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Supplement of

Response of the global surface ozone distribution to Northern Hemisphere sea surface temperature changes: implications for long-range transport

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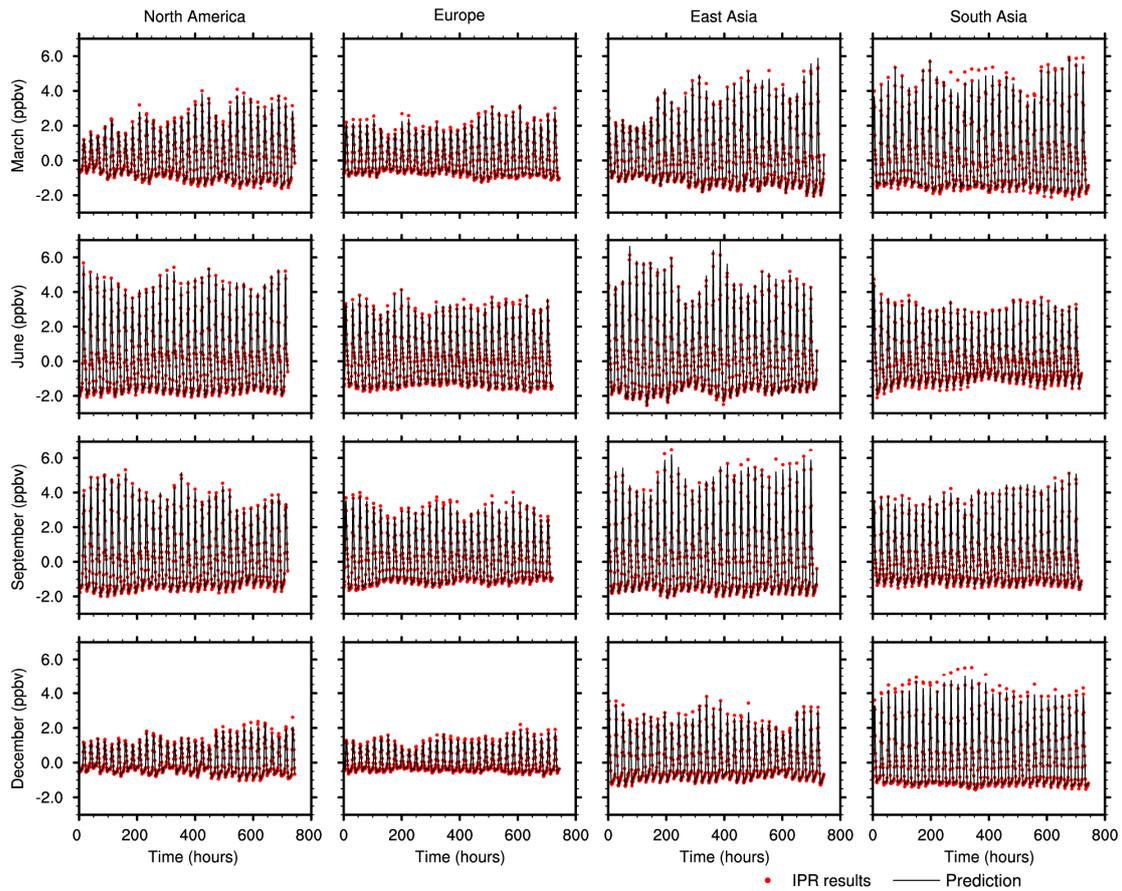


Figure S1. Hourly time-series of predicted O₃ changes (black lines) and the sum of IPR results (red dots) averaged over the four major regions of interest (i.e., America (15°N–55 °N; 60°W–125°W), Europe (25°N–65 °N; 10°W–50 °E), East Asia (15 °N–50 °N; 95°E–160 °E), and South Asia (5 °N–35 °N; 50 °E–95°E)) during March (first row), June (second row), September (third row) and December (last row) of random modeling years in the CTRL.

Table S1. Regionally and seasonally averaged (only ocean grid boxes are included) changes in surface O₃ concentrations (ppbv) over three ocean basins in the Northern Hemisphere (i.e., the North Pacific Ocean (15°N-65°N;100°E-90°W), North Atlantic Ocean (15°N-65°N; 100°W-20°E), and North Indian Ocean (5°N-30°N; 30°E-100°E)) for basin-scale SST perturbation cases relative to the control simulation. Positive changes that are significant at the 0.05 level evaluated using the Student’s t-test are marked in bold.

| Ozone (ppbv) | | DJF | MAM | JJA | SON | |
|----------------|------|----------------|--------------|--------------|--------------|--------------|
| North Pacific | +1°C | North Pacific | -0.56* | -0.71* | -0.78* | -1.22* |
| | | North Atlantic | -0.55* | -1.08* | -0.74* | -1.25* |
| | | North India | -1.05* | -0.59 | 0.16 | 0.20 |
| | -1°C | North Pacific | 0.32 | 0.55* | 1.04* | 1.00* |
| | | North Atlantic | 0.43* | 0.53* | 0.75* | 0.80* |
| | | North India | 0.77* | -0.06 | -0.03 | 0.16 |
| North Atlantic | +1°C | North Pacific | 0.05 | -0.02 | 0.38* | 0.01 |
| | | North Atlantic | 0.14 | 0.04 | -1.00* | -0.86* |
| | | North India | -0.45* | -1.31* | -0.63* | -0.72* |
| | -1°C | North Pacific | 0.11 | 0.32 | 0.11 | -0.30 |
| | | North Atlantic | -0.02 | -0.14 | 0.76* | 0.43* |
| | | North India | 0.39 | 0.59 | 0.38* | 0.48 |
| North India | +1°C | North Pacific | -0.34 | -0.11 | -0.14 | -0.88* |
| | | North Atlantic | -0.25 | -0.46 | -0.11 | -0.23 |
| | | North India | -1.59* | -0.42 | 0.81* | -2.11* |
| | -1°C | North Pacific | 0.32 | 0.32 | 0.50* | 0.52* |
| | | North Atlantic | -0.07 | -0.42 | 0.11 | -0.37* |
| | | North India | 1.32* | 0.89* | -0.38* | 1.84* |

