Response to Anonymous Referee #1

(Note: Reviewer comments are listed in grey, and responses to reviewer comments are in black. Pasted text from the new version of the paper is in italics.)

Yi et al. investigate the response of surface ozone concentrations due to changes in sea surface temperature (SST) in three different ocean basins (North Pacific –NP, North Atlantic – NA, and North Indian Ocean, NIO). The authors use an Earth System Model (CESM) and perform a set of sensitivity studies in which they alter in turn the climatological SSTs of +/-1°C over the NP, NA and NIO. The imposed variation in SST leads to changes in surface ozone up to 5 ppbv. The authors focused on the summer season and they show that changes in transport associated to the SSTs anomalies are important in driving ozone anomaly at the surface. In general, increased SST reduces the intercontinental transport of O3. Overall the manuscript is relatively well written and logically organized. However, in the introduction several references to previous work are missing, several parts of the manuscript need to be clarified and the authors should try to be consistent when displaying the results (see comments below). Overall, the study presents interesting new aspects and fits well with the scope of the journal. However, before publication large improvements are needed.

We really appreciate the reviewer's thoughtful and valuable comments. Following the reviewer's suggestion, we have extended the introduction and discussion based on these important references in the revised manuscript. The IPR analysis used in our study has been described more thoroughly to make it easier to understand. Based on the reviewer's comments, we have further clarified the text and improved the quality of relevant figures: high-resolution plots are provided in the revised manuscript, which are more distinguishable and understandable. We believe it substantially helps to improve our manuscript by addressing these issues. Please see our response to each comment below.

Major comments:

1) I suggest including a sensitivity test in which the SSTs in all 3 basins is increased. It will be interesting to see the effect of a generalized warming. I would also recommend to include a discussion of the results for winter season (see specific comments below)

Good suggestion. Following the reviewer's suggestion, we conducted two sensitivity tests with 1ºC SST warming and 1ºC SST cooling superimposed onto all three ocean basins (i.e., the North Pacific, North Atlantic and North Indian Ocean), denoted as "All-W" and "All-C", respectively. Their effects on surface O_3 distributions are compared with the sum of results from three individual warming or cooling cases during boreal summer (see Figure S5 or S6 below) and winter (see Figure S7 or S8 below). It shows that the responses of surface O_3 to a generalized SST anomaly over all three ocean basins generally resemble the sum of results from individual oceans. Slight differences are observed over the extratropical North Pacific for the warming cases in boreal summer.

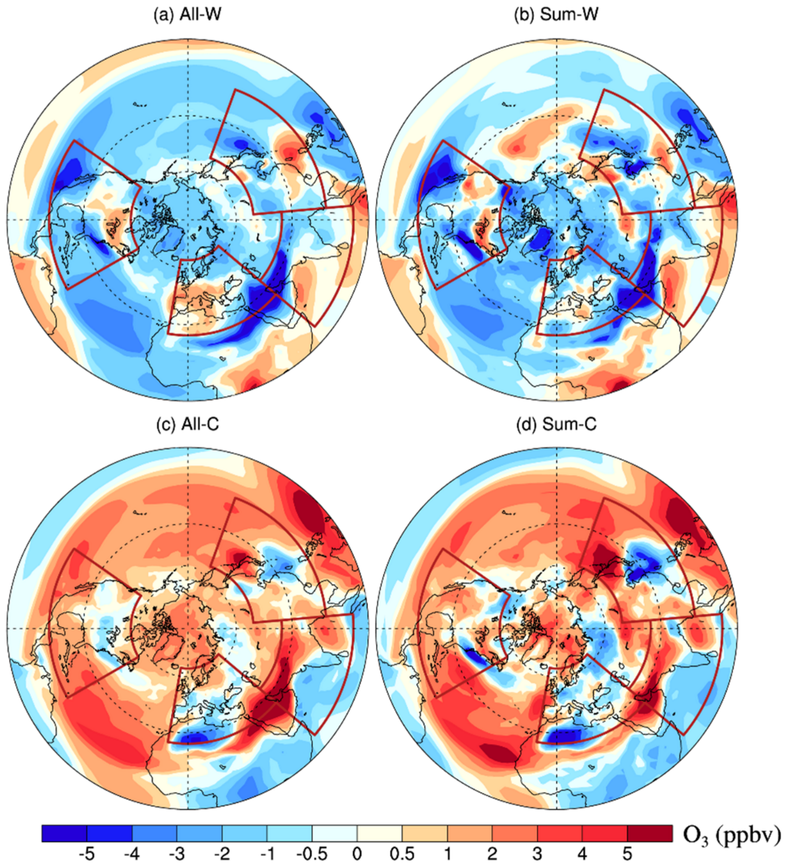

Figure S5. Left column shows the changes in the summertime (June-August) surface ozone concentrations (ppbv) in the Northern Hemisphere induced by 1 ºC warming (a) and 1 ºC cooling (b) in all three ocean basins (i.e., the North Pacific, North Atlantic and North Indian Ocean) relative to CTRL. Right column shows the sum of changes in the summertime (June-August) surface ozone concentrations (ppbv) from 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 CTRL, denoted as (b) Sum-W and (d) Sum-C, respectively. Four major regions of interest (i.e., NA (15°N–55 °N; 60°W–125°W), EU (25°N–65 °N;10°W-50 °E), EA (15 °N–50 °N; 95°E–160 °E) and SA (5 °N–35 °N; 50 °E–95°E)) are marked with red polygons.

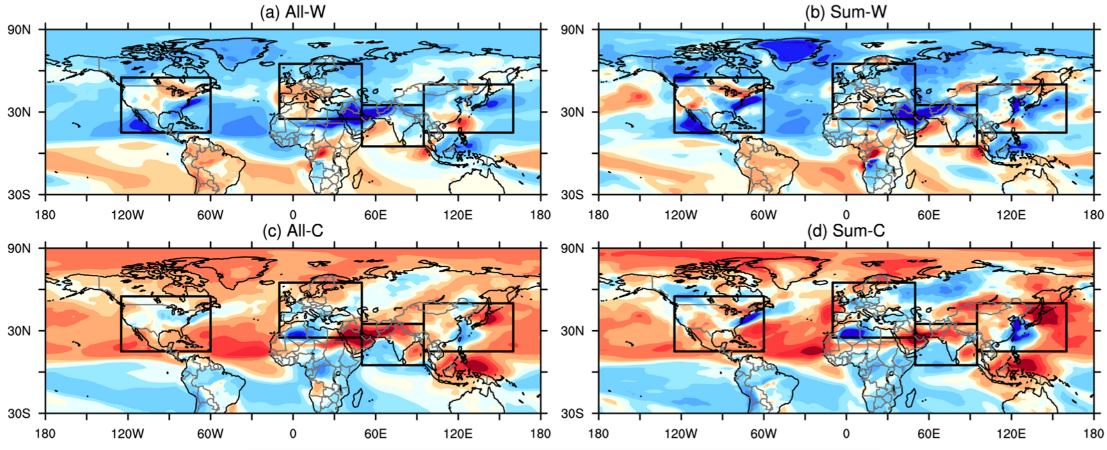

Figure S6. Same as Figure S5 but using the Mercator projection.

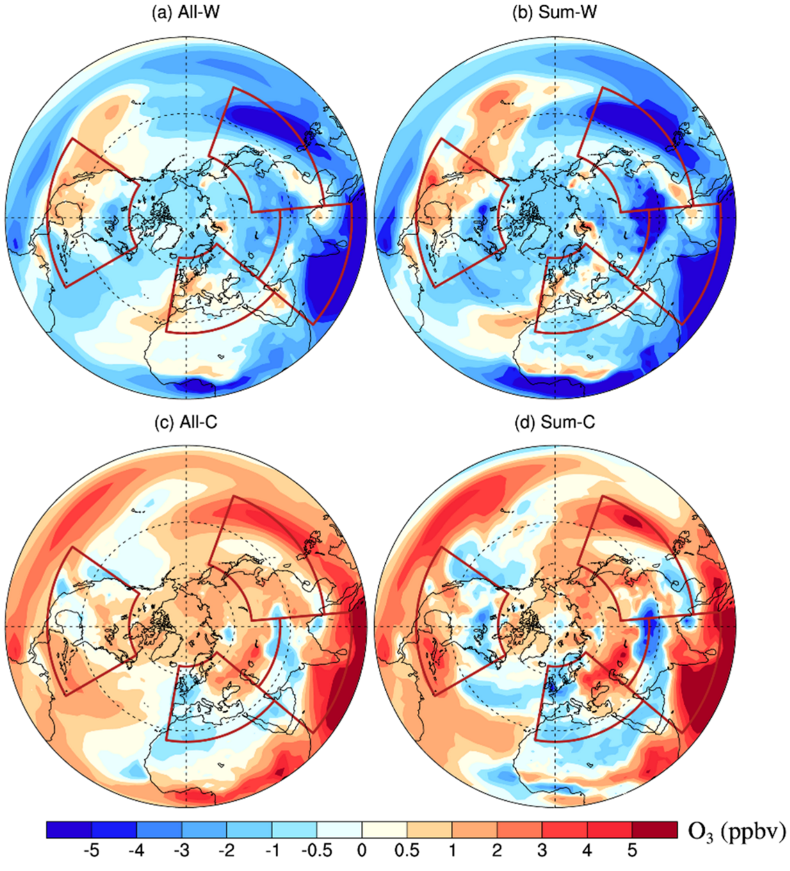

Figure S7. Same as Figure S5 but for the wintertime responses (December-February).

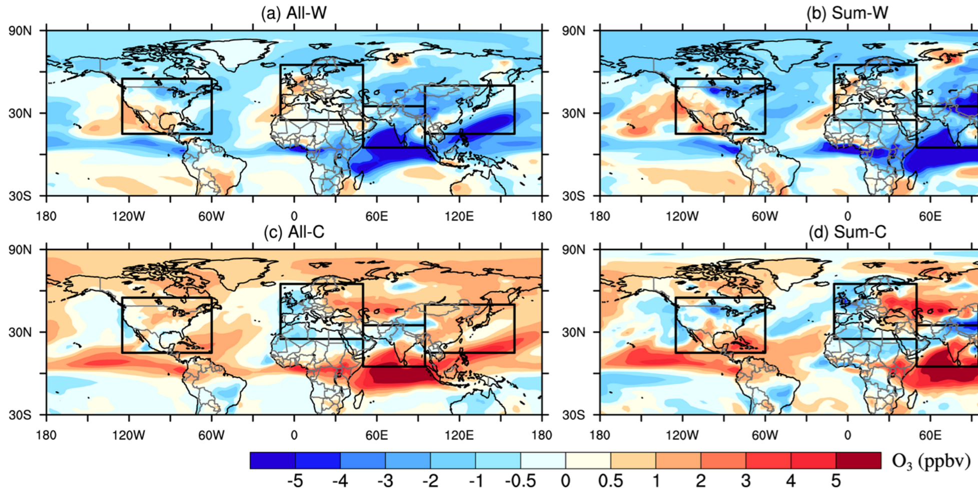

Figure S8. Same as Figure S7 but using the Mercator projection.

Considering nonlinear relationships existed in the climate system and O_3 formation processes, the response of surface O_3 to a generalized SST anomaly over all three oceans can not perfectly match the sum of individual results. Regardless those slight difference, our results indicate that the effect of a generalized SST warming on surface O_3 can be decomposed into individual regional ocean forcings. This may help to interpret the responses of surface O_3 to a global-wide warming documented in previous studies (Doherty et al., 2013;Jacob and Winner, 2009;Wu et al., 2008). In the revised manuscript, we made the following revisions in Section 3:

"We further conduct two sensitivity tests with 1 ^{o}C SST warming and 1 ^{o}C SST cooling superimposed onto all three ocean basins (i.e., the North Pacific, North Atlantic and North Indian Ocean) in the Northern Hemisphere, denoted as "All-W" and "All-C", respectively. Their effects on surface O_3 distributions are respectively compared with the sum of three individual warming cases (i.e., Pacific-W, Atlantic-W and Indian-W) and three cooling cases (i.e., Pacific-C, Atlantic-C and Indian-C). The responses of surface O_3 to a hemispheric SST anomaly generally resemble the sum of responses to different regional SST changes (see Figure S5 and S7 in the supplementary material)."

We also diagnosed the results for winter season, it shows that the responses of surface O_3 and other relevant variables are generally insignificant over land, especially over the four continental regions of interest (i.e., NA, EU, EA and SA). Therefore, we decided to focus mainly on boreal summers. More detailed discussion is provided in our reply to specific comments below.

2) I had major problems in understanding several figures: sometimes the figures are too

“crowded” and it is not possible to distinguish the continents (e.g. figures. 4, 6, 9); the panels are often very small in particular in figures 1, 3, 4, 6, 9. The few figures that are clear are the one using the Mercator (or equirectangular) type of projection (e.g., Figures 5, 7, 8, S4, S5). I recommend the authors to be consistent and use the Mercator projection for all figures.

Furthermore, the authors should also be consistent with the use of colorbars: sometimes they use white for values that are not significant (e.g. figure 1), other times for small values (e.g. figure 3), other times they don’t use it at all (e.g. figure 4). I recommend not using white color bins for small values, especially if they are significant as in figure 3. See specific comments. I struggle to understand the lack of consistency in making the plots (type of projections, type of colorbar, choice of significant levels, choice of how to display the significant values, etc) that makes it harder for the reader to follow.

Thanks for this really helpful suggestions. We agree that the quality of some figures are low. In our revised manuscript, high-resolution figures are provided that are more distinguishable. We also improved these figures (Figures 6 and 9) that look too “crowded” by removing unnecessary information. The continental outlines in all figures were thicker and darker than the old version. As for the type of projections, we compared the performance of different projections and decided to consistently use polar projection to exhibit our results in hemispheric scale (e.g., Figures 1, 3 and 4 as well as other figures in the supplementary material) while use Mercator projection for regional analysis (e.g., Figures 5-8). The polar projection looks better than Mercator projection when showing the continuous cross-regional relationship along the hemispheric-scale general circulation. Figures using the Mercator projection are also provided in the supplementary material. Please see Figures S2, S14 and S15 below for some examples. Following the reviewer’s suggestions, we also enhanced the consistency of these figures. We have removed white color bins for small values (e.g., Figure 3) and consistently used the same symbols to mark results that are significant at the 0.05 level (e.g., Figure 1). We also substantially increased the quality of figures which contain smaller plots. Now these figures can be read more easily and clearly. Following figures show you some examples about these improvements. Please see the revised manuscript for all figures.

