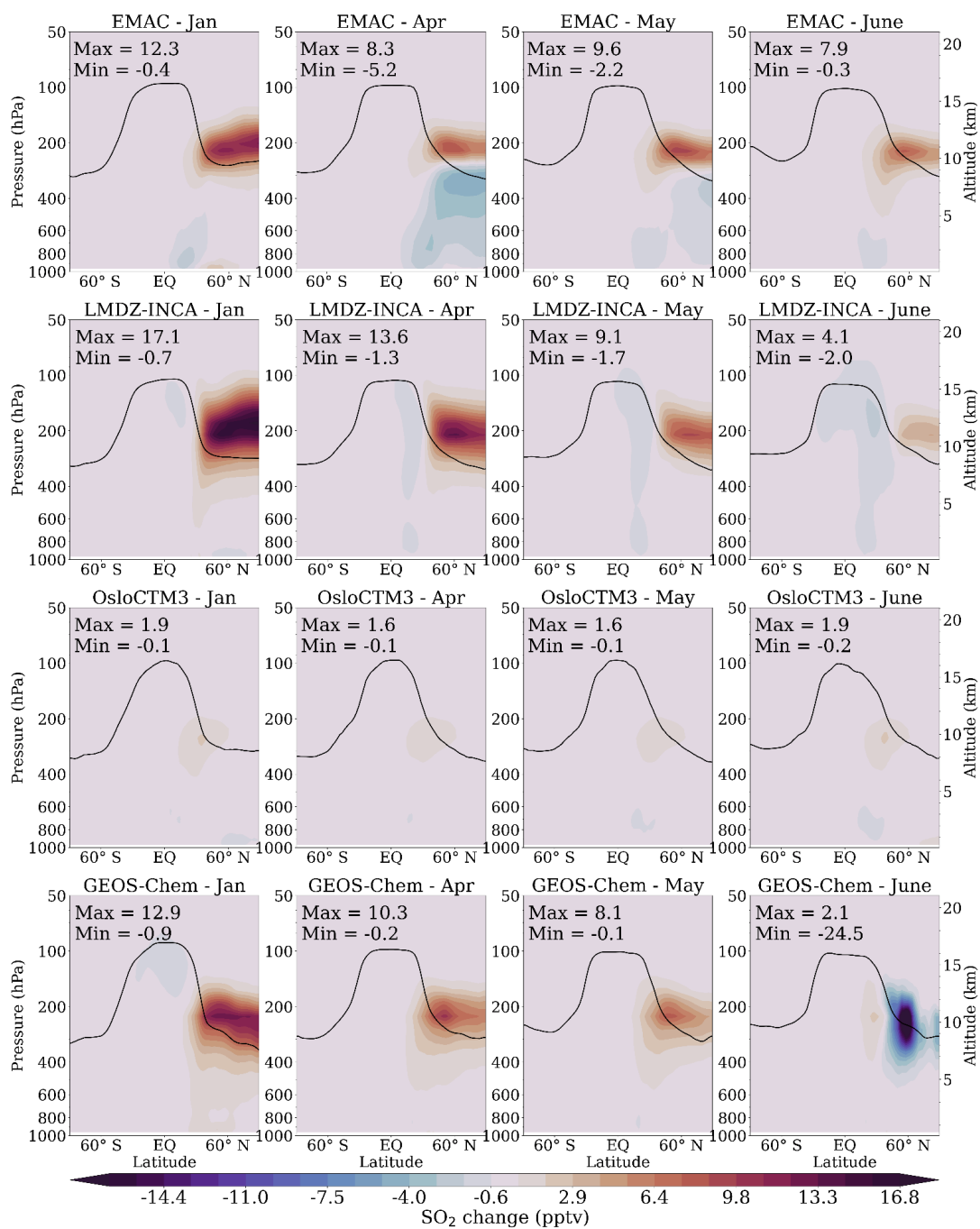


Figure S5: Same as Fig. S4 for sulfur dioxide (SO_2).