*Significant at the 0.05 level from Student’s t-test using 20 years of model results.

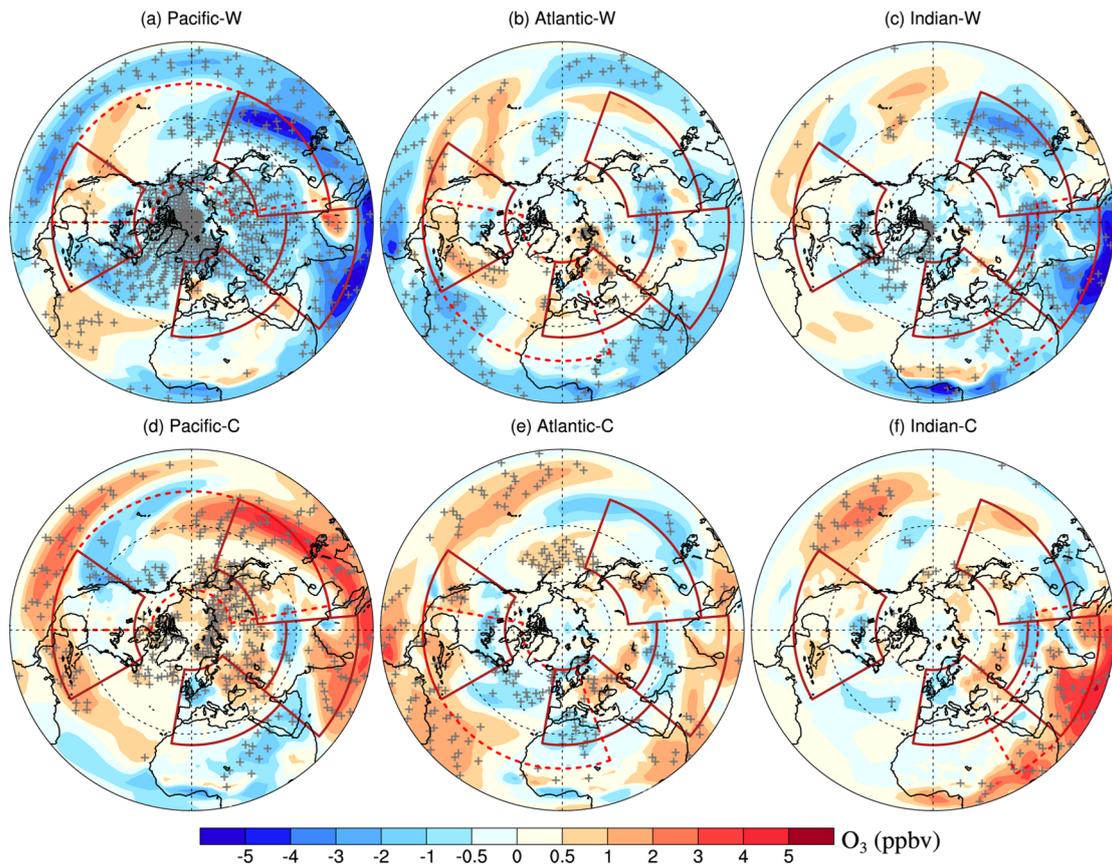


Figure S2. Changes in the wintertime (December-February) surface O_3 concentrations (ppbv) in the Northern Hemisphere for (a) Pacific-W, (b) Atlantic-W, (c) Indian-W, (d) Pacific-C, (e) Atlantic-C, and (f) Indian-C relative to the CTRL. The four major regions of interest (i.e., NA, EU, EA and SA) are marked with solid polygons. Red dashed lines mark the regions where the SST has been changed. The + symbols denote areas in which results are significant at the 0.05 level, evaluated using the Student's t test and 20 years of data.