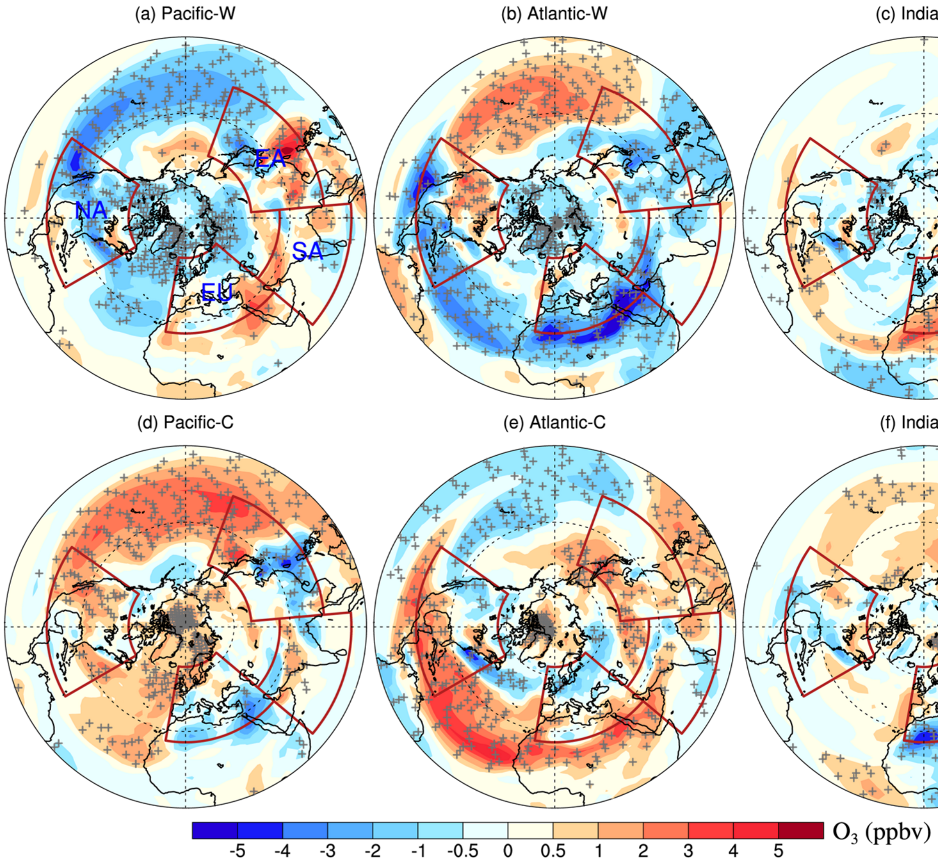

Figure 1. Changes in the summertime (June-August) surface ozone concentrations (ppbv) in the Northern Hemisphere induced by 1ºC warming (top) and 1 ºC cooling (bottom) in the North Pacific Ocean (left), North Atlantic Ocean (center), and North Indian Ocean (right) relative to CTRL. Four major regions of interest (i.e., NA (15°N–55 °N; 60°W–125°W), EU (25°N–65 °N; 10°W-50 °E), EA (15 °N–50 °N; 95°E–160 °E) and SA (5 °N–35 °N; 50 °E–95°E)) are marked with red polygons. The + symbols denote areas where results are significant at the 0.05 level as evaluated with a Student t-test using 20 years of data. (Plots using the Mercator projection are shown in Figure S2 in the supplementary material)

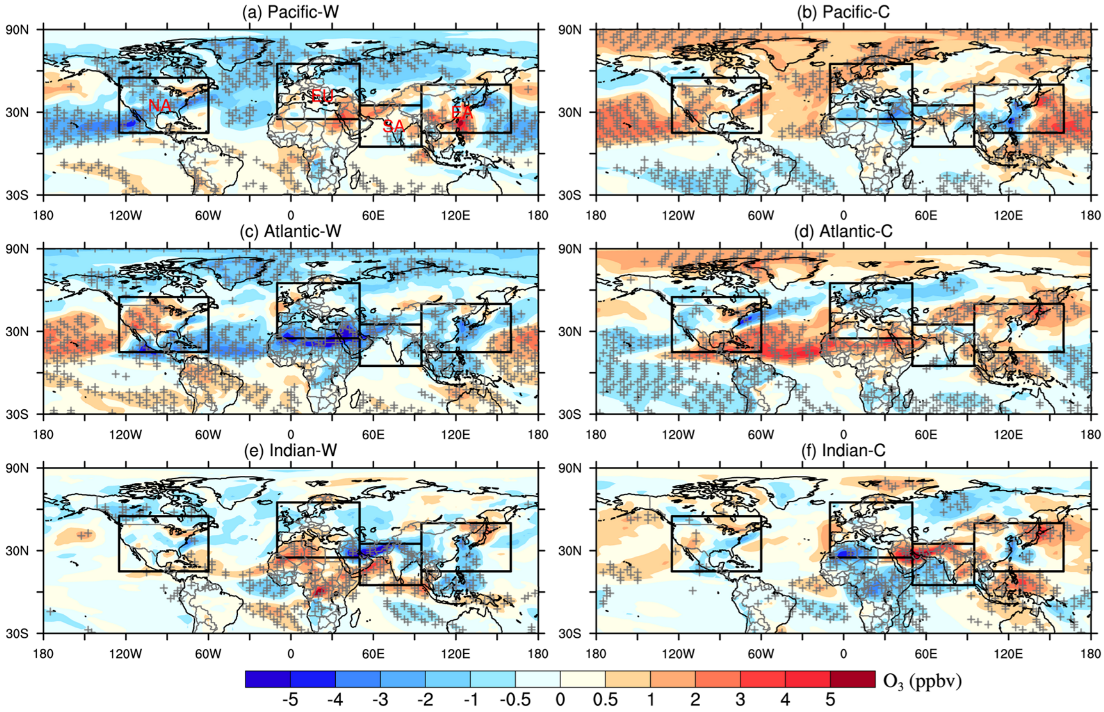

Figure S2. Changes in the summertime (June-August) surface ozone concentrations (ppbv) in the Northern Hemisphere induced by 1ºC warming (top) and 1 ºC cooling (bottom) in the North Pacific Ocean (left), North Atlantic Ocean (center), and North Indian Ocean (right) relative to CTRL. Four major regions of interest (i.e., NA (15°N–55 °N; 60°W–125°W), EU (25°N–65 °N; 10°W-50 °E), EA (15 °N–50 °N; 95°E–160 °E) and SA (5 °N–35 °N; 50 °E–95°E)) are marked with red polygons. The + symbols denote areas where results are significant at the 0.05 level as evaluated with a Student t-test using 20 years of data.

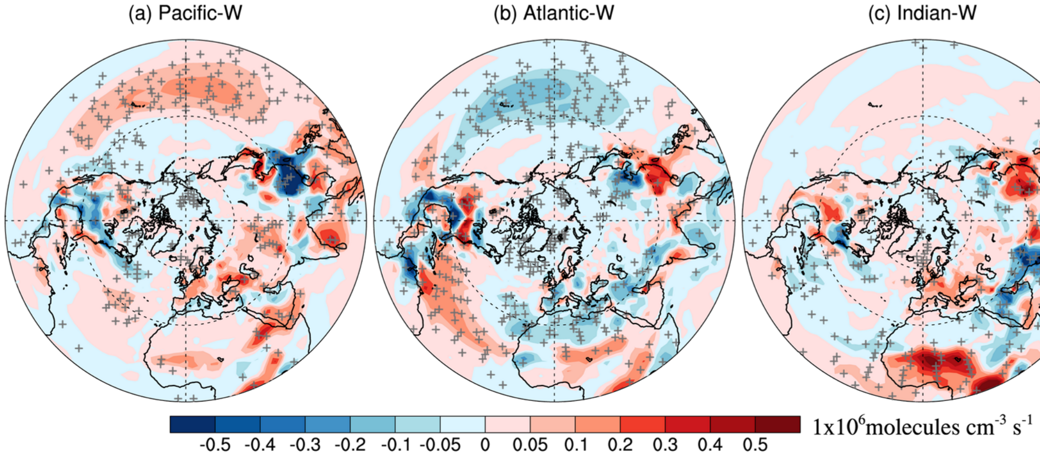

Figure 3. Perturbations of surface O_3 net-production rate (1×10^6 molecules cm^{-3} s^{-1}) for (a) Pacific-W, (b) Atlantic-W, and (c) Indian-W relative to CTRL in boreal summer. The + symbols denote areas where results are significant at the 0.05 level as evaluated

with a Student t-test using 20 years of data. (Plots using the Mercator projection are shown in Figure S14 in the supplementary material)

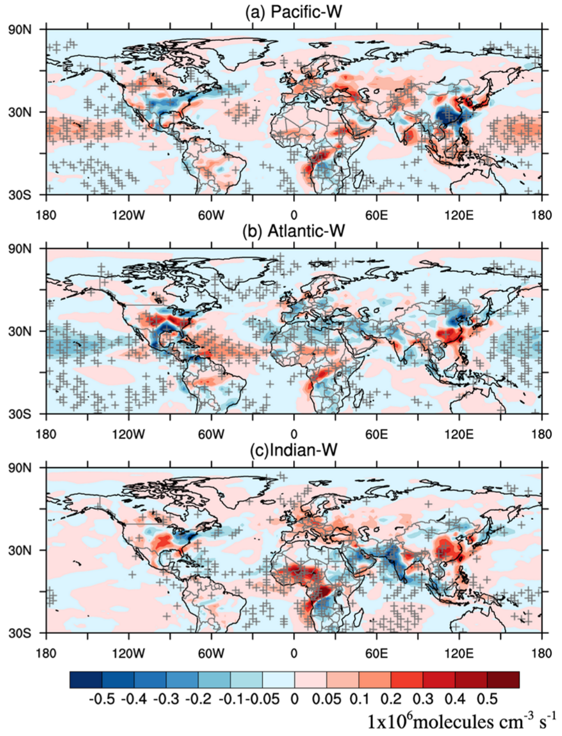

Figure S14. Perturbations of surface O_3 net-production rate ($1\text{x}10^6$ molecules cm^{-3} s^{-1}) for (a) Pacific-W, (b) Atlantic-W, and (c) Indian-W relative to CTRL in boreal summer. The + symbols denote areas where results are significant at the 0.05 level as evaluated with a Student t-test using 20 years of data.

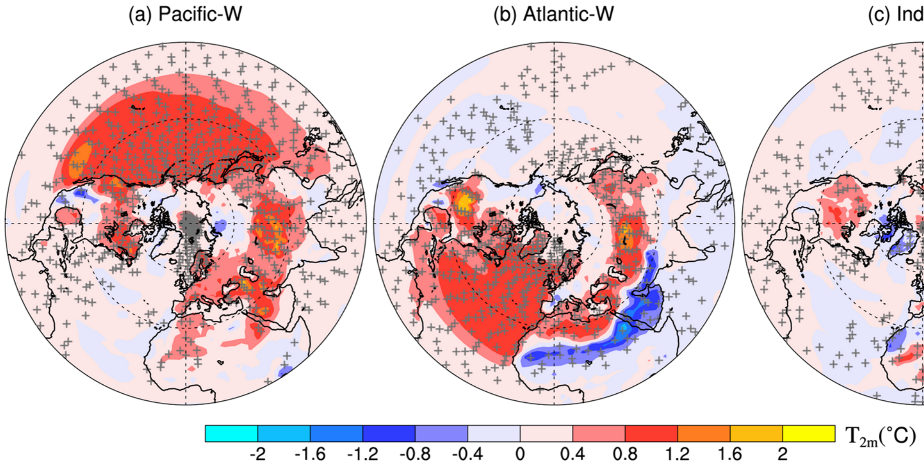

Figure 4. The difference in surface air temperature (℃) for (a) Pacific-W, (b) Atlantic-W, and (c) Indian-W relative to CTRL in the Northern Hemisphere in boreal summer. The + symbols denote areas where results are significant at the 0.05 level as evaluated

with a Student t-test. (Plots using the Mercator projection are shown in Figure S15 in the supplementary material)

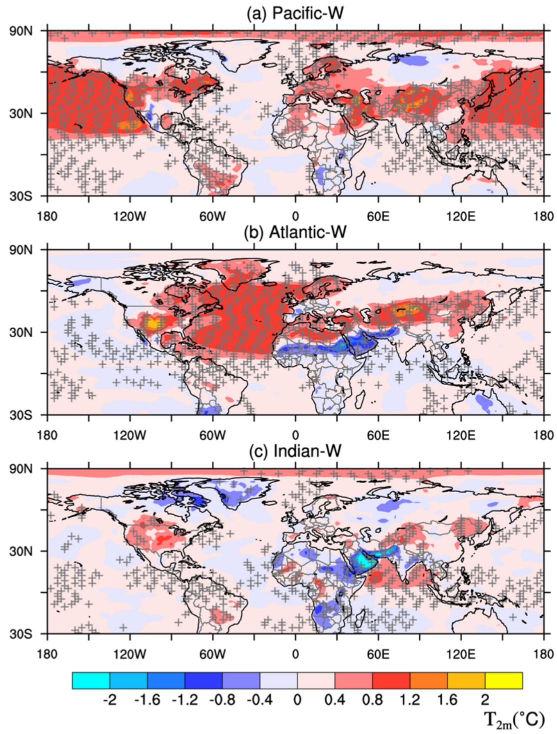

Figure S15. The difference in surface air temperature (ºC) for (a) Pacific-W, (b) Atlantic-W, and (c) Indian-W relative to CTRL in boreal summer. The + symbols denote areas where results are significant at the 0.05 level as evaluated with a Student t-test.

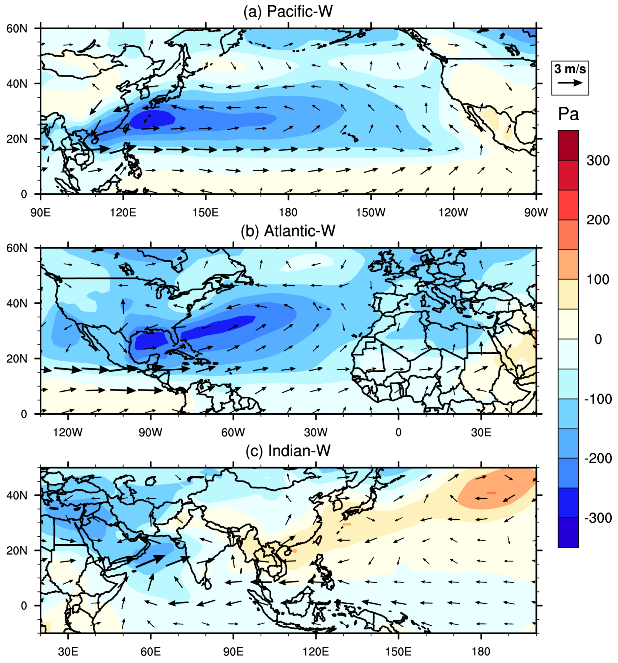

Figure 5. Changes in surface pressure (color contours, Pa) and 850 hPa wind (arrows,

m/s) for (a) Pacific-W, (b) Atlantic-W, and (c) Indian-W relative to CTRL in boreal summer.

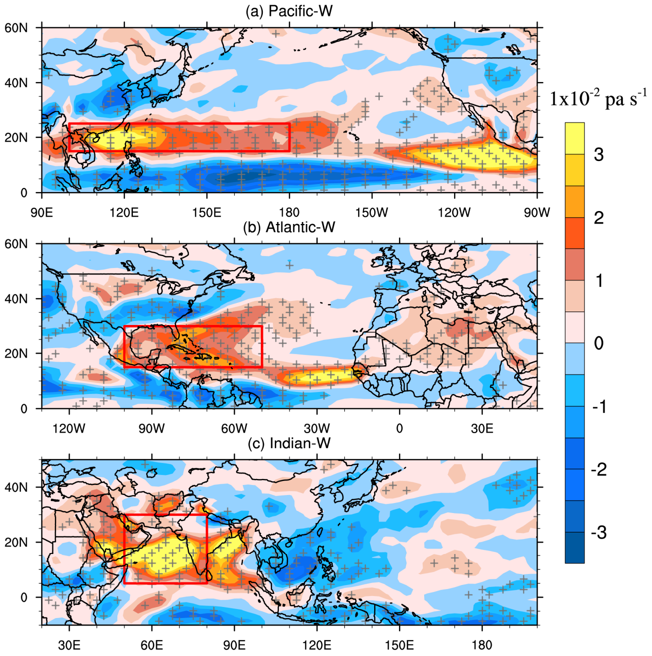

Figure 6. The spatial pattern of vertical velocity changes at 500 hPa (color contours, $1\mathrm{x}10^{-2}$ Pa s^{-1}) for (a) Pacific-W, (b) Atlantic-W, and (c) Indian-W relative to CTRL in boreal summer. Positive values indicate upward motion. Red polygons denote the regions where the surface pressure responses to SST anomalies are significant (see Figure 5 a-c). The + symbols indicate areas where results are significant at the 0.05 level as evaluated with a Student t-test using 20 years of data.