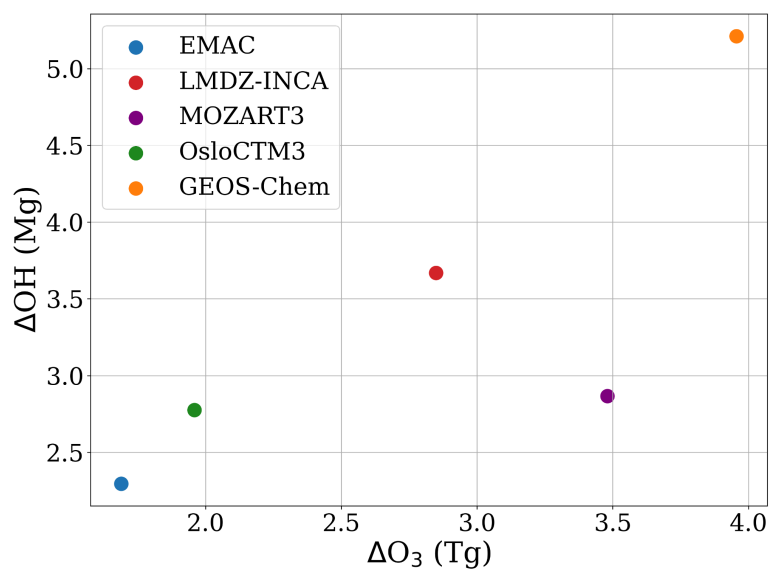


Figure S6: Scatterplot showing the OH mass burden perturbation against the ozone mass burden perturbation for each model, between 150 and 350 hPa. The perturbations are normalized to the NO_x emissions.