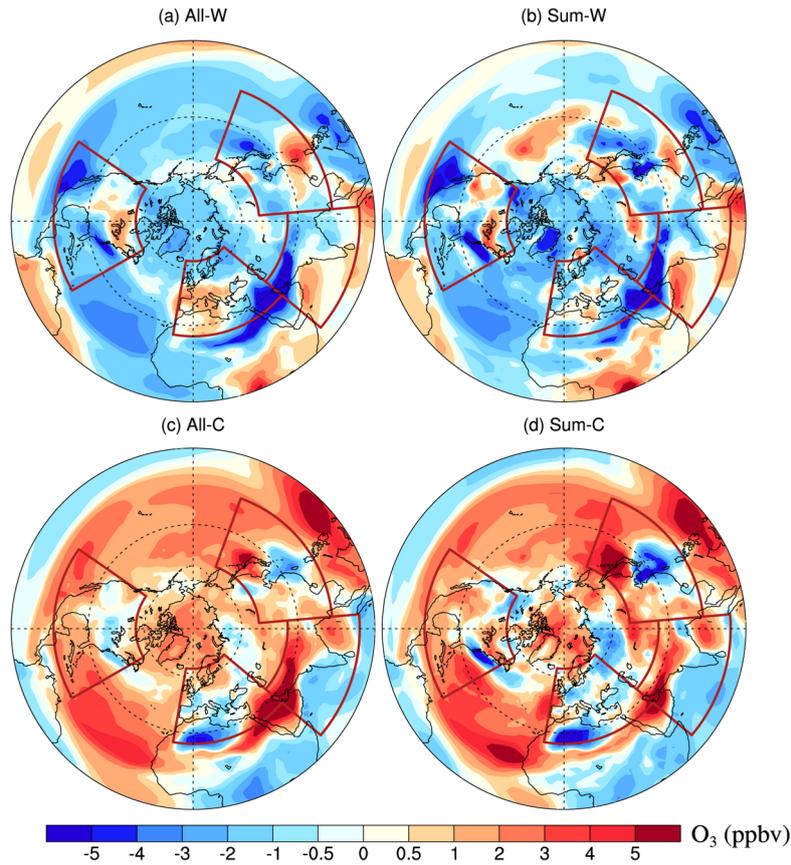


Figure S3. Left column: changes in the summertime (June-August) surface O_3 concentrations (ppbv) in the Northern Hemisphere induced by 1°C warming (a) and 1°C cooling (b) in all three ocean basins (i.e., the North Pacific, North Atlantic, and North Indian Oceans) relative to the CTRL. Right column: sum of changes in the summertime (June-August) surface O_3 concentrations (ppbv) from the three warming cases (i.e., Pacific-W, Atlantic-W and Indian-W) and three cooling cases (i.e., Pacific-C, Atlantic-C and Indian-C) relative to the CTRL, denoted as (b) Sum-W and (d) Sum-C, respectively. The four major regions of interest (i.e., NA, EU, EA and SA) are marked with polygons.

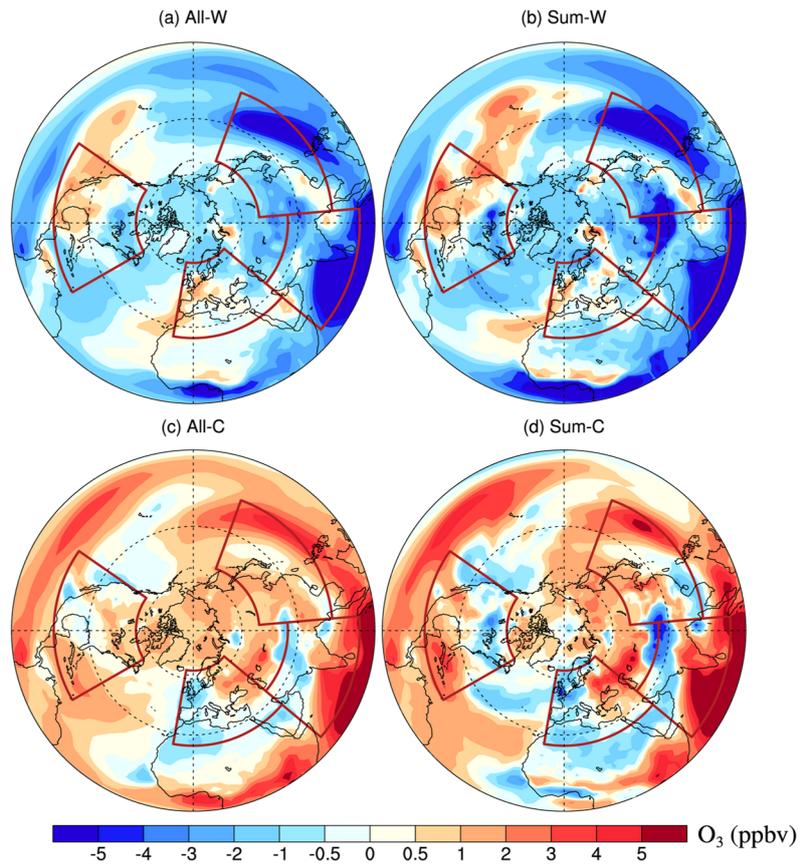


Figure S4. Same as Figure S3 but for the wintertime (December-February).