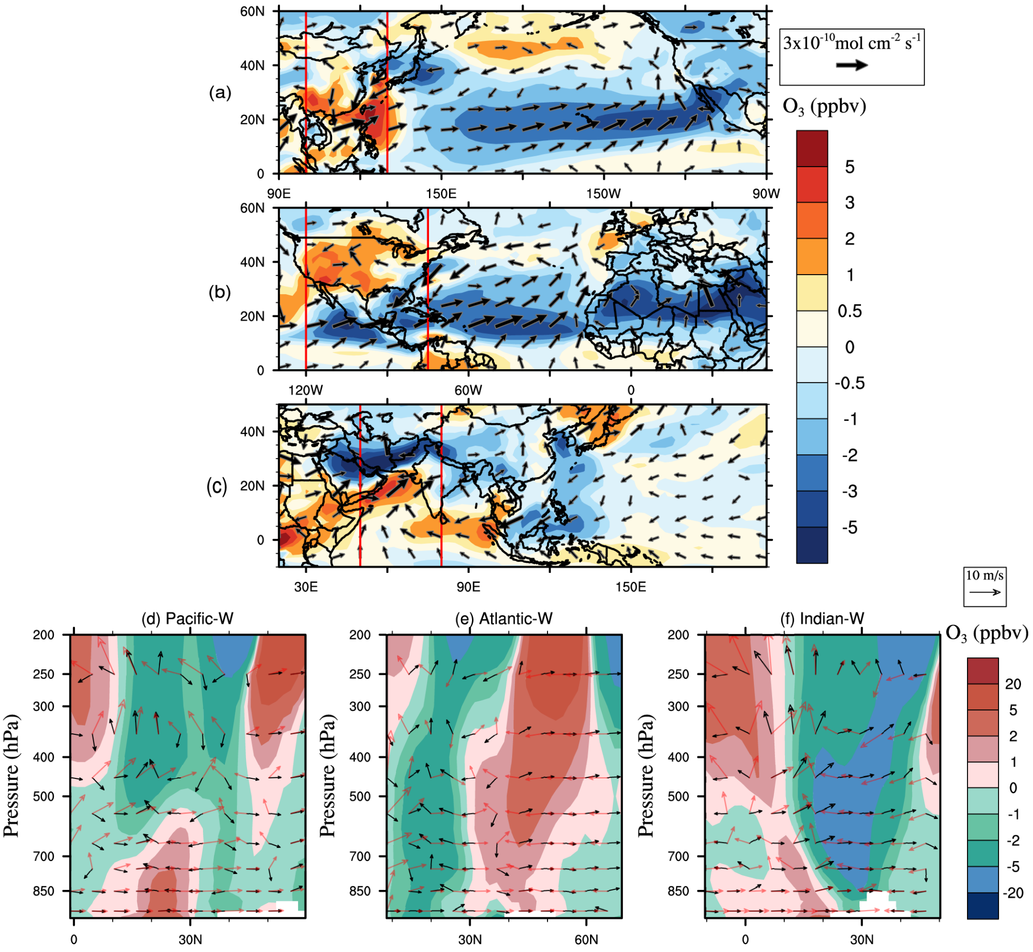

Figure 7. Top three rows: Changes in O_3 concentrations (color contours, ppbv) and horizontal fluxes (arrows, mol cm^{-2} s^{-1}) at surface level for (a) Pacific-W, (b) Atlantic-W, (c) Indian-W relative to CTRL in boreal summer. Last row: zonally averaged vertical and latitudinal distributions of tropospheric O_3 changes (color contours, ppbv) and wind pattern in CTRL (red arrows, m/s) and its perturbation (black arrows, m/s) in (d) Pacific-W, (e) Atlantic-W, (f) Indian-W relative to CTRL in boreal summer. The red rectangles in (a), (b) and (c) denote the longitudinal range used for zonal average in (d), (e) and (f), respectively. The vertical wind velocity is amplified 1000 times to be comparable with horizontal wind velocity.

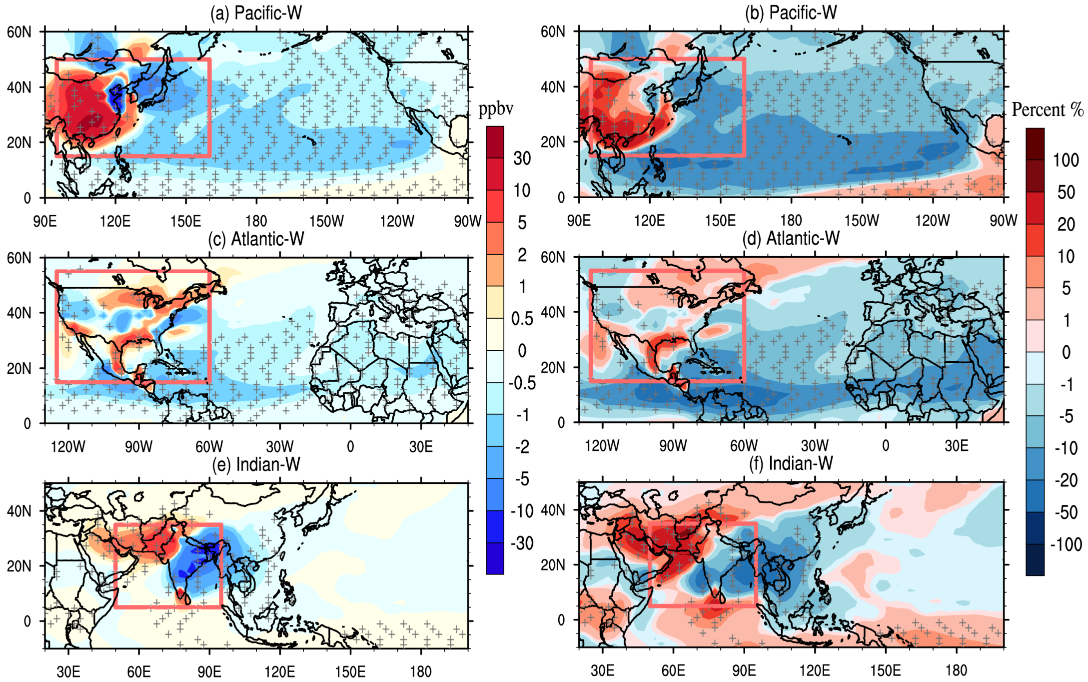

Figure 8. Left-hand panel: the difference in surface concentration (ppbv) of a CO-like tracer emitted from (a) East Asia for Pacific-W, (c) North America for Atlantic-W and (e) South Asia for Indian-W relative to CTRL in boreal summer. Right-hand panel: the percentage change in surface concentration of a CO-like tracer emitted from (b) East Asia for Pacific-W, (d) North America for Atlantic-W and (f) South Asia for Indian-W relative to CTRL in boreal summer. Red polygons denote the region where the CO-like tracer emitted from. The + symbol denotes areas where the results are significant at the 0.05 level evaluated with a Student t-test.

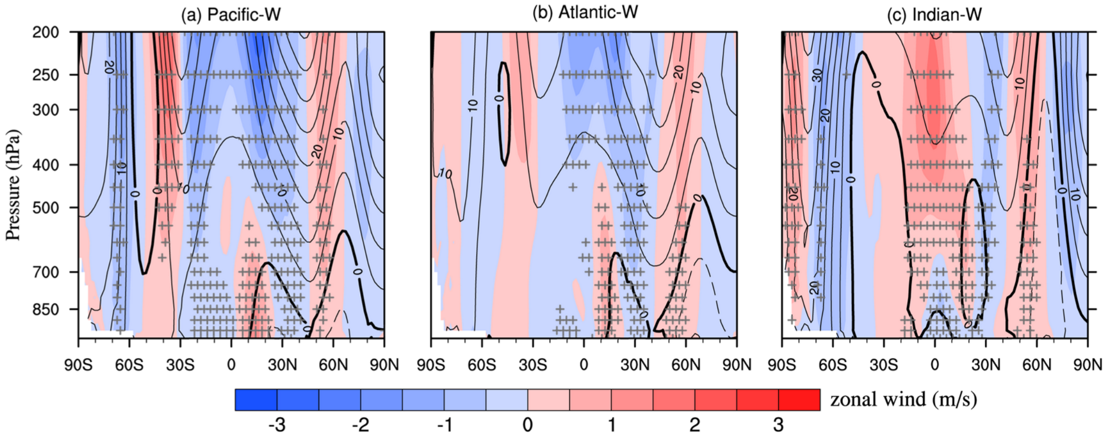

Figure 9. Zonally averaged changes in zonal wind (color contour, m/s) and geopotential height (contour, m) for (a) Pacific-W, (b) Atlantic-W and (c) Indian-W relative to CTRL in boreal summer. Black solid and dashed lines in the contours indicate positive and negative geopotential height anomalies, respectively (Contour interval: 5 m).The + symbol denotes areas where the zonal wind changes are significant at the 0.05 level

evaluated with a Student t-test.

3) In the introduction the authors do not cite several works done previously on the intercontinental transport of O3 and the meteorological factors affecting it, citing only 4 papers, which are not even the first to address these issues. Please make sure to include the references suggested in "specific comments" and possibly also extend the introduction/discussion.

Good suggestion! We have cited the references following the reviewer's suggestion and expanded our introduction and discussion accordingly. Please see the improved text below and refer to our response to specific comments for more details.

In the Introduction section, we have:

"…Long-range transport of O_3 *and its precursors have been extensively studied and their inter-continental impacts have been evaluated with measurements and model simulations (Parrish et al., 1993;Fehsenfeld et al., 1996;Wild and Akimoto, 2001;Creilson et al., 2003;Simmonds et al., 2004; Fiore et al., 2009; Brown-Steiner and Hess, 2011; Lin et al., 2014)."*

…

"Atmospheric circulation considerably determines the timescale and pathway of O_3 *transport (Auvray and Bey, 2005;Bronnimann et al., 2000;Hess and Mahowald, 2009). The efficiency of* O_3 *transport varies coherently with atmospheric circulations in different scales. Knowland et al. (2015) demonstrated the important role of mid-latitude storms in redistributing* O_3 *concentrations during springtime. The North Atlantic Oscillation (NAO) significantly affects surface and tropospheric* O_3 *concentrations over most of the Europe through influencing the intercontinental transport of air mass (Christoudias et al., 2012;Creilson et al., 2003;Pausata et al., 2012). Lamarque and Hess (2004) indicated that the Arctic Oscillation (AO) can modulate springtime tropospheric* O_3 *burdens over North America. The shift of jet stream position associated with climate change was found to strongly affect summertime surface* O_3 *variability over eastern North America (Barnes and Fiore, 2013)."*

General Minor comments:

- Why do the authors pick 11 years? Is 11 years enough to capture interannual O3 variability? The SSTs are fixed and in general 15-20 years should be enough to capture interannual atmospheric variability. I'm not sure about 11 though.

Good question. We originally preformed 11-year simulations referring to previous studies. For example, Doherty et al. (2013) conducted a 2000-year long unforced simulation to provide a comprehensive measure of model internal variability. They concluded that 5 years is long enough to capture the climate change signal with fixed SSTs. Given that the SST anomaly prescribed in our simulations (i.e., ±1ºC) is comparable to the climate change effects of a specific ocean, we originally thought that 11 years are enough to capture the relevant signal in our study (see Figure 1 and Figure R1 for example). However, following the reviewer's suggestion, we extended our simulations to 21 years with the first year used for model spin-up. It shows that the 20-year averaged results are generally consistent with the 11-year averaged results except for a few minor differences (e.g., see Figure 1 and Figure R1 below). In our revised manuscript, we redo our calculation and regenerate all plots based on the 20-year averaged results.

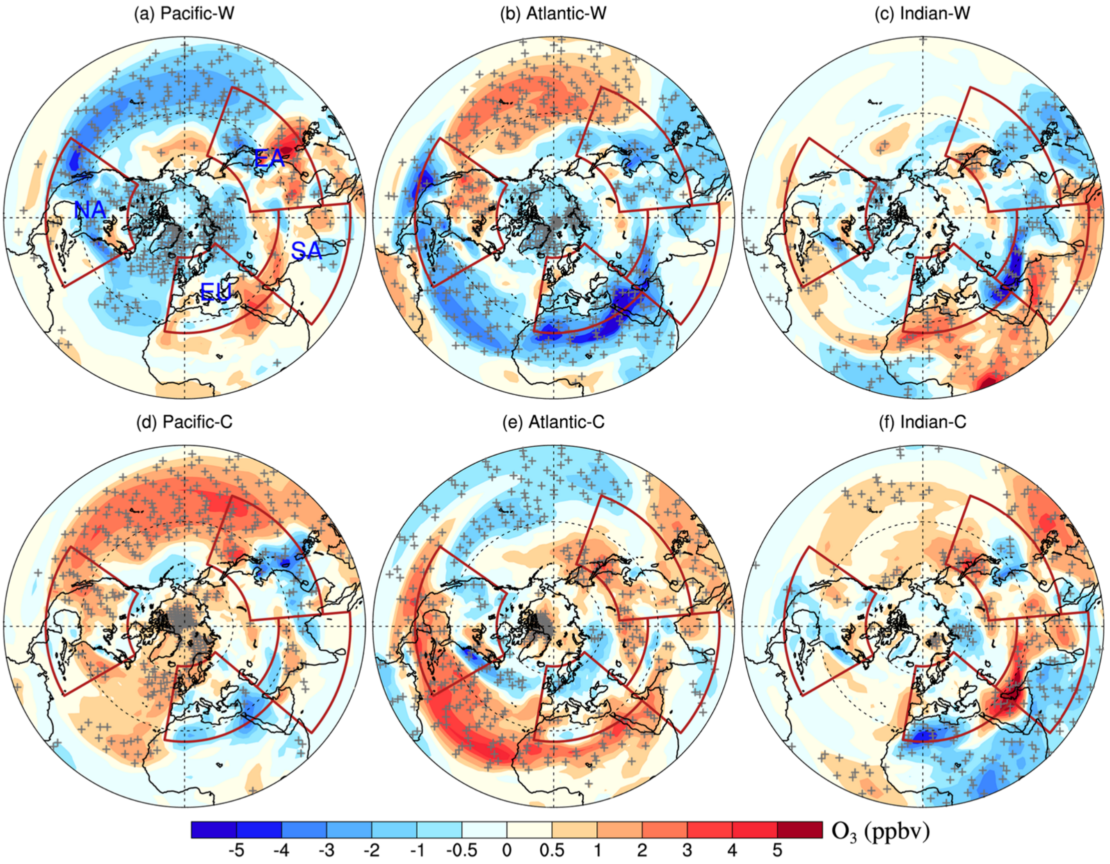

Figure 1. Changes in the summertime (June-August) surface ozone concentrations (ppbv) in the Northern Hemisphere induced by 1ºC warming (top) and 1 ºC cooling (bottom) in the North Pacific Ocean (left), North Atlantic Ocean (center), and North Indian Ocean (right) relative to CTRL. Four major regions of interest (i.e., NA (15°N–55 °N; 60°W–125°W), EU (25°N–65 °N;10°W-50 °E), EA (15 °N–50 °N; 95°E–160 °E) and SA (5 °N–35 °N; 50 °E–95°E)) are marked with red polygons. The + symbols denote areas where results are significant at the 0.05 level as evaluated with a Student

t-test using 20 years of data. (Plots using the Mercator projection are shown in Figure S2 in the supplementary material)