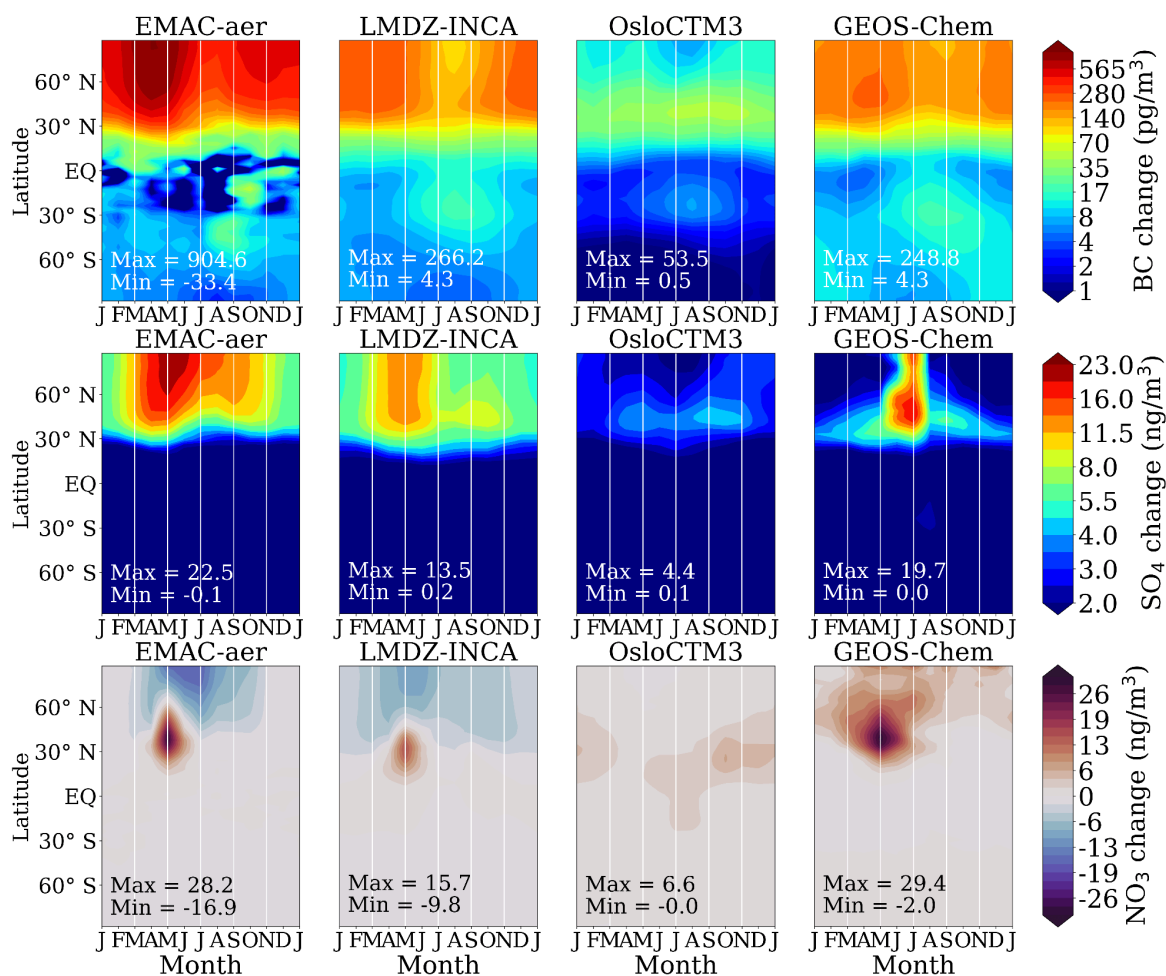


Figure S7: Hovmöller diagrams synthesizing the mean response in BC, SO₄ and NO₃ aerosols (from top to bottom), for LMDZ-INCA, OsloCTM3, EMAC-aer, and GEOS-Chem (from left to right). Each diagram consists of a vertical average between 150 and 350 hPa, the x and y axis displaying the months of the year and the latitude, respectively. Please note the different unit for BC, and the logarithmic scale for BC and SO₄.

S3. NO_x emissions

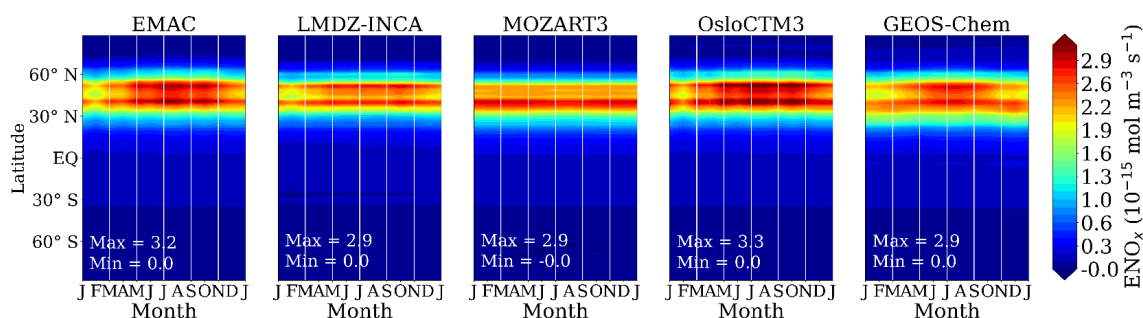


Figure S8: Hovmöller diagrams in NO_x emissions for each model, between 150 and 350 hPa.