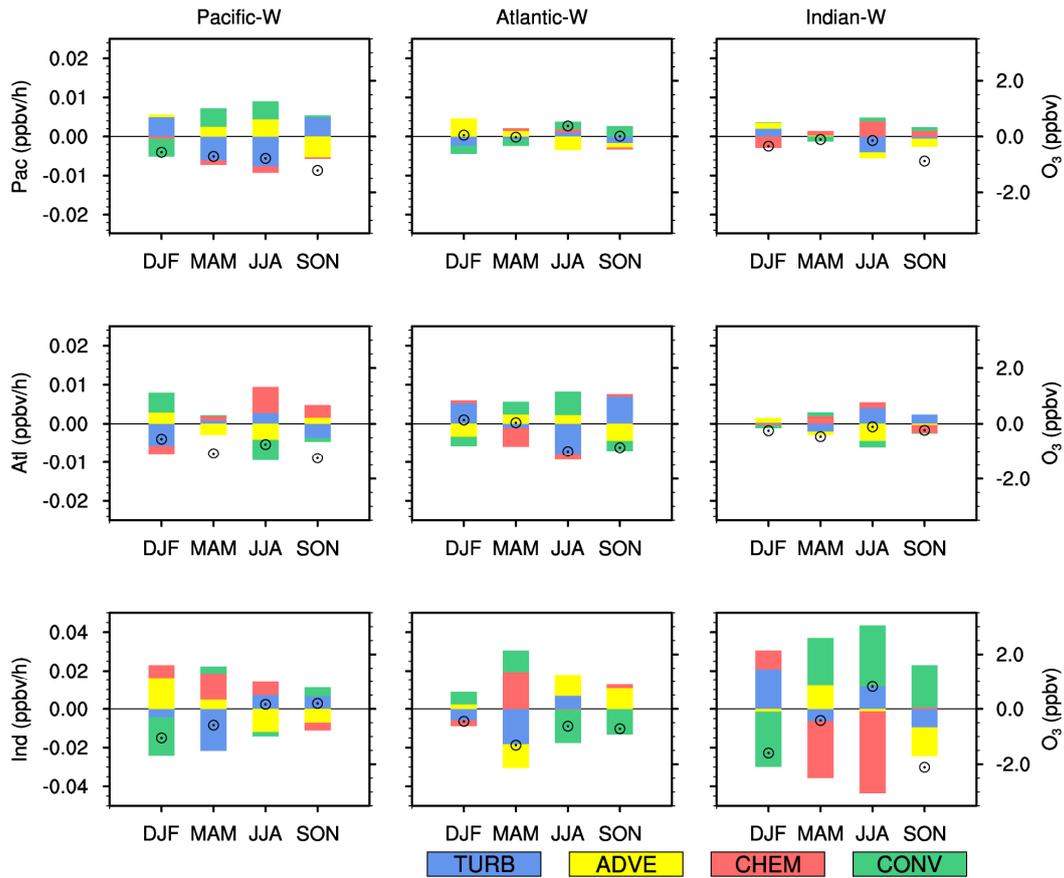


Figure S5. Seasonally averaged changes in the IPR contributions (bars, ppbv h^{-1} , left scale) and surface O_3 concentrations (hollow circles, ppbv , right scale) for Pacific-W (left), Atlantic-W (middle), and Indian-W (right) relative to the CTRL. Values are regionally averaged over North Pacific (15°N - 65°N ; 100°E - 90°W , demoted as Pac, first row), North Atlantic (15°N - 65°N ; 100°W - 20°E , demoted as Atl, second row) and North Indian Ocean (5°N - 30°N ; 30°E - 100°E , demoted as Ind, third row). IPR contributions from the four processes (i.e., TURB, ADVE, CHEM and CONV) are represented by different colors.