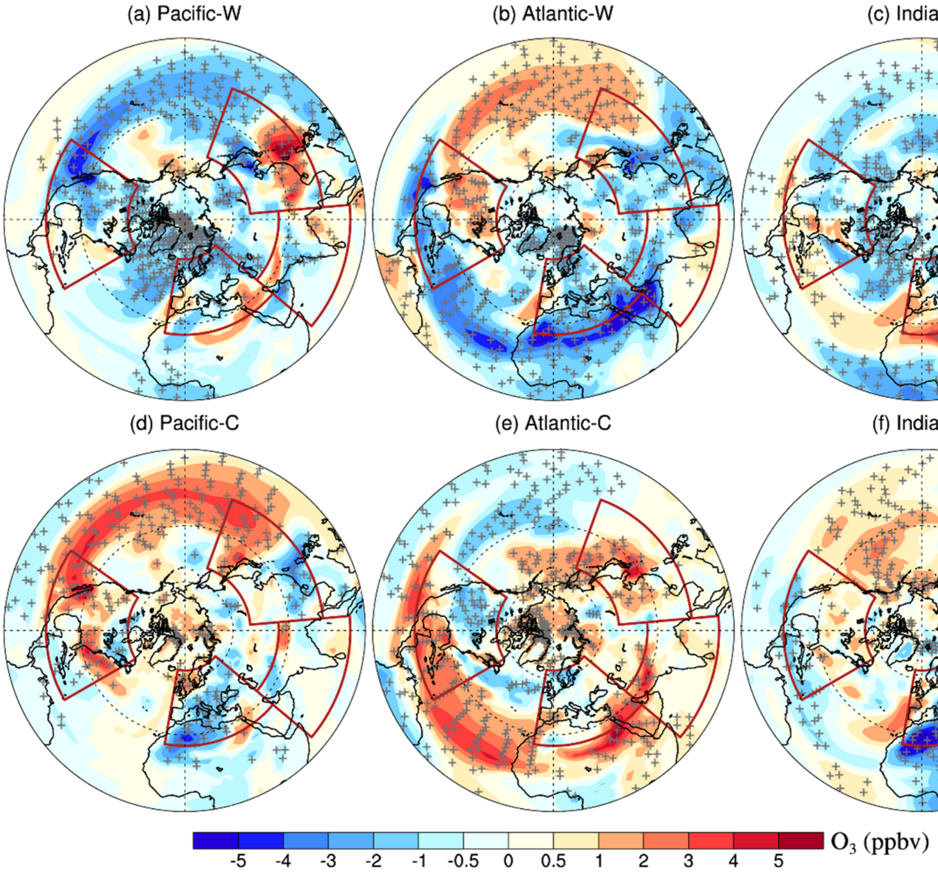

Figure R1. Same as Figure 1 but for 11-year simulations

- The authors use different significance levels throughout the manuscript (0.01 or 0.05). Please, pick one and use that for all the analysis.

Good suggestion. We pick the significant level of 0.05 to be consistent in our revised manuscript.

- I suggest not overusing sentences in which part of the text is in parenthesis in order to avoid writing another sentence (e.g.: LL24-25 Increasing 25 (**decreasing**) SST by 1 ºC in one of the regions of focus induces decreases (**increases**)). It makes it hard to follow. I think adding another sentence makes it much more easy to read (especially in the main text where there is no word limits).

We follow reviewer's suggestion and revised the relevant texts to avoid the overuse of parenthesis.

In the Abstract:

"…The responses of surface O_3 associated with basin-scale SST warming and cooling have similar magnitude but are opposite in sign. Increasing SST by 1 ºC in one of the oceans generally decreases surface O_3 concentrations, ranging from 1 to 5 ppbv. "

In the second paragraph of Section 3:

"Surface O_3 changes in response to positive and negative SST anomalies generally pronounce a consistent spatial pattern but are opposite in sign, suggesting robust relationships between surface O_3 levels and SST anomalies (Figure 1). Generally, an increase in summertime SST over a specific ocean basin tends to increase surface O_3 concentrations over the upwind regions but reduce it over downwind continents. For instance, an 1ºC warming over the North Pacific leads to a widespread decrease of surface O_3 over North Pacific, North America and North Atlantic by approximately 1 ppbv (Table S1), but may enhance the surface O_3 by nearly 3 ppbv over South China. Similarly, in the "Atlantic-W" case, the surface O_3 levels decrease by 1~2 ppbv over North Atlantic and Europe, but increase (~1 ppbv) over North America and North Pacific. For the North Indian Ocean, positive SST anomalies tend to increase the surface O_3 over the Indian Ocean and Africa, but decrease the surface O_3 over South and East Asia (Table 1). During boreal winter, a widespread decrease of surface O_3 is observed associated with the warming of different oceanic area. Significant changes (e.g., up to 5 ppbv) mainly occur over remote oceans. Over the populated continents, the response of surface O_3 to basin-scale SST changes is typically insignificant. Details are shown in Figure S3 in the supplementary material."

- It is not necessary to include the figure captions in the text. Sentences like "Figure 2 shows …" belong to figure captions not the main text, and make it hard to follow. Please, discuss directly the results and point to the figure that shows them in the running text, e.g. *Larger anomalies (i.e., up to 5ppbv) are simulated in locations including the east coast of China, the Indian subcontinent, and remote oceans (Figure 1 and Figure S2).*

We have changed the text accordingly in our revised manuscript.

For example:

"…In this study, the SST induced process-level O_3 changes are spatially averaged over four populated continental regions (i.e., NA, EU, EA and SA, Figure 2) and three ocean

basins (i.e., the North Pacific, North Atlantic and North Indian Oceans, Figure S9).”

Specific comments:

LL59-61 Beside the missing reference pointed out in the short comment by Dr. Meiyun Lin there are several other key references missing that are related to the O3 long-range transport: Parrish et al., 1993; Fehsenfeld et al., 1996; Wild and Akimoto, 2001; Creilson et al., 2003; Simmonds et al., 2004.

Good suggestion. We have added these important references related to the O_3 long-range transport in our revised manuscript:

“…Long-range transport of O_3 and its precursors have been extensively studied and their inter-continental impacts have been evaluated with measurements and model simulations (Parrish et al., 1993;Fehsenfeld et al., 1996;Wild and Akimoto, 2001;Creilson et al., 2003;Simmonds et al., 2004; Fiore et al., 2009;Brown-Steiner and Hess, 2011;Lin et al., 2014).”

LL66 Here as well, the authors do not cite several studies on the topic (e.g., Bronnimann et al. 2000; Hess and Mahowald, 2009; Pausata et al. 2012).

We have cited these valuable studies and expanded our introduction:

“…Atmospheric circulation considerably determines the timescale and pathway of O_3 transport (Auvray and Bey, 2005;Bronnimann et al., 2000;Hess and Mahowald, 2009). The efficiency of O_3 transport varies coherently with atmospheric circulations in different scales. Knowland et al. (2015) have demonstrated the important role of mid-latitude storms in redistributing O_3 concentrations during springtime. The North Atlantic Oscillation (NAO) significantly affects surface and tropospheric O_3 concentrations over most of the Europe through influencing the intercontinental transport of air mass (Christoudias et al., 2012;Creilson et al., 2003;Pausata et al., 2012). Lamarque and Hess (2004) indicated that the Arctic Oscillation (AO) can modulate springtime tropospheric O_3 burdens over North America. The shift of jet stream position associated with climate change are found to strongly affect summertime surface O_3 variability over eastern North America (Barnes and Fiore, 2013).”

L104 remove spaces before and after comma.

We removed these spaces.

"The mechanisms responsible for the SST variability includes ocean circulation variability, wind stress, and ocean-atmosphere feedbacks (Deser et al., 2010;Frankignoul, 1985)."

L113 remove the hyphen after impacts.

We removed this mistake in our revised manuscript:

"Except for the ENSO impacts, very few studies to date have been conducted to directly address the linkage between SST-O_3 *interactions."*

L114 ENSO is an oscillation; hence "ENSO spring" does not mean anything. Please specify the ENSO phase the authors are referring to.

We changed "ENSO spring" to "strong La Niña spring" for clear clarification:

"Lin et al. (2015) find that more frequent deep stratospheric intrusions appear over the western US during strong La Niña springs owning to the meandering of polar jet towards it. This process can increase western US surface O_3 *levels remarkably."*

LL114-115 indulge a bit more and provide the explanation of how ENSO affects stratospheric intrusions in western US. Otherwise the reader is forced to look it up.

Good suggestion. We revised this sentence in the introduction section to briefly explain the impacts of ENSO on stratospheric intrusions in western US:

"Lin et al. (2015) find that more frequent deep stratospheric intrusions appear over the western US during strong La Niña springs owning to the meandering of polar jet towards it. This process can increase western US surface O_3 *levels remarkably."*

L194 mention also here at least some of the individual processes accounted for.

We revised this sentence in Section 2.3 to give some examples of the individual processes:

"This technique calculates the accumulated contributions of individual processes (e.g., chemical production and loss, advection, vertical diffusion, dry deposition, etc.) to ozone predictions during the model simulation, which has been widely used for air pollution diagnostics (Li et al., 2012;Tao et al., 2015;Zhang and Wu, 2013)."

LL233-234 the sentence is unclear.

Here we means the responses of surface O_3 to SST changes in different cases behave differently in terms of spatial distribution. Different oceans warming can impact the surface O_3 at specific regions. In our revised manuscript, we changed this sentence in Section 3 for clarification:

"*Our simulations reveal that different oceans can exert distinct region-specific effects on O_3 distributions.*"

LL253-254 It's not clear to me how the authors can conclude that the change in CHEM is "therefore" causing the increase in ozone at the surface over NA due to warmer Atlantic SSTs. See also comment on figure 2.

Good question. The integrated process rate (IPR) method can decompose the contribution of different physical and chemical processes to O_3 evolution. Typically a positive change in IPR is responsible for the increase of surface O_3 due to the change of SST, which is sometimes balanced by certain negative IPR changes. For instance, the increase in VDIF is always accompanied with a commensurate decrease in DRYD, resulting in an insignificant net change in TURB (here TURB=VDIF+DRYD). We redraw these plots and merge VDIF and DRYD into TURB and DEEP and SHAL into CONV (see Figure 2). Now it shows that the increase of CHEM tends to play the dominate role in enhancing the surface O_3 concentrations over North America.

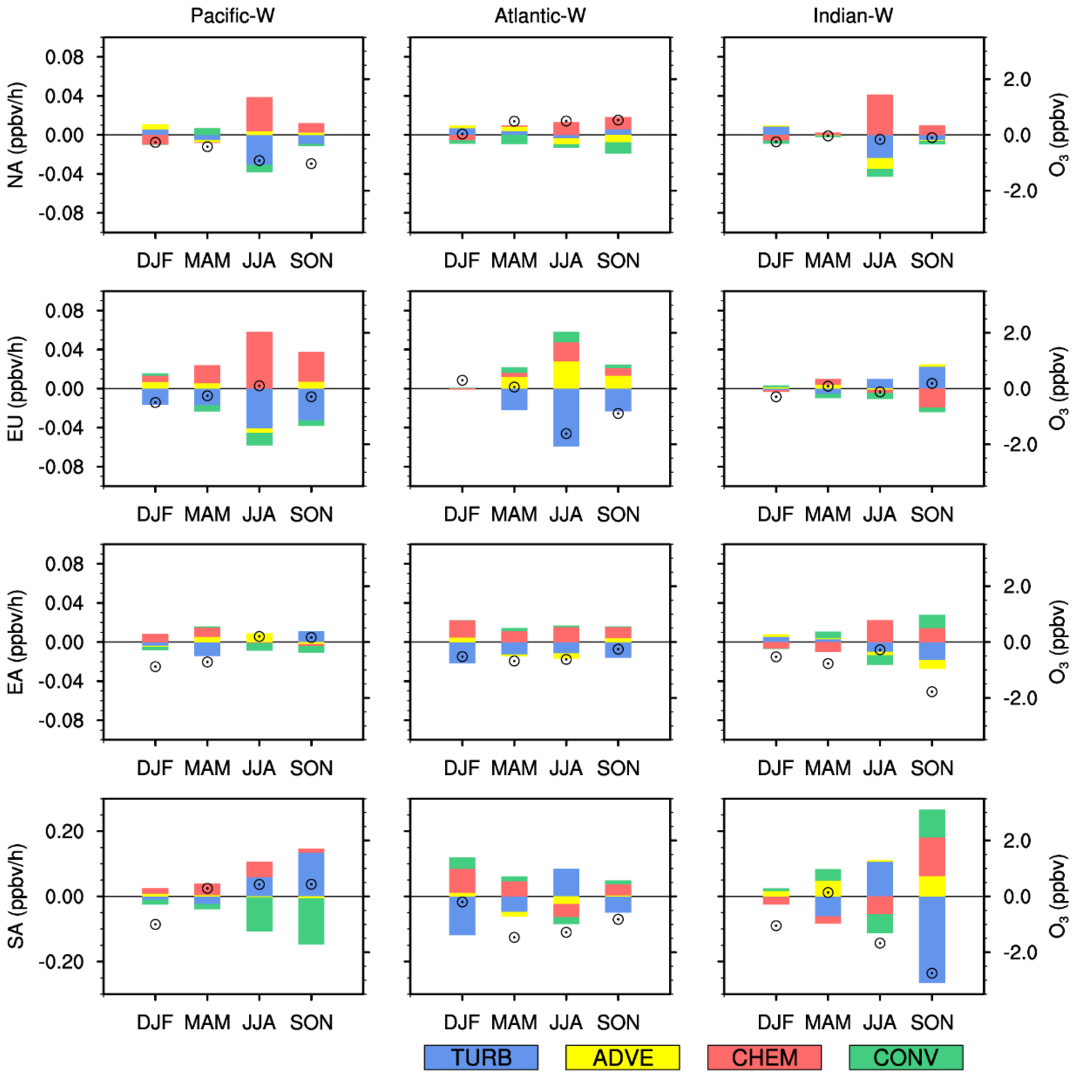

Figure 2. Seasonally averaged changes in IPR contributions (bars, ppbv/h, left scale) and surface O_3 concentrations (hollow circles, ppbv, right scale) for Pacific-W (left), Atlantic-W (middle) and Indian-W (right) relative to CTRL. Values are regionally averaged over NA (first row), EU (second row), EA (third row) and SA (last row), respectively. TURB is defined as the sum of VDIF and DRYD. CONV is the sum of DEEP and SHAL. IPR contributions from four processes (i.e., TURB, ADVE, CHEM and CONV) are represented by different colors. A more detailed IPR result is shown in Figure S10 in the supplementary material.