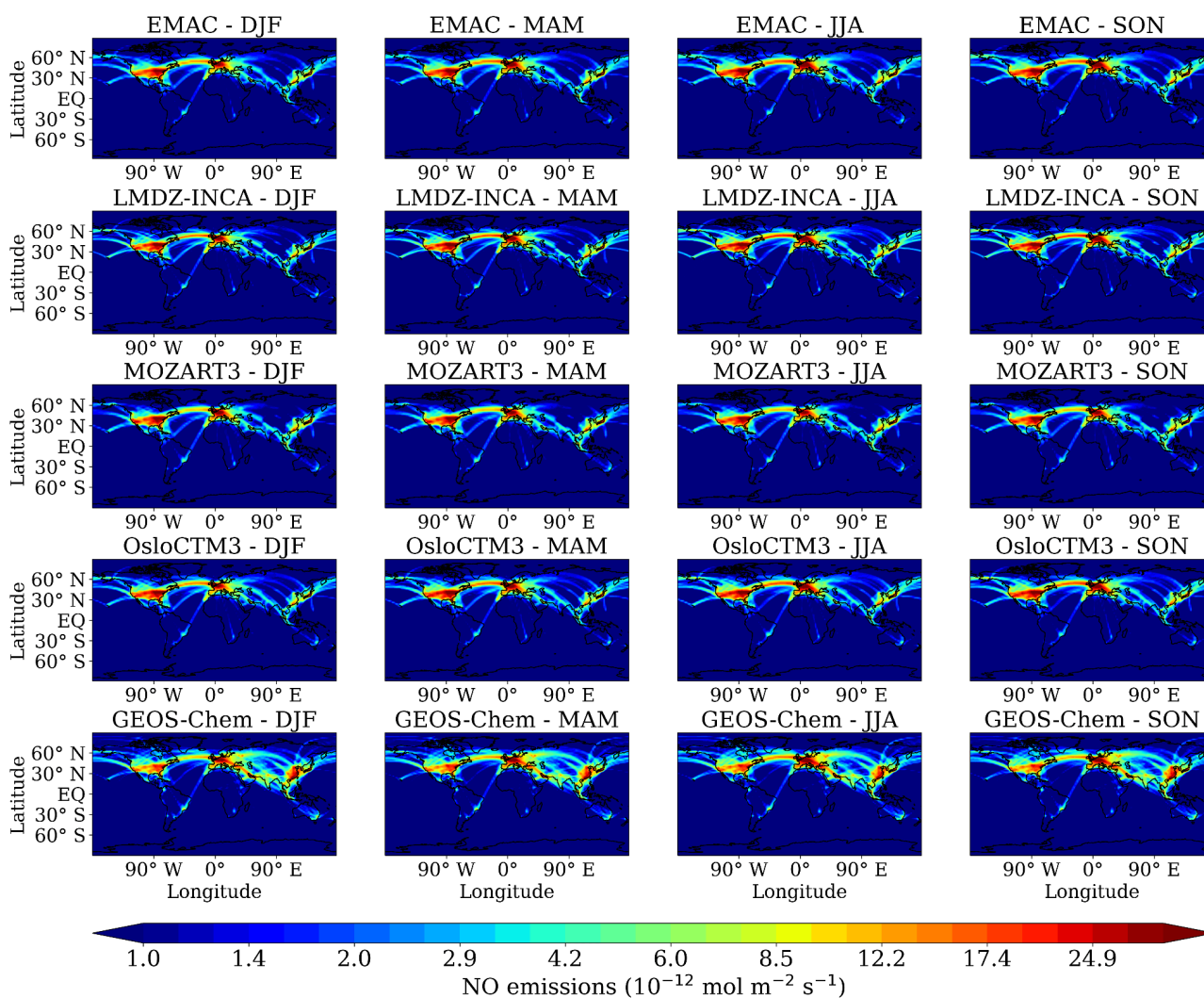


Figure S9: Partial columns showing aviation NO_x emissions between 150 and 400 hPa, for each model (from top to bottom) and during the four seasons (from left to right). Please note the logarithmic scale in the colorbar.