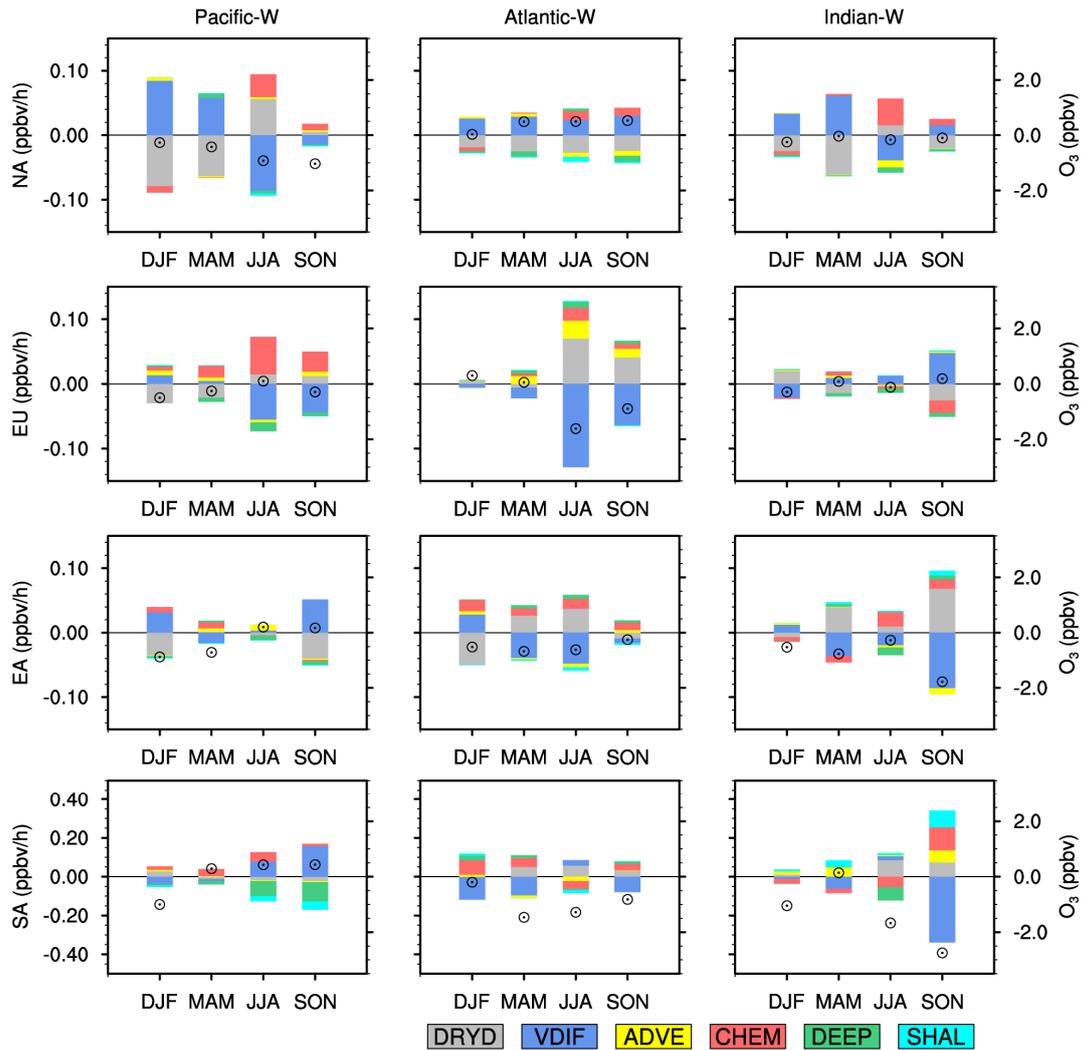


Figure S6. Seasonally averaged changes in the IPR contributions (bars, ppbv h^{-1} , left scale) and surface O_3 concentrations (hollow circles, ppbv , right scale) for Pacific-W (left), Atlantic-W (middle), and Indian-W (right) relative to the CTRL. Values are regionally averaged over NA (first row), EU (second row), EA (third row) and SA (last row). IPR contributions from the six processes (i.e., DRYD, VDIF, ADVE, CHEM, DEEP and SHAL) are represented by different colors.

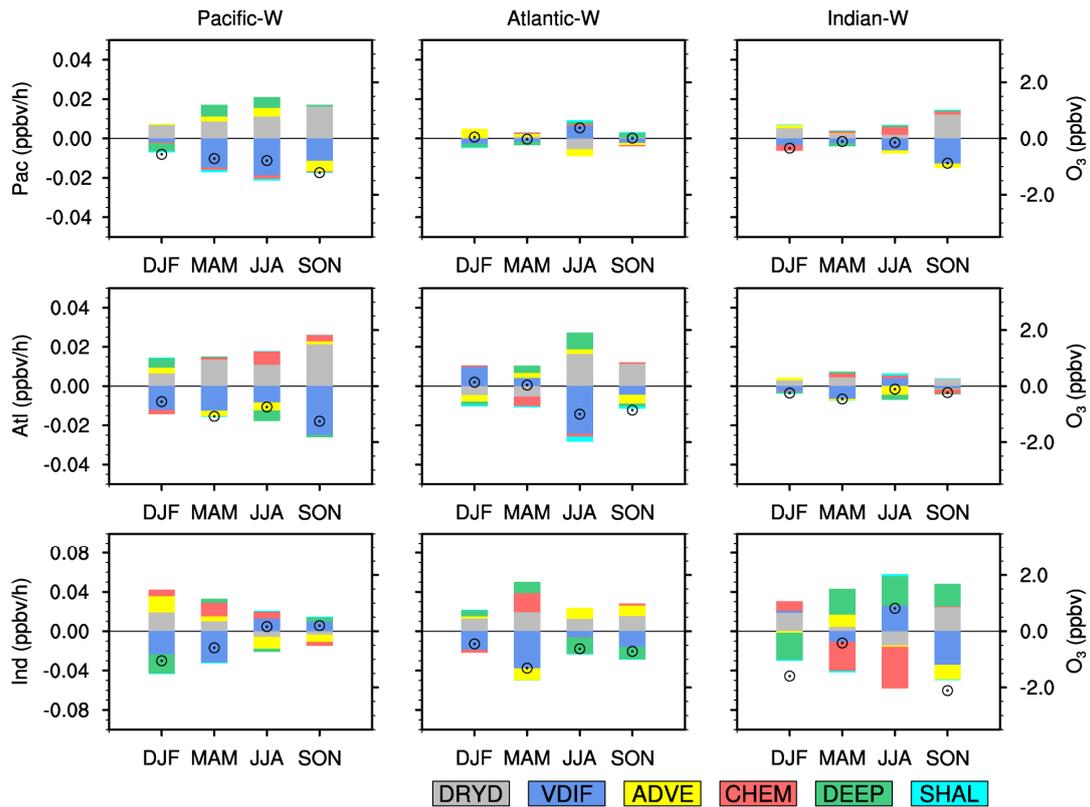


Figure S7. Same as Figure S6 but for the three ocean basins defined in our study.