To clarify our analysis, we added more descriptions on the IPR analysis in both Section 2.3 and Section 4.1 in the revised manuscript:

In Section 2.3:

"In this study, we added the IPR scheme to the CESM modeling framework to track the contribution of 6 physicochemical processes (i.e., gas-phase chemistry (CHEM), advection (ADVE), vertical diffusion (VDIF), dry deposition (DRYD), shallow convection (SHAL) and deep convection (DEEP)) to O_3 *concentrations in every grid box. Wet deposition and aqueous-phase chemistry are ignored here due to the low solubility and negligible chemical production of* O_3 *in water (Jacob, 1999). Therefore, CHEM represents the net production (production minus loss) rate of* O_3 *due to gas-phase photochemistry. DRYD represents the dry deposition fluxes of* O_3*, which is an important sink for* O_3*. The other IPR terms (i.e., ADVE, VDIF, SHAL and DEEP) represent contributions from different transport processes. The IPR scheme tracks and archives the* O_3 *flux in each grid from every processes during each model time-step. The sum of* O_3 *fluxes from these six processes matches well the change of* O_3 *concentration. The performance of IPR is verified through comparing the predicted hourly* O_3 *changes with the sum of individual fluxes from the 6 processes. As shown in Figure S1, the hourly surface* O_3 *changes are well represented by the sum of these fluxes in the model."*

In Section 4.1, we have:

"The IPR analysis is used to evaluate the contribution of different physicochemical processes to O_3 *evolution. It has been widely used in air quality studies to examine the cause of pollution episode (Li et al., 2012;Wang et al., 2010). When applied in climate sensitivity relevant analysis (usually measuring the difference between two equilibrium states), the net change of all IPRs approaches zero. Typically, the positive changes in IPRs are mainly responsible for the increase of surface* O_3*, which may further induce* O_3 *removal to balance these factors in an equilibrium state. Therefore, here the IPR analysis is not used to budget the SST induced* O_3 *concentration changes, instead it helps to examine the relative importance of different transport and chemical processes in driving the sensitivity of* O_3 *to a SST forcing. In this study, the SST induced process-level* O_3 *changes are spatially averaged over four populated continental regions (i.e., NA, EU, EA and SA, Figure 2) and three ocean basins (i.e., the North Pacific, North Atlantic and North Indian Oceans, Figure S9). In most cases, vertical diffusion (VDIF) and dry deposition (DRYD) are the key processes controlling the* O_3 *variation. The downward transport of* O_3 *through diffusion is an important source for surface* O_3 *while*

dry deposition act as a sink. Both processes are closely dependent on turbulent motions. The efficiencies of O_3 *transport by vertical diffusion and its corresponding dry deposition are simultaneously determined by the strength of turbulence. Here we define a new term TURB as the sum of DRYD and VDIF, which can capture the overall effect of turbulence changes on surface* O_3 *concentrations. In addition, we merge SHAL and DEEP as CONV to represent the total contribution of convective transport to surface* O_3 *(Figure 2 and Figure S9). More detailed IPR results are shown in Figure S10 and S11 in the supplementary material."*

L264 "inconsistent surface O3 response": do the authors mean "opposite surface O3 response"?

We replaced "inconsistent" with "opposite":

"These opposite changes over upwind and downwind regions lead to distinct surface O_3 *responses."*

L270 I understand the authors' point on investigating only summer since it's the seasons with higher O3 concentration at the surface. However, during winter and spring the ozone at the surface is mainly affect by changes in long-range transport and stratosphere-troposphere exchange. Hence, it is important to understand how the warming in the SST in different basins can affect long range and stratosphere-troposphere exchange. I would suggest expanding the analysis to also winter.

Thanks for this helpful suggestion. In this study, we had investigated both the SST-O_3 relationship in both summer and winter seasons (see Figure 1 and Figure S3). It shows that in boreal winter, the warming of different oceans generally induces a widespread decrease of surface O_3. However, significant changes (up to 5 ppbv) mainly happen over remote oceanic regions. Over land, the O_3 response to SST changes is generally insignificant (see Figure S3). Besides surface O_3, the responses of meteorological fields to SST changes are also significant only over remote oceans (see Figure R3). Similar to the summer case, physical transport is the key process modulating surface O_3 during winters. As shown in Figure R2 and R3, these vertical and horizontal wind field changes are more robust over oceans than the polluted continents. Since the main focus of this study is to examine how O_3 air pollution in a populated continent is affected by regional SST changes, we therefore pay most attention to boreal summers than other seasons.

In the revised manuscript, we follow the reviewer's suggestions and add a brief discussion in Section 3 for wintertime response:

"…During boreal winter, a widespread decrease of surface O_3 *is observed associated with the warming of different oceans. Significant changes (e.g., up to 5 ppbv) mainly occur over remote oceanic areas. Over the polluted continents, the response of surface* O_3 *to basin-scale SST changes is typically insignificant. Details are shown in Figure S3 in the supplementary material."*

We further clarified why we only focus on summertime in Section 4.1:

"In the following subsections, the mechanisms of the SST-O_3 *relationship for the four polluted continents are further explored. Here we focus on boreal summers since the surface* O_3 *response to SST changes is more robust during this period than other seasons."*

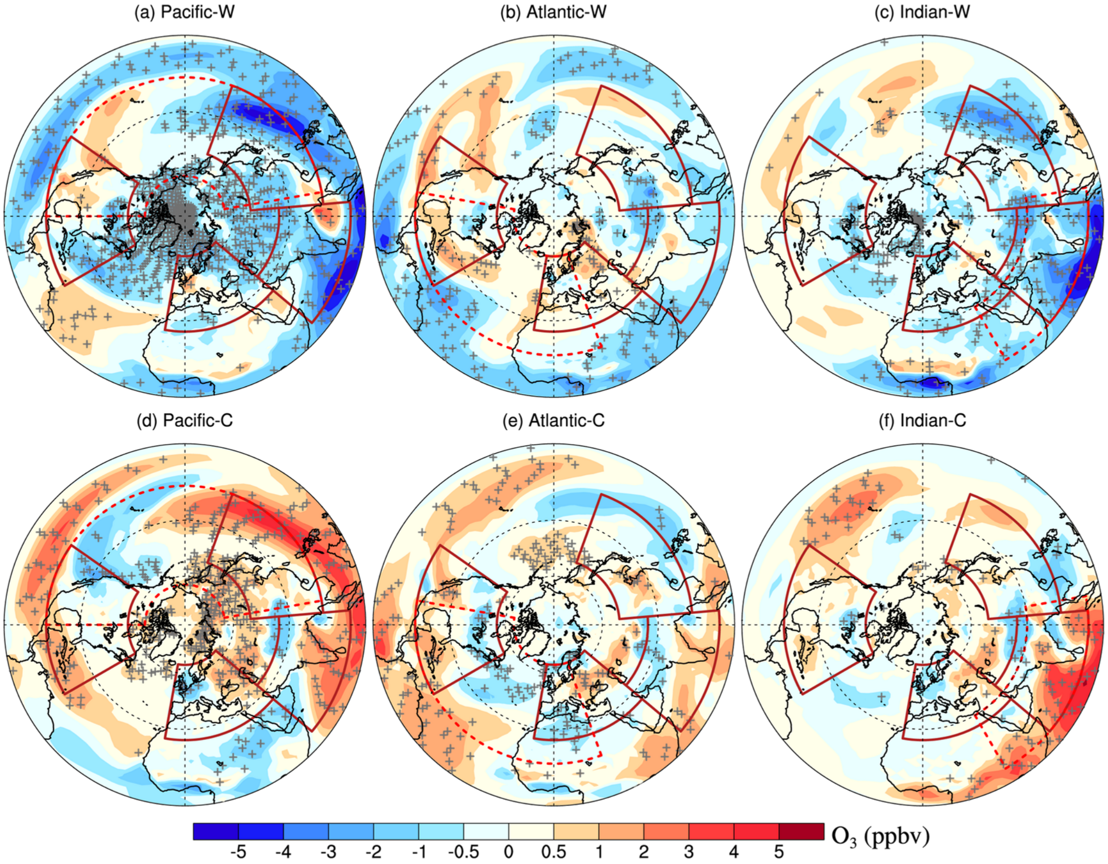

Figure S3. Changes in the wintertime (December-February) surface ozone concentrations (ppbv) in the Northern Hemisphere for (a) Pacific-W, (b) Atlantic-W, (c) Indian-W, (d) Pacific-C, (e) Atlantic-C and (f) Indian-C relative to CTRL. Four major regions of interest (i.e., NA (15°N–55 °N; 60°W–125°W), EU (25°N–65 °N;10°W-

50 °E), EA (15 °N–50 °N; 95°E–160 °E) and SA (5 °N–35 °N; 50 °E–95°E)) are marked with red solid polygons. Red dashed lines mark the regions where the SST has been changed. The + symbols denote areas where results are significant at the 0.05 level as evaluated with a Student t-test using 20 years of data.

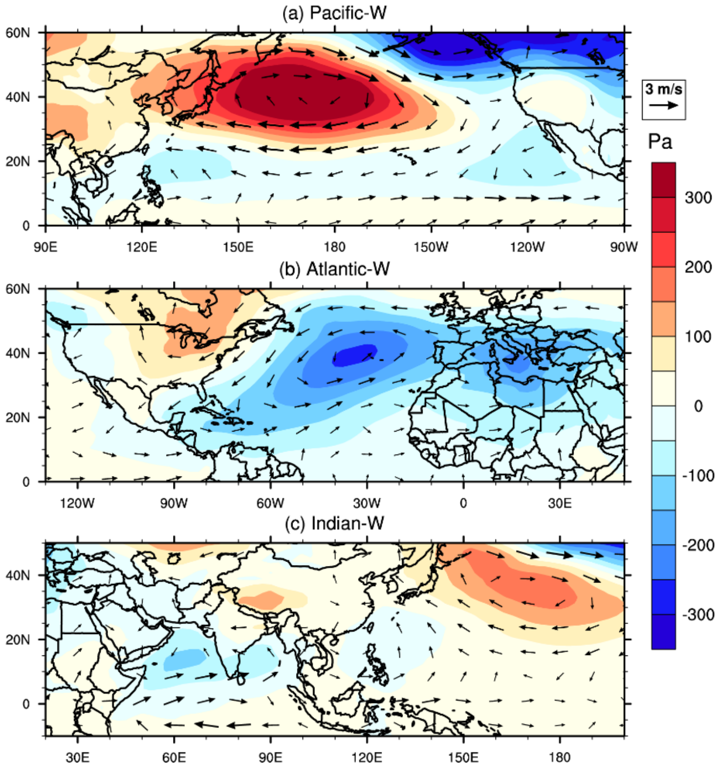

Figure R2. Changes in surface pressure (color contours, Pa) and 850 hPa wind fields (arrows, m·s^{-1}) for (a) Pacific-W, (b) Atlantic-W, and (c) Indian-W relative to CTRL during boreal winters.

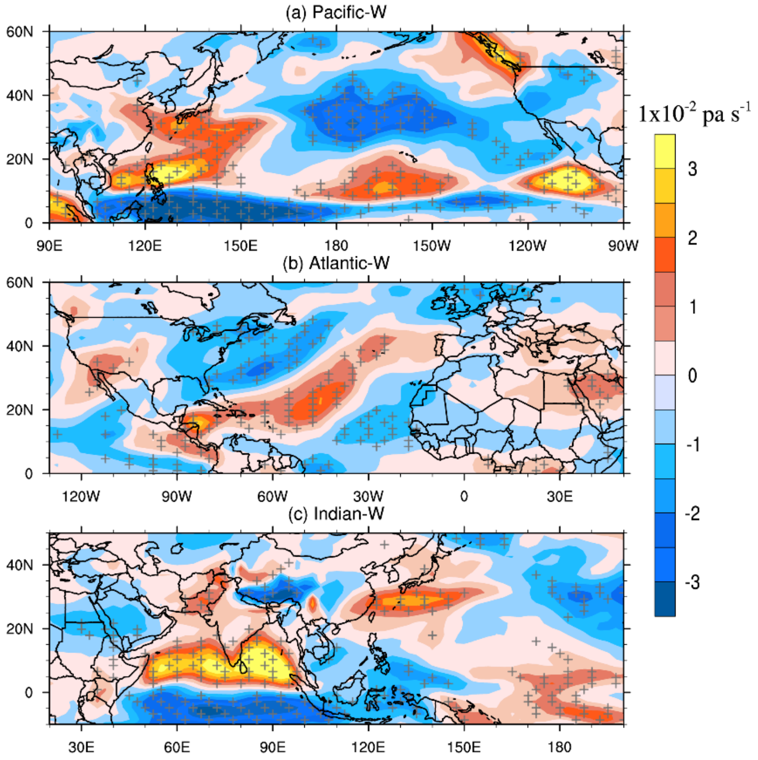

Figure R3. The spatial distribution of vertical velocity changes at 500 hPa (color contours, $1x10^{-2}$ Pa s^{-1}) for (a) Pacific-W, (b) Atlantic-W, and (c) Indian-W relative to CTRL in boreal winters. Positive values indicate upward motion. The + symbols indicate areas where results are significant at the 0.05 confidence interval as evaluated with a Student t-test using 20 years of data.

L291 "is believed": Beliefs do not belong to science. Please rephrase it and provide references to support the *belief*.

The effect of the North Indian Ocean warming on cloud formation has been well-documented in precious studies (Chaudhari et al., 2016;Roxy et al., 2015;Xi et al., 2015). We have rephrased this sentence as below (or see the revised text in Section 4.2):

"…Previous studies indicated that moist convection is more sensitive to the SST changes in the tropical oceans rather than mid- or high- latitude oceans (Lau and Nath, 1994;Lau et al., 1997;Hartmann, 2015). The SST increase over the North Indian Ocean tends to strengthen moist convection that eventually facilitates cloud formation in the upper troposphere (Chaudhari et al., 2016;Roxy et al., 2015;Xi et al., 2015)…"

LL356-357 The authors stated that the O3 changes at the surface over North America (Fig. 7 "b", which is actually c) are negligible. However, they look quite large (regionally) to me: over the Great Lakes, California and Baja California peninsula; also along the east coast of Unites States the changes are not that small. Furthermore, the changes aloft (that the authors define “large”) are of the same order of magnitude that the changes seen at the surface.