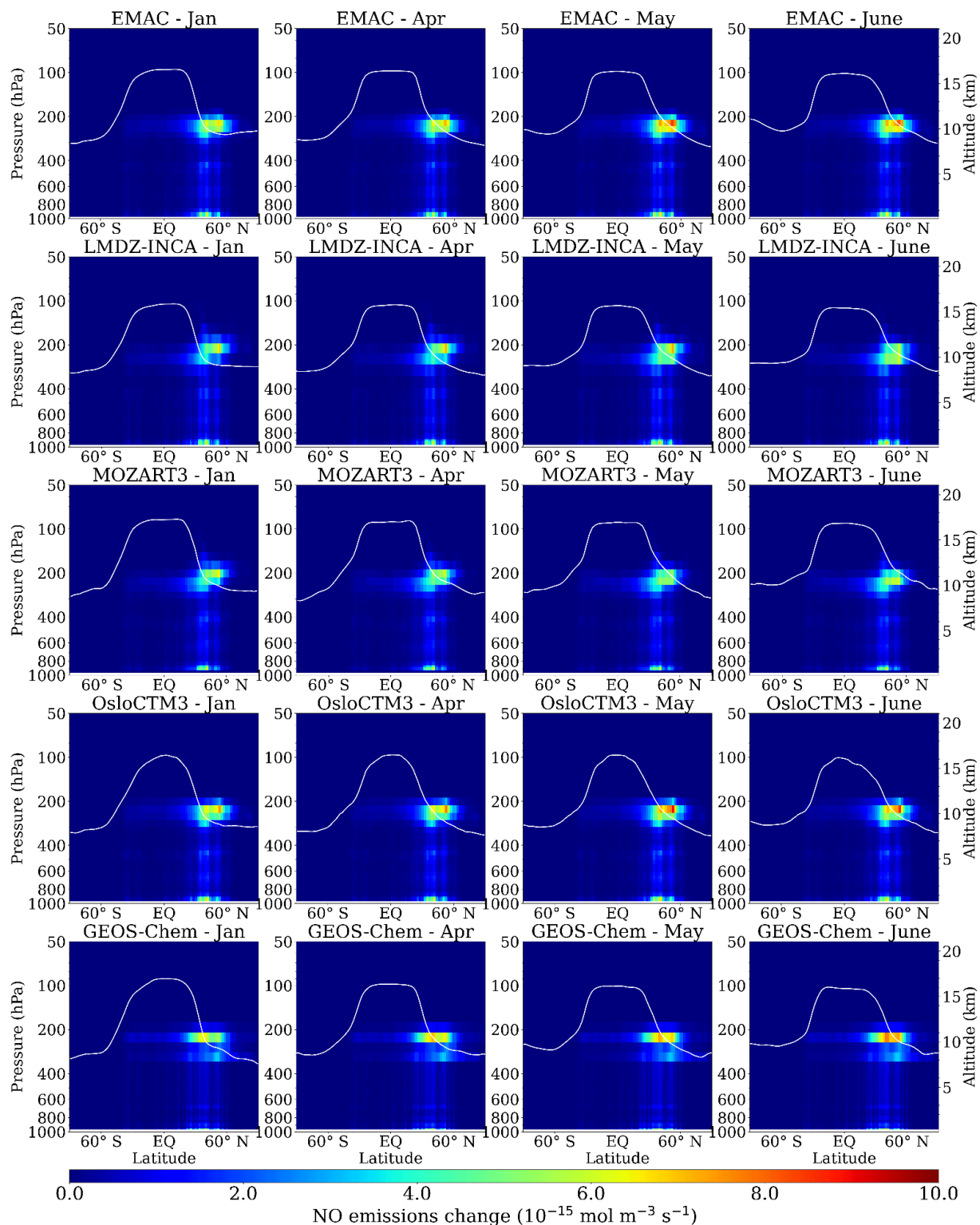


Figure S10: Zonal cross sections in NO_x emissions for each model (from top to bottom) during Jan, April, May, and June (from left to right).

S4. Linearity of the responses with respect to NO_x emissions

Table S2: Ratio between the 100% perturbation and the 20% perturbation rescaled up to 100%, for each model (columns) and gaseous species (row). TCH₄ refers to methane lifetime.

Ratio 100% / 20%	LMDZ-INCA	MOZART3	OsloCTM3
O ₃	1.13	1.18	1.09
NO _y	1.08	0.97	1.04
NO _x	0.94	0.92	1.04
HNO ₃	1.00	0.97	1.03
PAN	1.12	1.11	1.14
CO	1.10	1.12	1.08
TCH ₄	1.09	1.09	1.05
OH	1.11	1.14	1.08