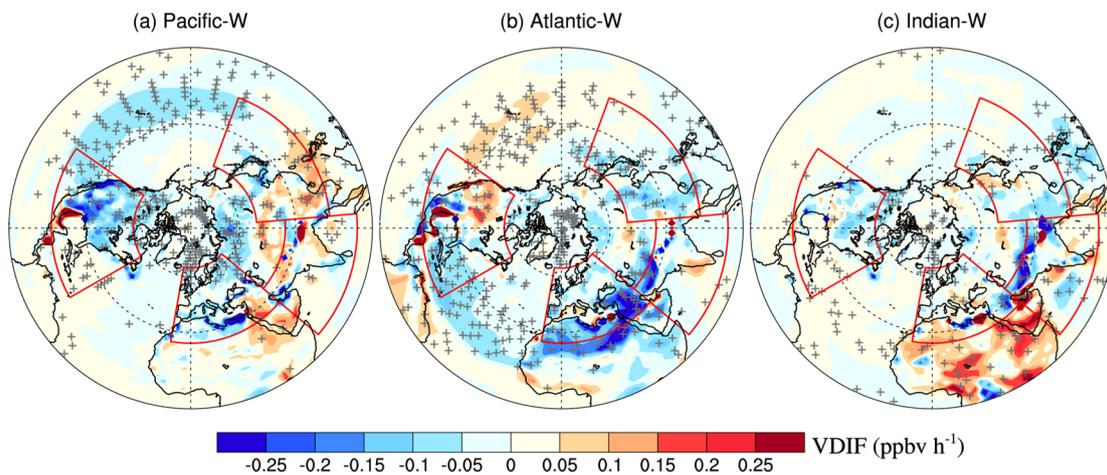


Figure S8. Changes in VDIF (ppbv h^{-1}) for (a) Pacific-W, (b) Atlantic-W, and (c) Indian-W relative to the CTRL in the boreal summer. The four major regions of interest (i.e., NA, EU, EA and SA) are marked by red solid lines. The + symbols denote areas where the results are significant at the 0.05 level, evaluated using the Student's t test and 20 years of data.

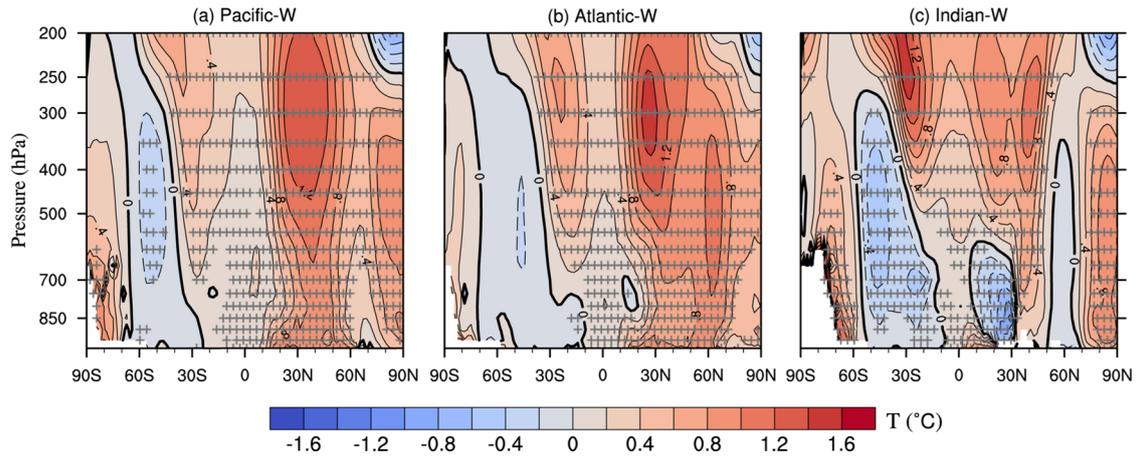


Figure S9. Vertical-meridional distributions of changes in the air temperature (contours, °C) for (a) Pacific_W (zonal averaged from 100°E-90°W), (b) Atlantic_W (zonal averaged from 100°W-180°W), and (c) Indian_W (zonal averaged from 30°E-100°E) relative to the CTRL in boreal summer. Black solid and dashed lines in the contours indicate positive and negative air temperature anomalies, respectively (contour interval: 0.2 °C). The + symbol denotes areas where the changes of air temperature are significant at the 0.05 level, evaluated using Student's t test and 20 years of data.

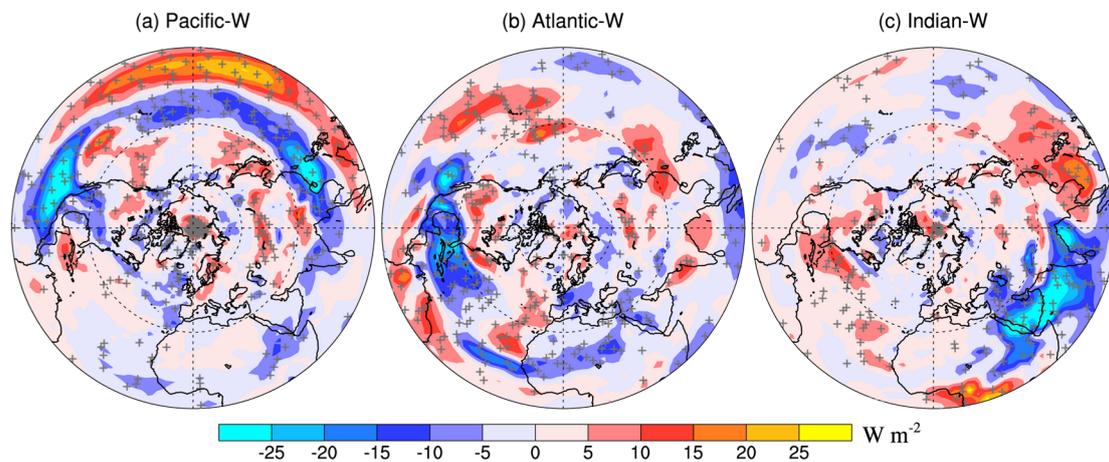


Figure S10. Perturbations of the surface solar radiations (W m^{-2}) for (a) Pacific-W, (b) Atlantic-W, and (c) Indian-W relative to the CTRL in the boreal summer. The + symbols denote areas where the results are significant at the 0.05 level, evaluated by Student's t test and 20 years of data.