Good question. We agree that the surface O_3 changes over NA (~1-2 ppbv) are large and significant for regional air quality management. In the revised manuscript, we have revised this description in Section 4.3:

“…O_3 changes are observed to be larger in the upper troposphere than at the surface (Figure 7e)…”

We also reordered the plots in Figure 7:

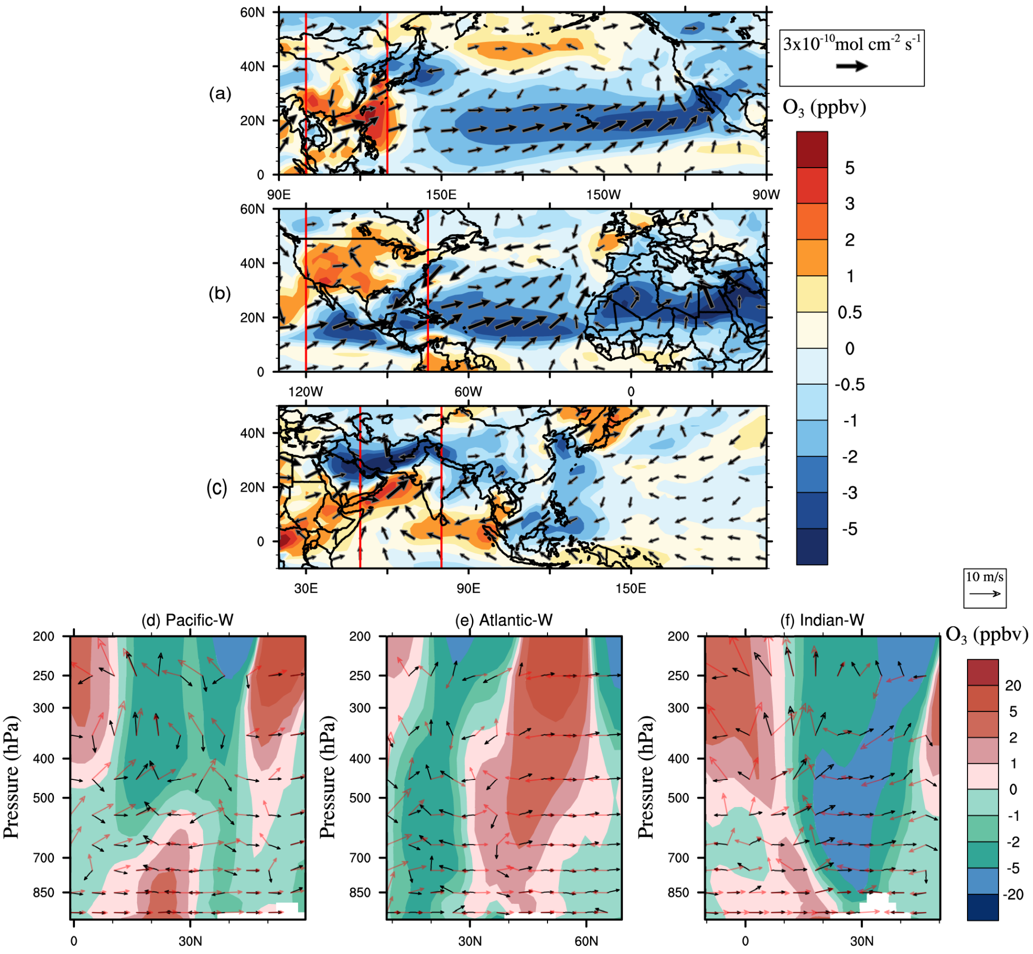

Figure 7. Top three rows: Changes in O_3 concentrations (color contours, ppbv) and horizontal fluxes (arrows, mol cm^{-2} s^{-1}) at the surface level for (a) Pacific-W, (b) Atlantic-W, (c) Indian-W relative to CTRL in boreal summer. Last row: zonally average of tropospheric O_3 changes (color contours, ppbv) and wind fluxes in CTRL (red arrows, m/s) and its perturbation (black arrows, m/s) in (d) Pacific-W, (e) Atlantic-W, (f) Indian-W relative to CTRL in boreal summer. The red rectangles in (a), (b) and (c) denote the

longitudinal range used for zonal average in (d), (e) and (f), respectively. The vertical wind velocity is amplified 1000 times to make it comparable to horizontal wind velocity.

L357-359 Given the above-mentioned comments, I am not sure how the authors could state that the changes seen in figure 7c are mostly due to enhanced photochemical production. This comment is also related to my previous comments on LL253-254.

Good question. Following our detailed response to the previous comments on L253-254, the IPR analysis helps to identify the key processes associated to the SST induced O_3 evolution. For example, the warming of the North Atlantic Ocean leads to 1~2 ppbv increase in surface O_3 over North America. Ignoring VDIF and DRYD (they tend to offset each other in most cases, resulting in an insignificant net change in TURB, see Figure 2). Therefore, the change of CHEM is the dominant factor leading to the surface O_3 increase over North America. Please refer to our response to previous comments on L253-254 for more detail. Figure 7, on the other hand, further indicates that changes in the horizontal fluxes of O_3 over North America show no significant effect on the corresponding increase of surface O3 levels.

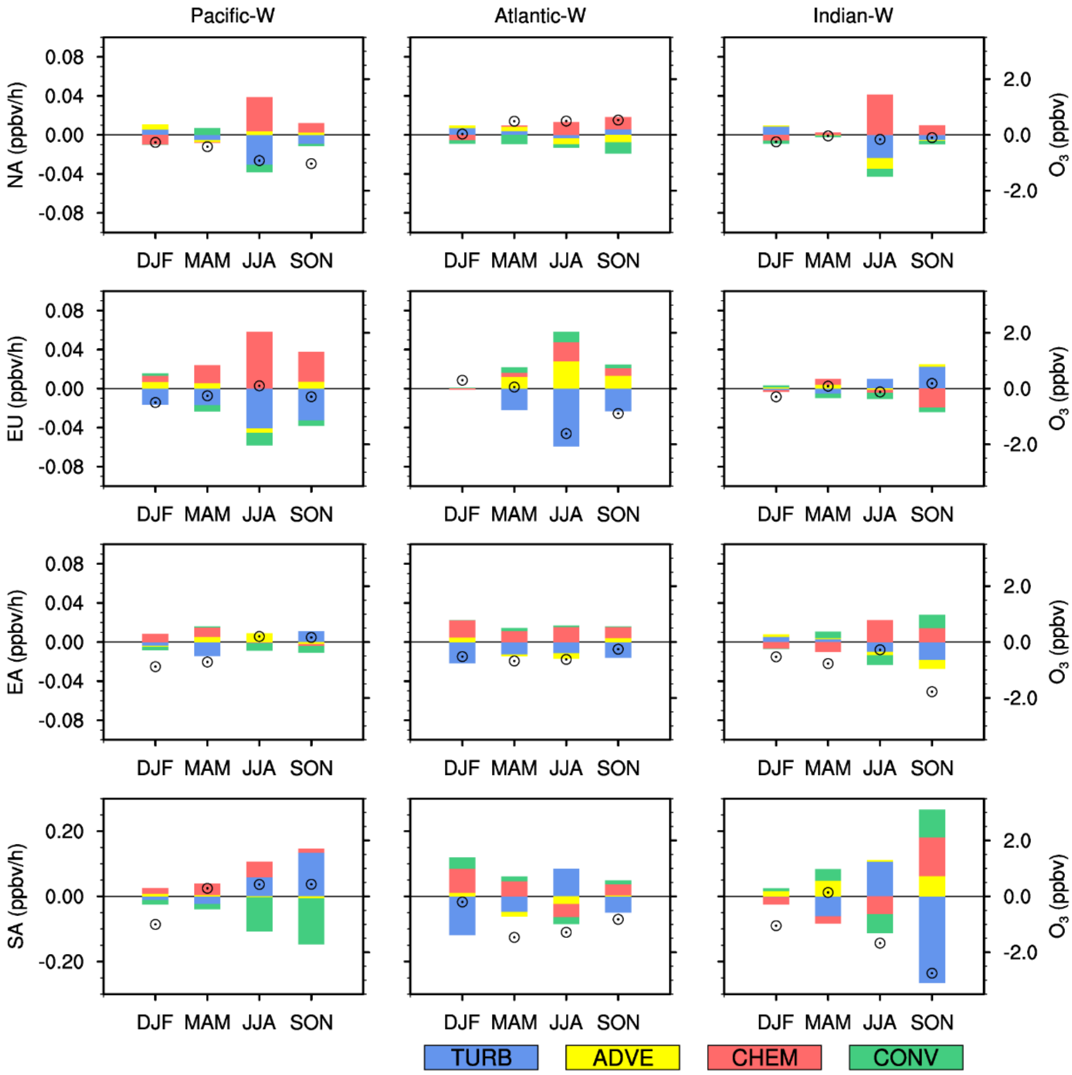

Figure 2. Seasonally averaged changes in IPR contributions (bars, ppbv/h, left scale) and surface O_3 concentrations (hollow circles, ppbv, right scale) for Pacific-W (left), Atlantic-W (middle) and Indian-W (right) relative to CTRL. Values are regionally averaged over NA (first row), EU (second row), EA (third row) and SA (last row), respectively. TURB is defined as the sum of VDIF and DRYD. CONV is the sum of DEEP and SHAL. IPR contributions from four processes (i.e., TURB, ADVE, CHEM and CONV) are represented by different colors. A more detailed IPR result is shown in Figure S10 in the supplementary material.

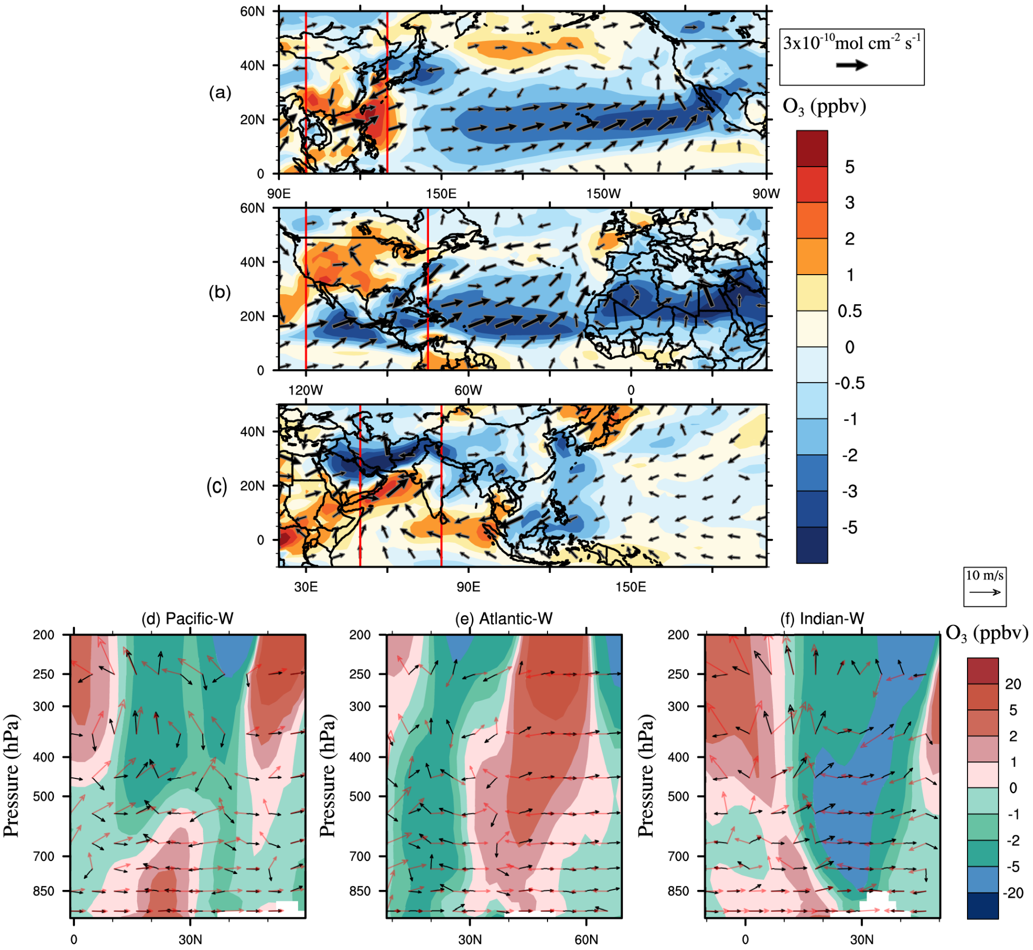

Figure 7. Top three rows: Changes in O_3 concentrations (color contours, ppbv) and horizontal fluxes (arrows, $\mathrm{mol\ cm^{-2}\ s^{-1}}$) at the surface level for (a) Pacific-W, (b) Atlantic-W, (c) Indian-W relative to CTRL in boreal summer. Last row: zonally average of tropospheric O_3 changes (color contours, ppbv) and wind fluxes in CTRL (red arrows, m/s) and its perturbation (black arrows, m/s) in (d) Pacific-W, (e) Atlantic-W, (f) Indian-W relative to CTRL in boreal summer. The red rectangles in (a), (b) and (c) denote the longitudinal range used for zonal average in (d), (e) and (f), respectively. The vertical wind velocity is amplified 1000 times to make it comparable to horizontal wind velocity.

In the revised manuscript, we rephrased this analysis to clarify our statement (P15-16, L440-446):

"In the "Atlantic-W" case, the SST warming induced surface pressure anomalies lead to substantial O_3 redistribution, especially over the North Atlantic Ocean (Figure 7b). As for North America, changes in the horizontal fluxes of O_3 show no significant effect on the O_3 increase. In addition, O_3 changes are observed to be larger in the upper

troposphere than at the surface (Figure 7e). As demonstrated in Section 4.1, the response of lower altitude NA O_3 *to the North Atlantic warming is mainly caused by enhanced chemical production, rather than physical transport."*

LL366-368 please refer to figure 2 as well.

Thanks, referred.

"According to the IPR analysis, the surface O_3 *increase over the Indian Ocean is mainly caused by the downward transport of* O_3 *from upper layers. However, over the nearby Indian subcontinent, the suppressed deep convection tends to decrease surface* O_3 *there (Figure 2)."*

L369 The IPR analysis show suppressed deep-convection. However, the warming of the Indian Ocean strengthens the Indian Summer Monsoon, as also stated by the authors (e.g. LL290-292), hence I wonder why the deep-convection is weakened. Please comment on that.

Good question. Changes in DEEP in the IPR analysis indicates that a warming of Indian Ocean tends to reduce surface O_3 over South Asia (Figure S10), but increase surface O_3 over North Indian Ocean (Figure S11). This is because that the warming of the North Indian Ocean enhances the deep convection above it while suppress the deep-convection over the Indian subcontinent. According to previous studies (e.g., Hartmann, 2015;Lau et al., 1997;Lau and Nath, 1994), the SST increase over the Indian Ocean strengthens deep-convection above it. A low-pressure anomaly is observed centered over the Arabian Sea (Figure 5). It consequently strengthens the southwesterly flow towards the Indian subcontinent, as a part of the Indian Summer Monsoon. On the other hand, the enhanced upward movement of moist air above the Indian Ocean enhances cloud formation. This tends to block solar radiation reaching the earth surface and cools the surface air over the Indian subcontinent. A remarkable reduction of surface solar radiation and air temperature are shown in Figure S17 and Figure 4, respectively. This decrease in surface temperature over the Indian subcontinent may suppress the development of deep-convection there.