S5. Aerosol surface perturbation

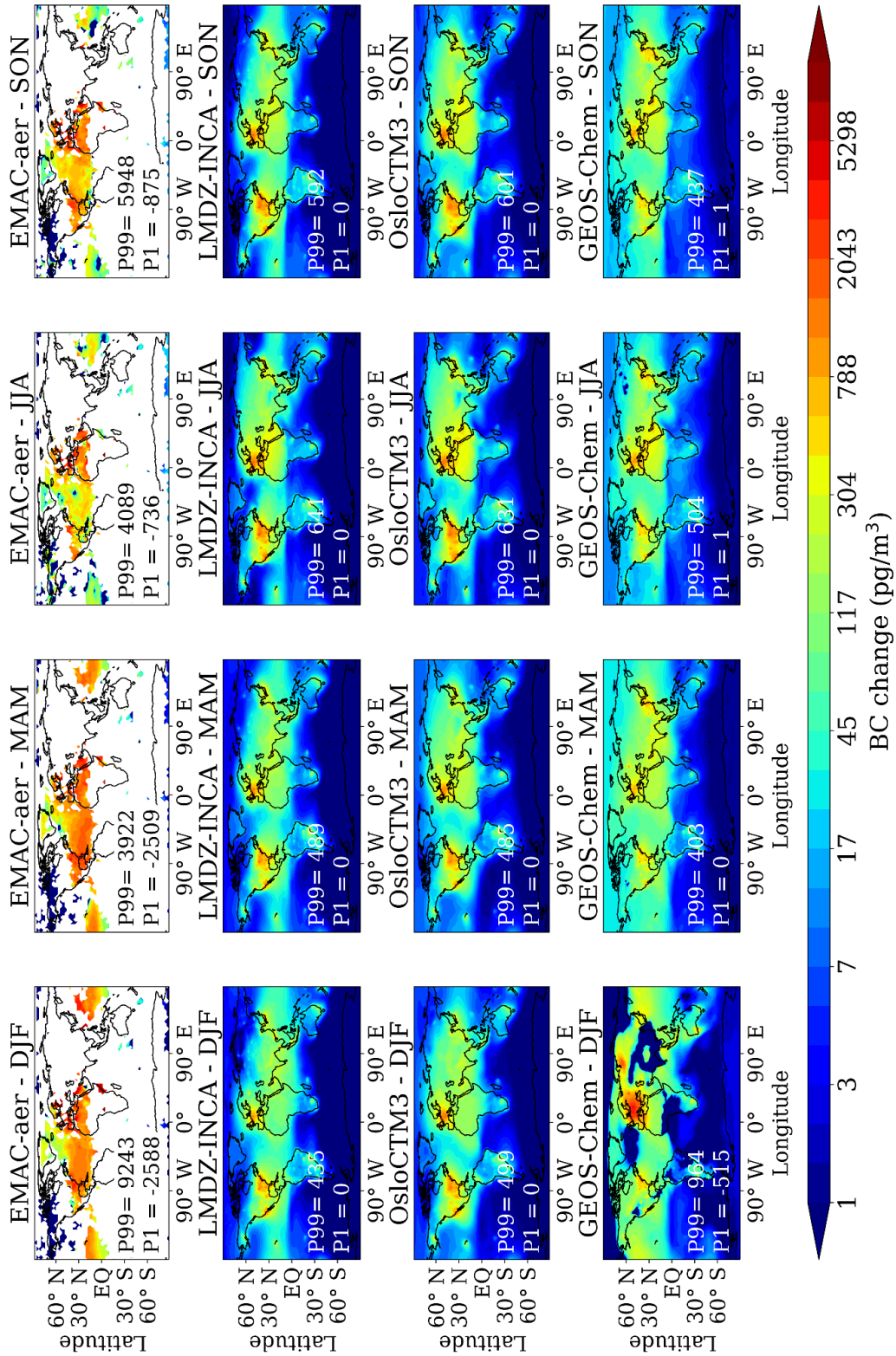


Figure S11: Surface maps of BC response to aviation emissions, for each model and each season. The percentiles 1 and 99 are indicated in the bottom left corner of each panel. Please note the logarithmic scale in the legend.