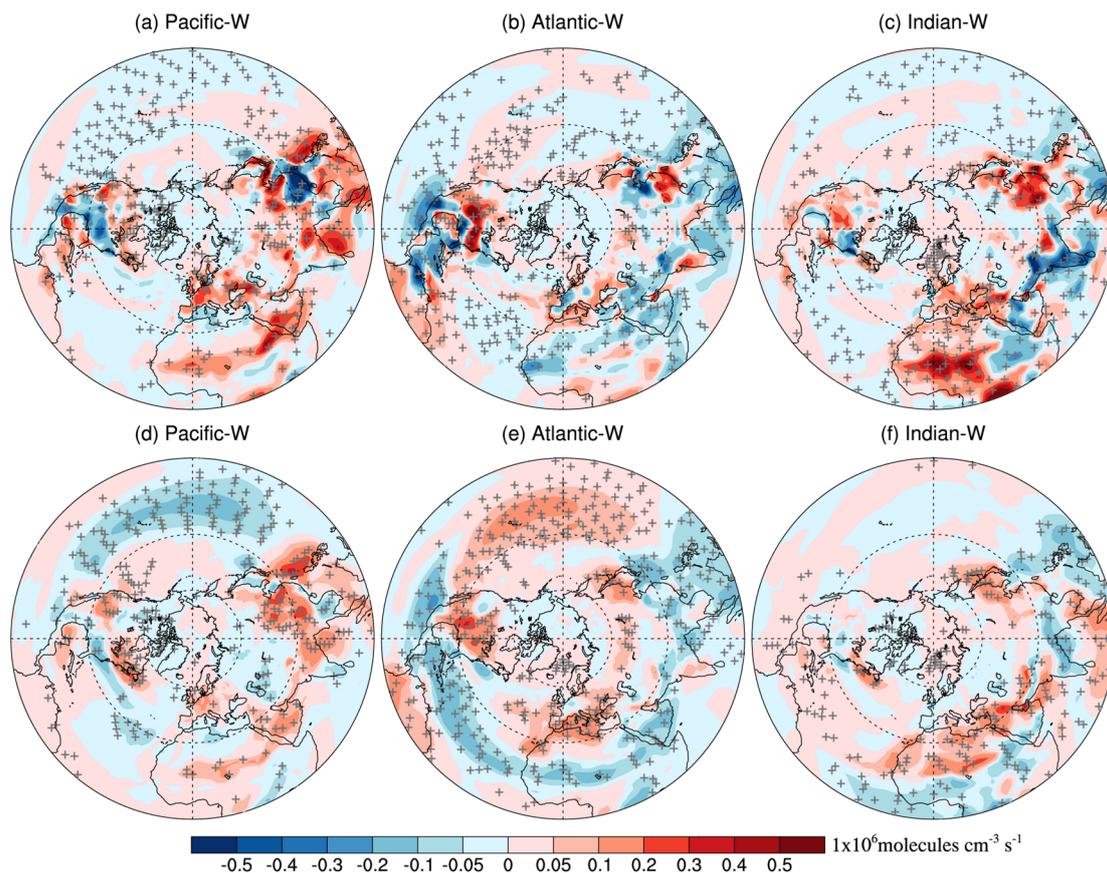


Figure S11. Top row: perturbations of the surface chemical O₃ production rate (1×10^6 molecules $\text{cm}^{-3} \text{s}^{-1}$) for (a) Pacific-W, (b) Atlantic-W, and (c) Indian-W relative to the CTRL in the boreal summer. Bottom row: perturbations of surface chemical O₃ loss rate (1×10^6 molecules $\text{cm}^{-3} \text{s}^{-1}$) for (d) Pacific-W, (e) Atlantic-W, and (f) Indian-W relative to the CTRL in the boreal summer. The + symbols denote areas where the results are significant at the 0.05 level, evaluated using the Student's t test and 20 years of data.