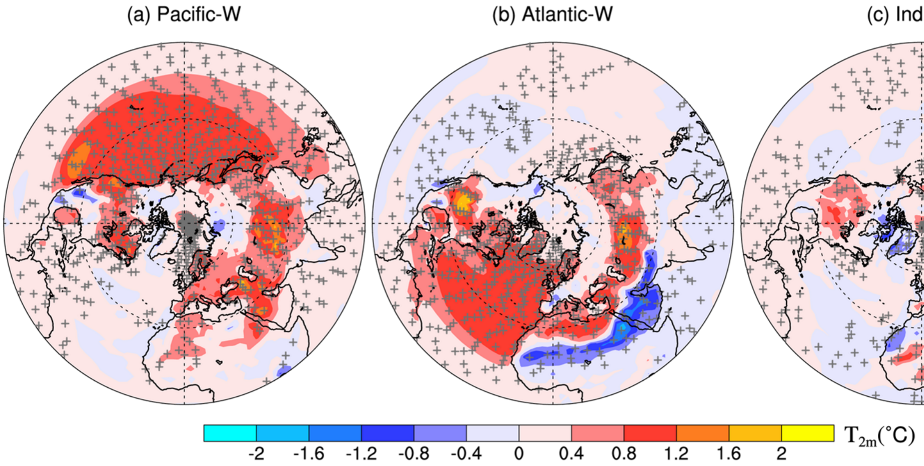

Figure 4. The difference in surface air temperature (℃) for (a) Pacific-W, (b) Atlantic-W, and (c) Indian-W relative to CTRL in the Northern Hemisphere in boreal summer. The + symbols denote areas where results are significant at the 0.05 level as evaluated with a Student t-test. (Plots using the Mercator projection are shown in Figure S15 in the supplementary material)

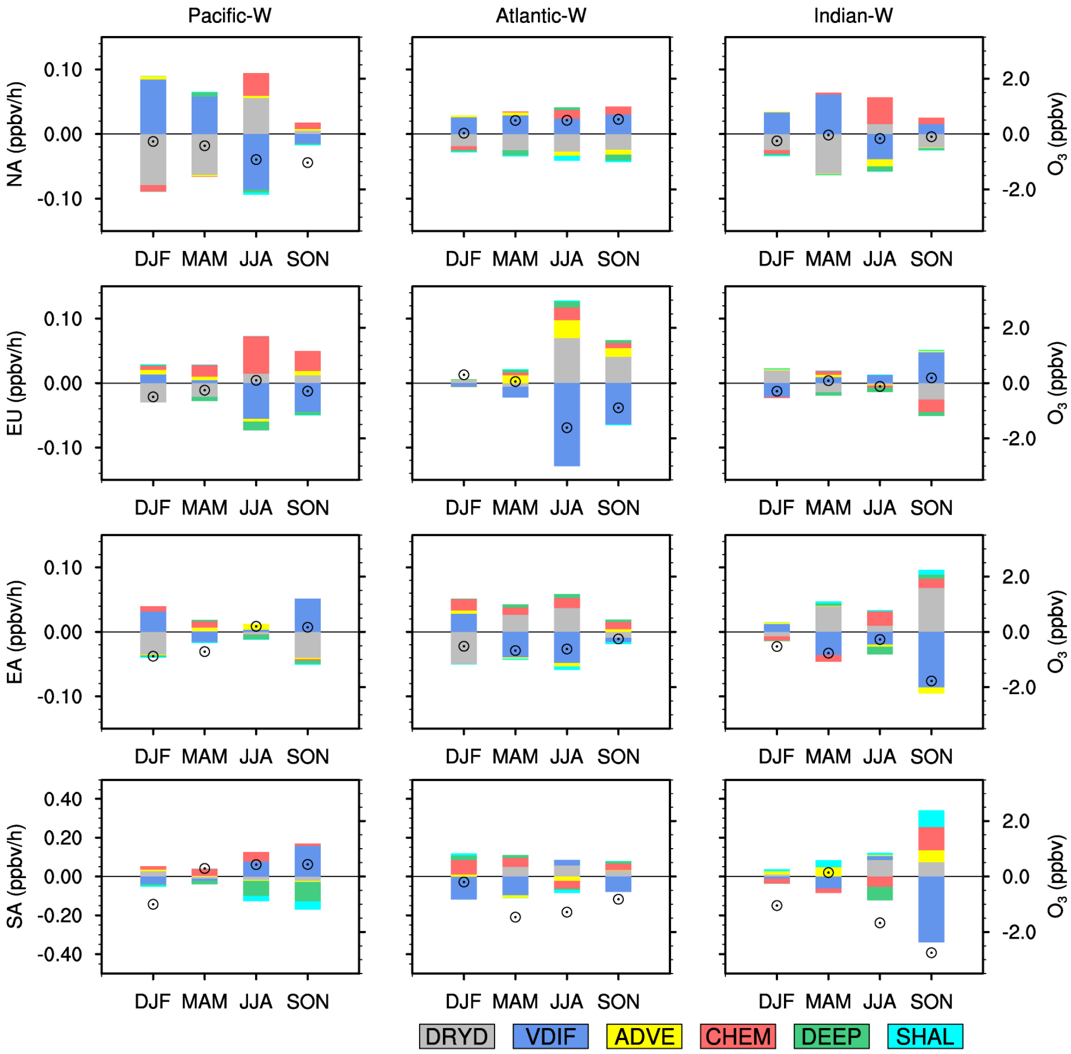

Figure S10. Seasonally averaged changes in IPR contributions (bars, ppbv/h, left scale) and surface O_3 concentrations (hollow circles, ppbv, right scale) for Pacific-W (left), Atlantic-W (middle) and Indian-W (right) relative to CTRL. Values are regionally averaged over NA (first row), EU (second row), EA (third row) and SA (last row), respectively. IPR contributions from six processes (i.e., gas-phase chemistry (CHEM), advection (ADVE), vertical diffusion (VDIF), dry deposition (DRYD), shallow convection (SHAL) and deep convection (DEEP)) are represented by different colors.

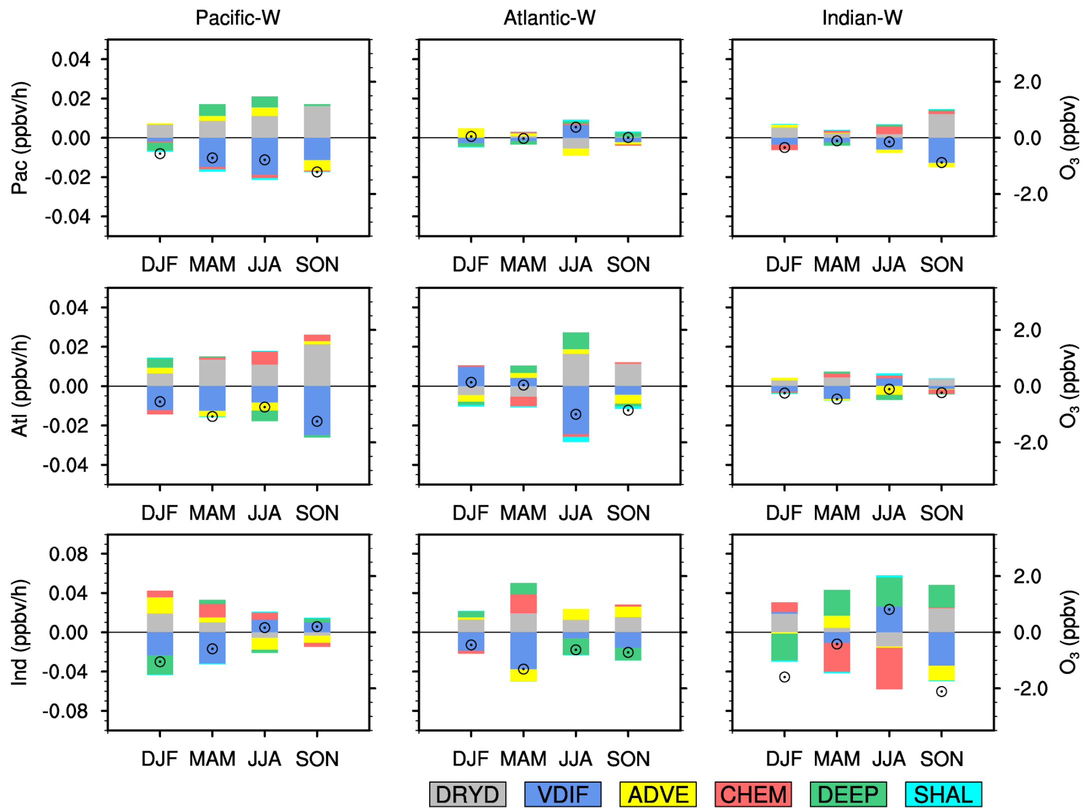

Figure S11. Same as Figure S6 but for three ocean basins defined in our study.

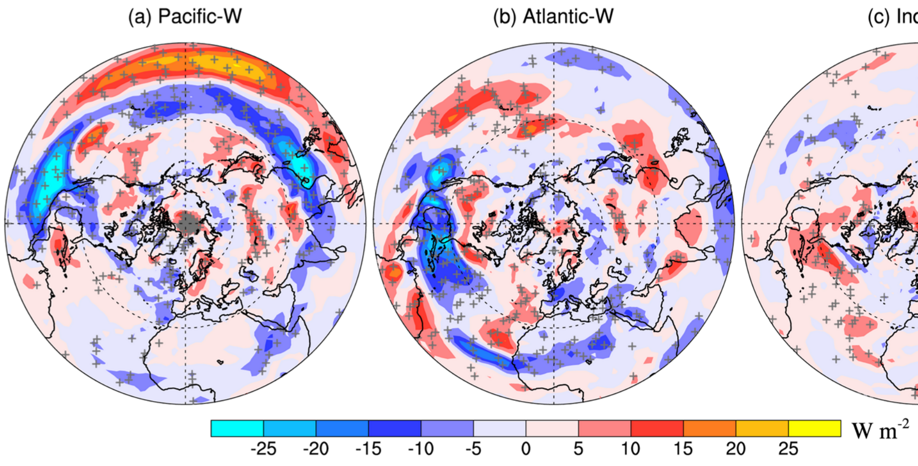

Figure S17. Perturbations of surface solar radiations (W m^{-2}) for (a) Pacific-W, (b) Atlantic-W, and (c) Indian-W relative to CTRL in boreal summer. The + symbols denote areas where results are significant at the 0.05 level evaluated with a Student t-test.

We have clarified the corresponding text in Section 4.2:

"An increase in SST of 1 °C in any ocean basin leads to a widespread enhancement of surface air temperature (i.e., the air temperature at 2m) over most continental areas (Figure 4). An exception is the North Indian Ocean, where an increase in SST tends to cool the Indian subcontinent by 1-2 °C. This temperature decrease is not only limited to the surface, but also spreads to 600hPa (Figure S16). Associated with this temperature decrease, there is a remarkable reduction of solar radiation received at the continent beneath (more than 15 W/m^2, Figure S17). Previous studies indicated that moist convection is more sensitive to the SST changes in the tropical oceans rather than mid- or high- latitude oceans (Hartmann, 2015;Lau and Nath, 1994;Lau et al., 1997). The SST increase over the North Indian Ocean tends to strengthen moist convection that eventually facilitates cloud formation in the upper troposphere (Chaudhari et al., 2016;Roxy et al., 2015;Xi et al., 2015). The latent heat released from convective activities warms the air temperature over upper troposphere significantly (Sabeerali et al., 2012;Xi et al., 2015). Meanwhile, the corresponding increase of cloud-cover blocks solar radiation reaching the surface of Indian subcontinent and cools the air temperature of lower troposphere there. These processes lead to opposite air temperature changes between upper and lower troposphere over South Asia in response to North Indian warming (as shown in Figure S16), which may further suppresses the development of deep convection over the Indian subcontinent."

LL396-400 Beside the fact that Figure 9 is difficult to read. The reduction in geopotential height over the Arabian Sea seems actually to increase the southwesterly flow towards the Indian subcontinent. Furthermore, the land sea contrast may play a very small role in enhancing or weakening the strength of the Indian Summer Monsoon (Molnar et al. 2010). Hence, an in depth analysis should be done before claiming that the change in land-sea contrast is what weakens the "thermal wind". Furthermore, the changes in temperature does not show a clear decrease in land-sea contrast, since there is a warming of SST, a cooling of the Tibert Plateau and northwestern Indian subcontinent, and a warming north of that cooling. Hence I really don't see the authors' point.

In any case, the sentence is not very clear and should be reformulated: "This nonuniform increase in air temperature (i.e., more significant at mid-latitudes) weakens the meridional temperature gradient, resulting in a reduction of thermal winds." What is more significant at mid-latitudes? The nonuniform increase in temperature? Or the fact that the temperature increases more there than the ocean? Or what?

Good question. The original Figure 9 contains many variables (i.e., air temperature, wind pattern and geopotential height at 500 hPa) that make it difficult to read. The changes of westerly wind are also hard to distinguish in Figure 9. In the revised manuscript, we illustrated our result in a more clear way. The zonal averaged changes in zonal wind and geopotential height are now shown in Figure 9, which is more distinguishable.

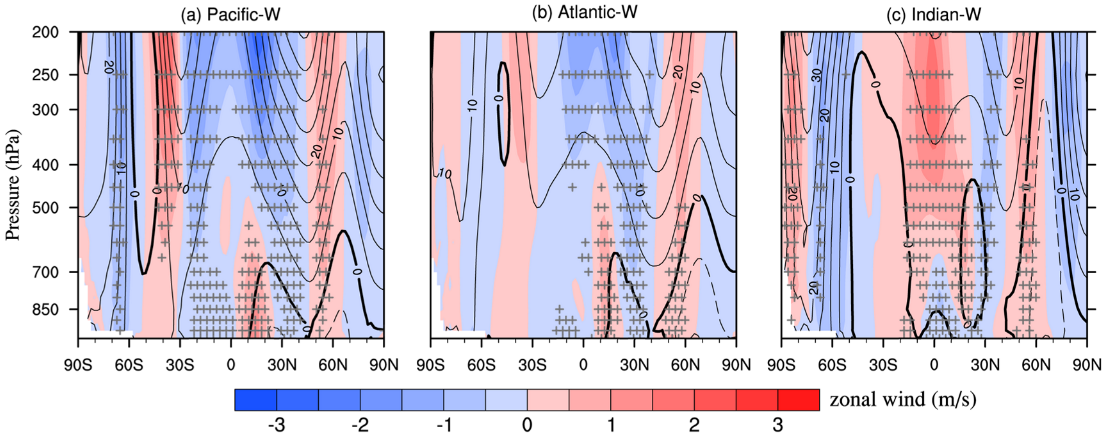

Figure 9. Zonally averaged changes in zonal wind (color contour, m/s) and geopotential height (contour, m) for (a) Pacific-W, (b) Atlantic-W and (c) Indian-W relative to CTRL in boreal summer. Black solid and dashed lines in the contours indicate positive and negative geopotential height anomalies, respectively (Contour interval: 5 m).The + symbol denotes areas where the zonal wind changes are significant at the 0.05 level evaluated with a Student t-test.

We agree that the increase in southwesterly flow towards the Indian subcontinent could not be simply explained by the changes in land-sea thermal contrast. According to our analysis, the warming of the North Indian Ocean creates a warm-core cyclonic anomaly centered over the Arabian Sea, which is responsible for the enhancement of the southwesterly flow towards the Indian subcontinent. A detail description is provided in our response to the comments on L369. The "thermal wind" theory here was used to explain the weakening of the westerly wind at mid-latitudes associated with the basin-scale SST warming. We find that a basin-scale SST warming, especially for the North Pacific and North Atlantic, tends to increase the air temperature (Figure S16) and geopotential height (Figure 9) more significantly at mid-latitudes than elsewhere. Consequently, the meridional temperature and geopotential height gradients are decreasing in the tropical-to-mid-latitude troposphere while increasing at higher latitudes. It tends to decrease the zonal westerly wind at lower-middle latitudes (25°N - 45 °N) in the Northern Hemisphere while increase it at higher latitudes (Figure 9).