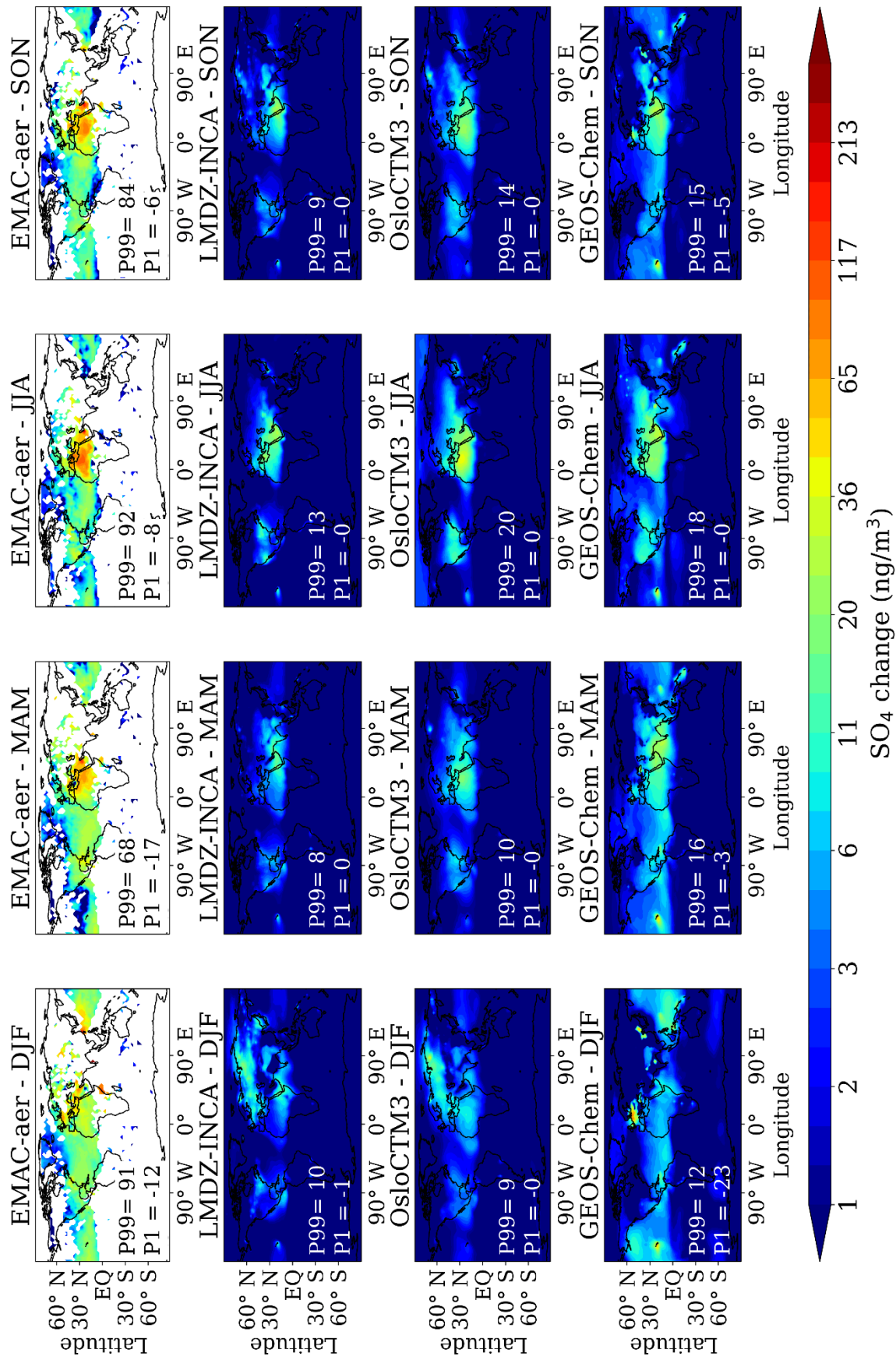


Figure S12: Same as Fig. S11 for SO_4 .