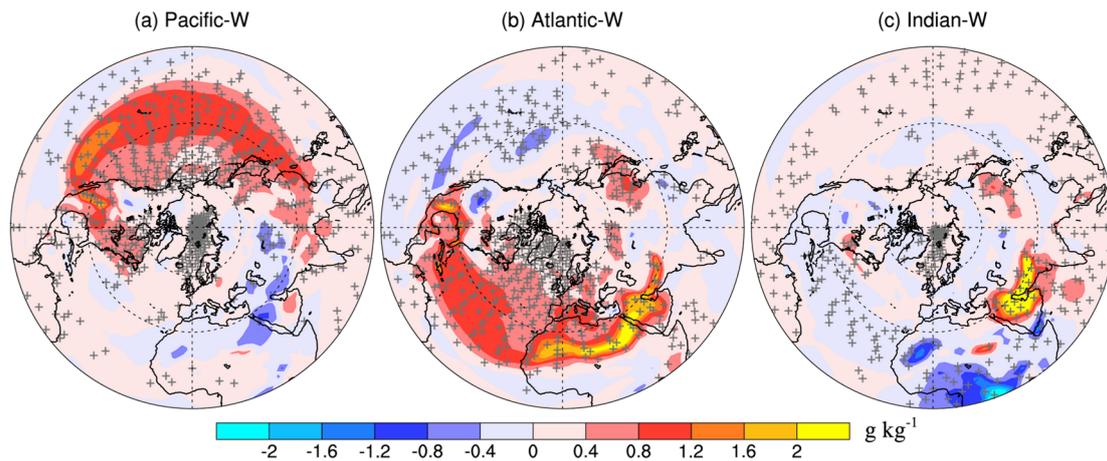


Figure S12. Perturbations of the surface specific humidity (g kg^{-1}) for (a) Pacific-W, (b) Atlantic-W, and (c) Indian-W relative to the CTRL in the boreal summer. The + symbols denote areas where the results are significant at the 0.05 level, evaluated using Student's *t* test and 20 years of data.

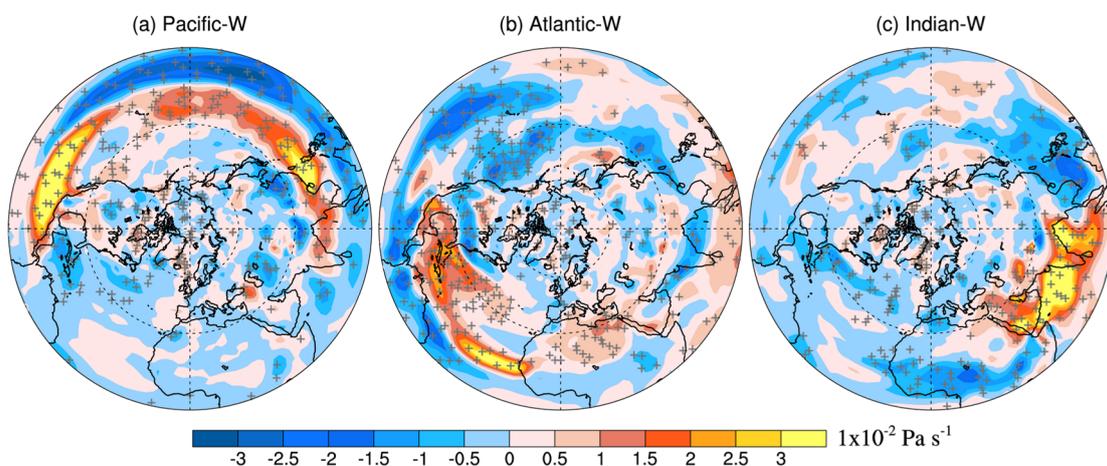


Figure S13. Spatial pattern of vertical velocity changes at 500 hPa (color contours, $1 \times 10^{-2} \text{ Pa s}^{-1}$) for (a) Pacific-W, (b) Atlantic-W, and (c) Indian-W relative to the CTRL in the boreal summer. Positive values indicate upward motion. The + symbols indicate areas where results are significant at the 0.05 level, evaluated using the Student's *t* test and 20 years of data.

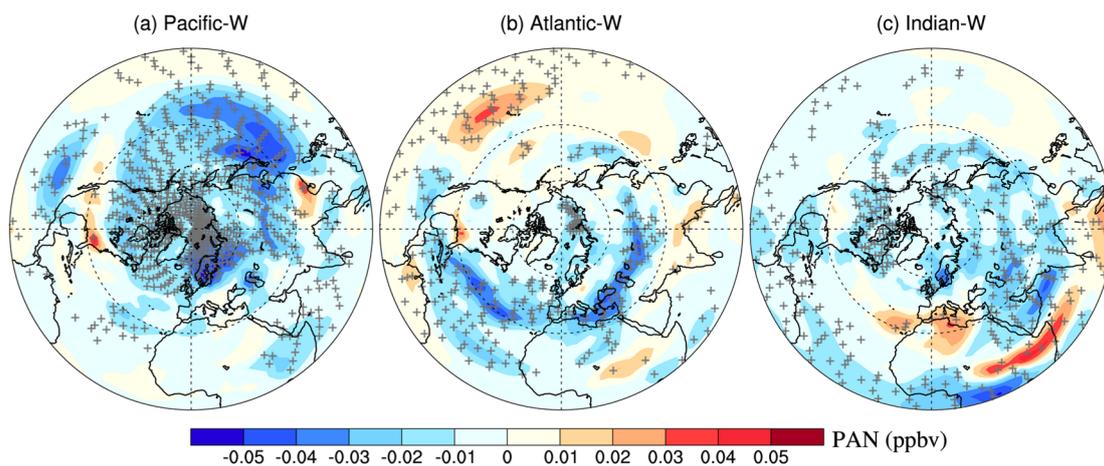


Figure S14. Changes in the summertime (June-August) PAN concentrations (ppbv) at 500 hPa for (a) Pacific-W, (b) Atlantic-W, and (c) Indian-W relative to the CTRL. The + symbols denote areas where the results are significant at the 0.05 level, evaluated using the Student's *t* test and 20 years of data.