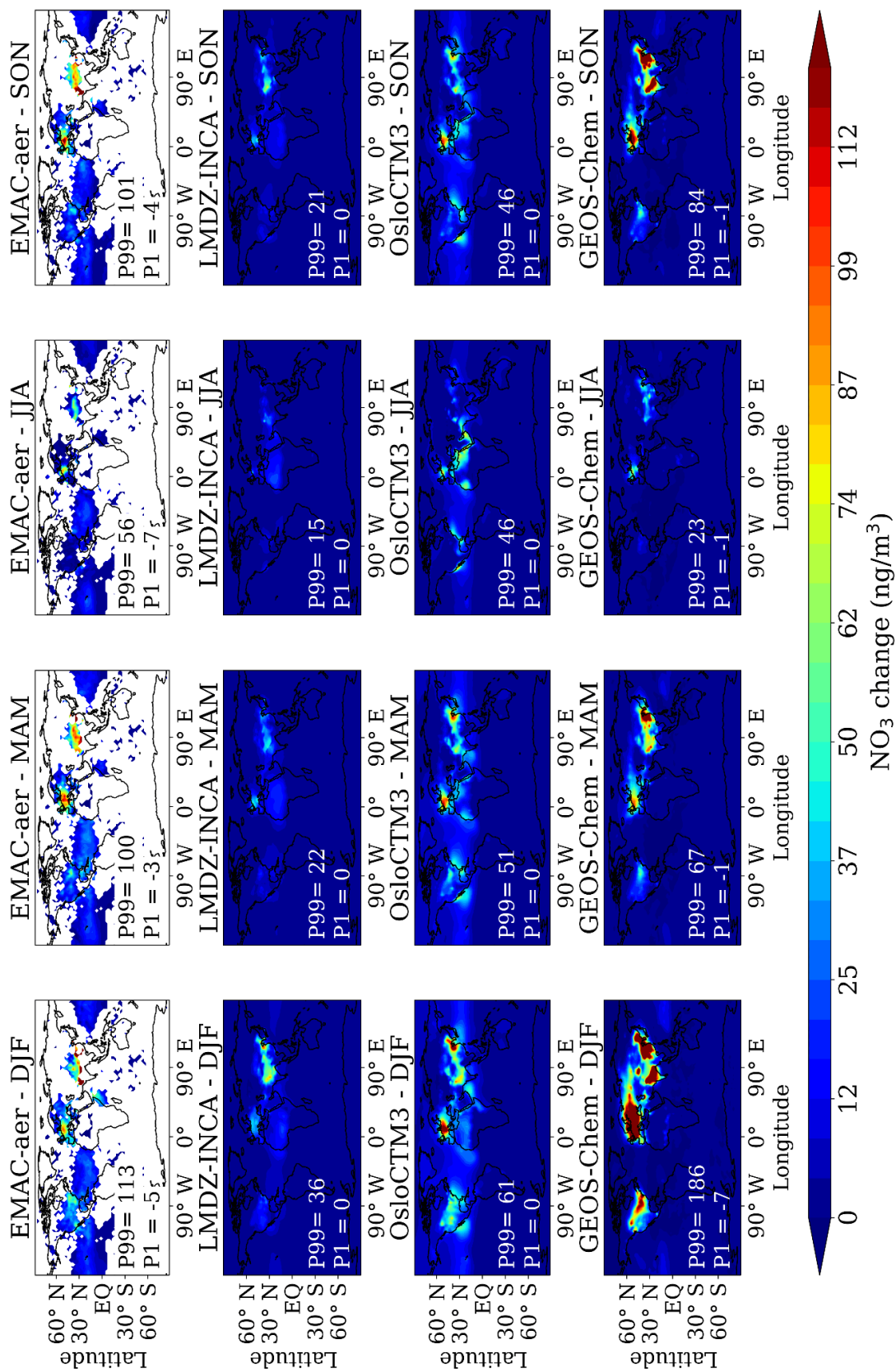


Figure S13: Same as Fig. S11 for NO_3 .

S6. Radiative forcing terms

Table S3: Effective radiative forcings from the different terms linked to NO_x emissions, as in Fig. 12a. The value in brackets shown for the short-term ozone forcing in LMDZ-INCA is calculated from an offline version of the LMDZ GCM radiative code, as described in Terrenoire et al. (2022). The row ‘Total CH₄’ corresponds to the sum of all ERFs related to CH₄, i.e. CH₄ direct effect, long-term ozone, and stratospheric H₂O. The row ‘Total’ corresponds to the sum of the two rows showing the short-term ozone ERF and ‘Total CH₄’.

ERF (mW m ⁻²)	EMAC-NO _x	LMDZ-INCA	MOZART3	OsloCTM3	GEOS-Chem
Short-term ozone	27.6	43.0 [40.6]	42.2	33.8	56.0
CH ₄ direct effect	-11.9	-15.4	-11.5	-11.6	-22.0
Long-term ozone	-4.83	-6.24	-4.68	-4.73	-8.93
Stratospheric H ₂ O	-1.56	-2.02	-1.51	-1.53	-2.89
Total CH ₄	-18.3	-23.6	-17.7	-17.9	-33.8
Total	9.36	19.4	24.5	15.9	22.2

Table S4: Effective direct radiative forcings of the different aerosol species, as in Fig. 12b.

Aerosol-radiation interactions (mW m ⁻²)	EMAC-aer (2015)	LMDZ-INCA (2014–2018)	OsloCTM3 (2014–2017)	GEOS-Chem (2019)
BC	6.37	2.08	0.82	2.65
OC	-1.16	-0.09	-0.05	-0.19
SO ₄	-11.2	-6.85	-5.10	-8.09
NO ₃	-3.82	-1.62	-13.5	-6.36
Total Aerosol	-10.2	-6.47	-17.8	-12.0