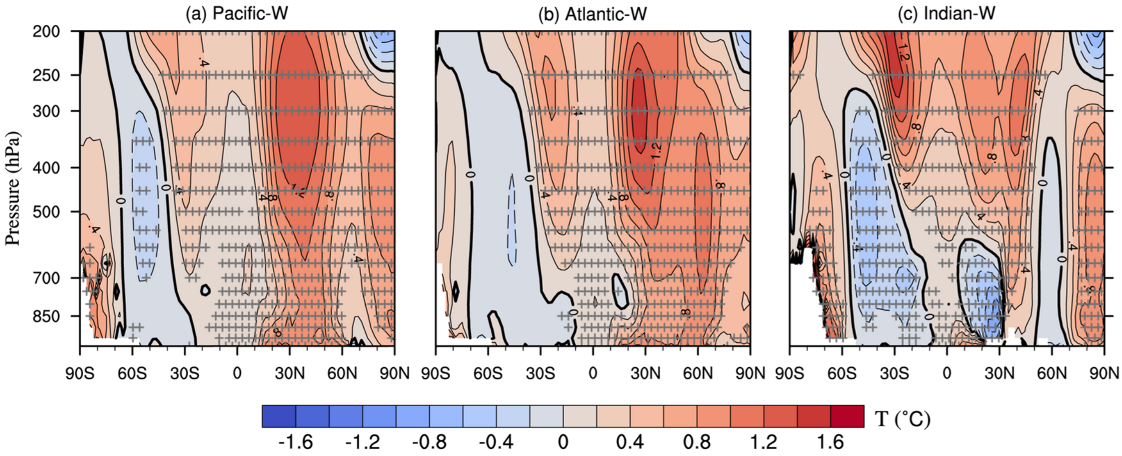

Figure S16. Vertical-meridional distributions of air temperature differences (contours, ºC) between (a) Pacific_W (zonally averaged from 100°E-90°W) (b) Atlantic_W (100°W-180°W) (c) Indian_W (30°E-100°E) and CTRL in boreal summer. Black solid and dashed lines in the contours indicate positive and negative air temperature anomalies, respectively (contour interval: 0.2 ^{o}C).The + symbol denotes areas where the changes of air temperature are significant at the 0.05 level evaluated with a Student t-test.

In the revised manuscript, we clarified our analysis in Section 5:

"…A basin-scale SST increase in the Northern Hemisphere tends to weaken the westerly wind at lower mid-latitudes (25°N - 45 °N) while enhance it at higher latitudes (Figure 9). In general, increases of the geopotential height induced by basin-scale SST warming are more significant at mid-latitudes than other latitudes, consistent with air temperature changes. Consequently, the meridional geopotential height gradient is decreasing in the tropics and mid-latitudes while increasing at higher latitudes, which weakens the mid-latitude westerlies and thus long-range transport of O_3 from North America and East Asia."

LL383-385 Referring to figure 8b, the authors state: "Similarly, for the North American tracer, a warming of North Atlantic SSTs by 1°C slightly increases (~2%) concentrations in North America but decreases (3-4 %) concentrations over downwind Europe". To me it looks like a slight decrease over Europe and quite an increase over large areas of North America. Please correct/clarify.

We previously showed absolute change. If switching to the percentage change (see the Figure 8 below), the pattern would be different. To avoid confusion, we decide to show both absolute and percentage changes in Figure 8 and remove the word “slightly” in this sentence in Section 4.3:

“…Similarly, for the North American tracer, a warming of North Atlantic SSTs by 1°C increases (~1%) concentrations in North America but decreases (3-4 %) concentrations over downwind Europe (Figure 8d).”

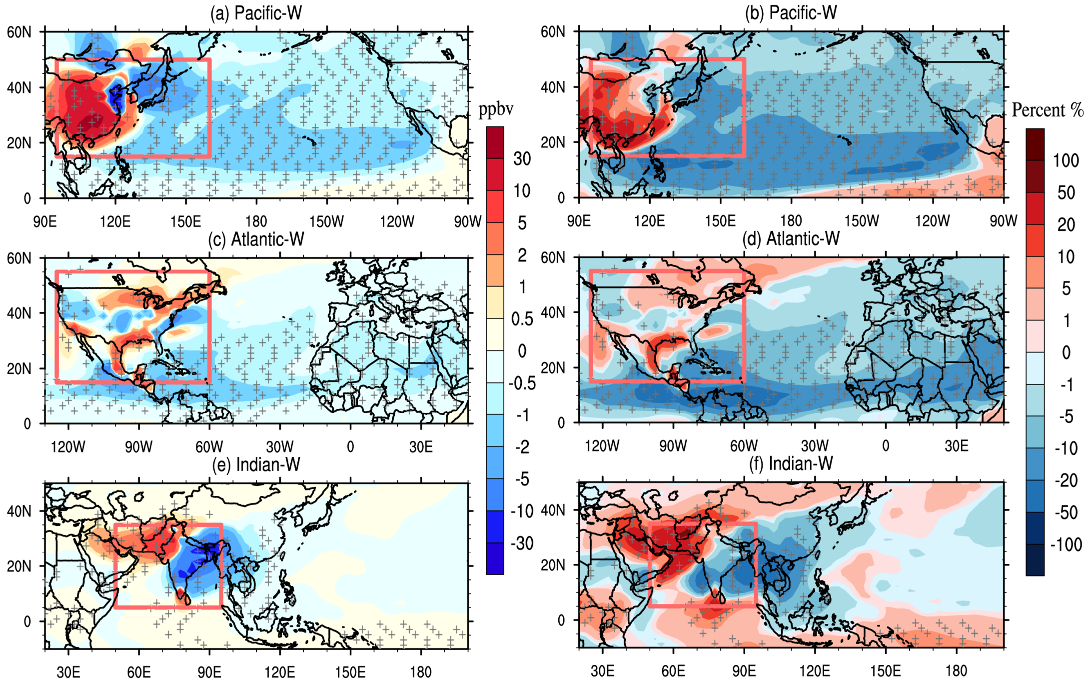

Figure 8. Left-hand panel: the difference in surface concentration (ppbv) of a CO-like tracer emitted from (a) East Asia for Pacific-W, (c) North America for Atlantic-W and (e) South Asia for Indian-W relative to CTRL in boreal summer. Right-hand panel: the percentage changes in surface concentration of a CO-like tracer emitted from (b) East Asia for Pacific-W, (d) North America for Atlantic-W and (f) South Asia for Indian-W relative to CTRL in boreal summer. Red polygons denote the region where the CO-like tracer emitted from. The + symbol denotes areas where the results are significant at the 0.05 level evaluated with a Student t-test.

L443 I suggest to replace “reveal” with “show”

We have rephrased this sentence in Section 6 following the reviewer’s suggestion:

“We further show that air temperature is an important factor controlling surface O_3

responses to SST changes."

Figure 2: It is not clear to me how one can get the changes in O3 from the IPR analysis. It seems that the positive anomalies counterbalance the negative ones (if so this should be made clear, readers may not be familiar with the IPR analysis you are presenting). Therefore I wonder how can the total O3 anomalies be negative or positive (the circle)? It's not clear to me how to read the figure. Please clarify.
Why don't the authors plot in figure2 only the CONV and the TURB and instead place the figure with the full analysis in the supplementary?

Good suggestion. The IPR analysis helps to identify the key processes that cause O_3 changes. Since some processes always offset the others (e.g., VERD and DRYD), we follow the reviewer's suggestion and merge those processes and show the CONV and the TURB instead (see the new Figure 2 below), and put the more detailed decomposition in the supporting information. In addition, we added more descriptions in the revised Section 2.3 and Section 4.1:

In Section 2.3

"To provide a process-level explanation on the response of surface O_3 to regional SST changes, the Integrated Process Rate (IPR) method is applied. This technique calculates the accumulated contributions of individual processes (e.g., chemical production and loss, advection, vertical diffusion, dry deposition, etc.) to ozone predictions during the model simulation, which has been widely used for air pollution diagnostics (Li et al., 2012;Tao et al., 2015;Zhang and Wu, 2013). In this study, we added the IPR scheme to the CESM modeling framework to track the contribution of 6 physicochemical processes (i.e., gas-phase chemistry (CHEM), advection (ADVE), vertical diffusion (VDIF), dry deposition (DRYD), shallow convection (SHAL) and deep convection (DEEP)) to O_3 concentrations in every grid box. Wet deposition and aqueous-phase chemistry are ignored here due to the low solubility and negligible chemical production of O_3 in water (Jacob, 1999). Therefore, CHEM represents the net production (production minus loss) rate of O_3 due to gas-phase photochemistry. DRYD represents the dry deposition fluxes of O_3, which is an important sink for O_3. The other IPR terms (i.e., ADVE, VDIF, SHAL and DEEP) represent contributions from different

transport processes. The IPR scheme tracks and archives the O_3 *flux in each grid from every processes during each model time-step. The sum of* O_3 *fluxes from these six processes matches well the change of* O_3 *concentration. The performance of IPR is verified through comparing the predicted hourly* O_3 *changes with the sum of individual fluxes from the 6 processes. As shown in Figure S1, the hourly surface* O_3 *changes are well represented by the sum of these fluxes in the model."*

In Section 4.1, we have:

"The IPR analysis is used to evaluate the contribution of different physicochemical processes to O_3 *evolution. It has been widely used in air quality studies to examine the cause of pollution episode (Li et al., 2012;Wang et al., 2010). When applied in climate sensitivity relevant analysis (usually measuring the difference between two equilibrium states), the net change of all IPRs approaches zero. Typically, the positive changes in IPRs are mainly responsible for the increase of surface* O_3*, which may further induce* O_3 *removal to balance these factors in an equilibrium state. Therefore, here the IPR analysis is not used to budget the SST induced* O_3 *concentration changes, instead it helps to examine the relative importance of different transport and chemical processes in driving the sensitivity of* O_3 *to a SST forcing. In this study, the SST induced process-level* O_3 *changes are spatially averaged over four populated continental regions (i.e., NA, EU, EA and SA, Figure 2) and three ocean basins (i.e., the North Pacific, North Atlantic and North Indian Oceans, Figure S9). In most cases, vertical diffusion (VDIF) and dry deposition (DRYD) are the key processes controlling the* O_3 *variation. The downward transport of* O_3 *through diffusion is an important source for surface* O_3 *while dry deposition act as a sink. Both processes are closely dependent on turbulent motions. The efficiencies of* O_3 *transport by vertical diffusion and its corresponding dry deposition are simultaneously determined by the strength of turbulence. Here we define a new term TURB as the sum of DRYD and VDIF, which can capture the overall effect of turbulence changes on surface* O_3 *concentrations. In addition, we merge SHAL and DEEP as CONV to represent the total contribution of convective transport to surface* O_3 *(Figure 2 and Figure S9)."*

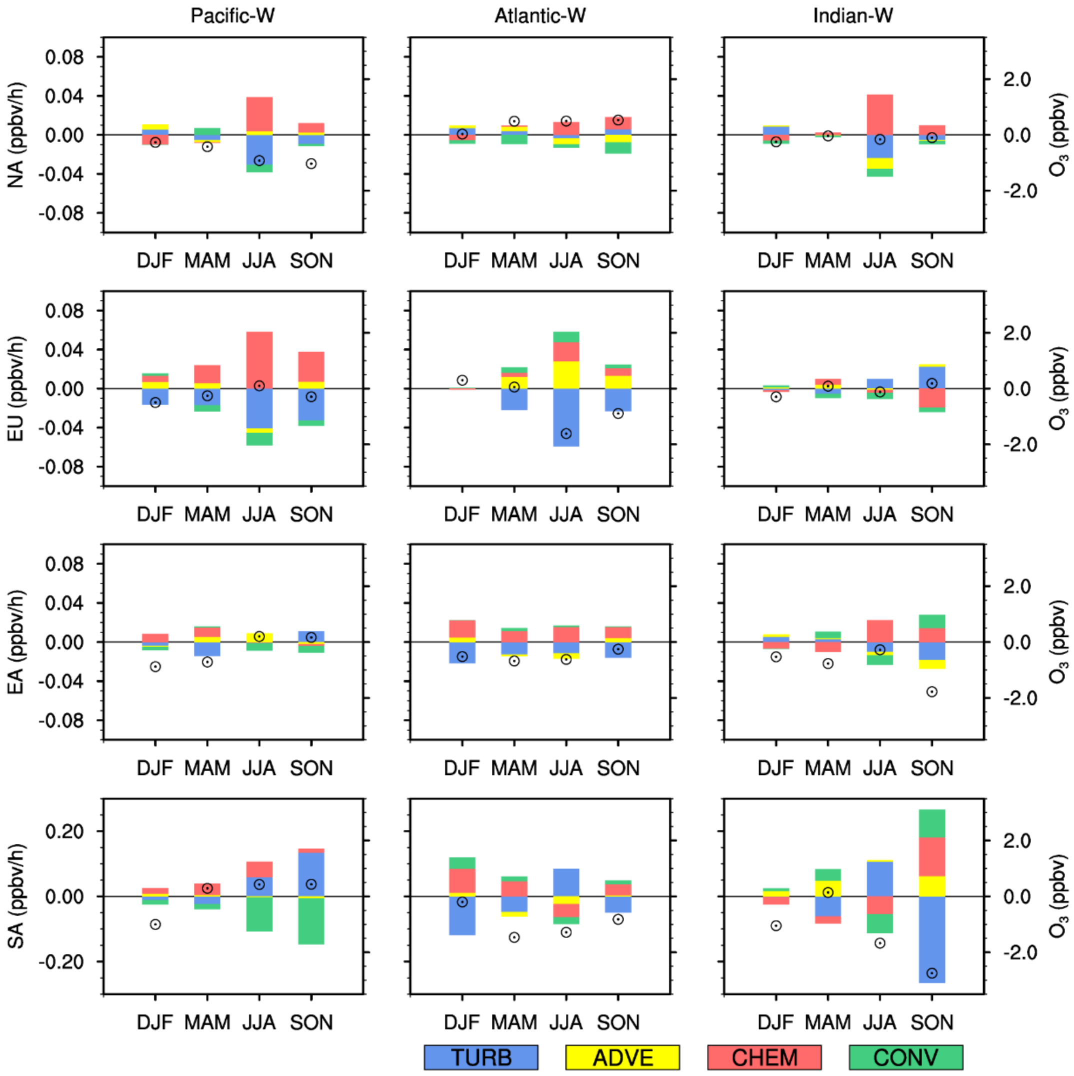

Figure 2. Seasonally averaged changes in IPR contributions (bars, ppbv/h, left scale) and surface O_3 concentrations (hollow circles, ppbv, right scale) for Pacific-W (left), Atlantic-W (middle) and Indian-W (right) relative to CTRL. Values are regionally averaged over NA (first row), EU (second row), EA (third row) and SA (last row), respectively. TURB is defined as the sum of VDIF and DRYD. CONV is the sum of DEEP and SHAL. IPR contributions from four processes (i.e., TURB, ADVE, CHEM and CONV) are represented by different colors. A more detailed IPR result is shown in Figure S10 in the supplementary material.

Figure 3: the authors use 0.05 as significance level while in figure 1 was 0.01. Please pick one level. In figure 1 white colors were used for non-significant values, please be consistent. Furthermore, in figure 3 sometime white areas present significant changes.

Good suggestion. We used 0.05 as the significance level for all relevant figures. We have also removed white color bins used for small values and non-significant values. Please see the revised Figure 3 below for an example.

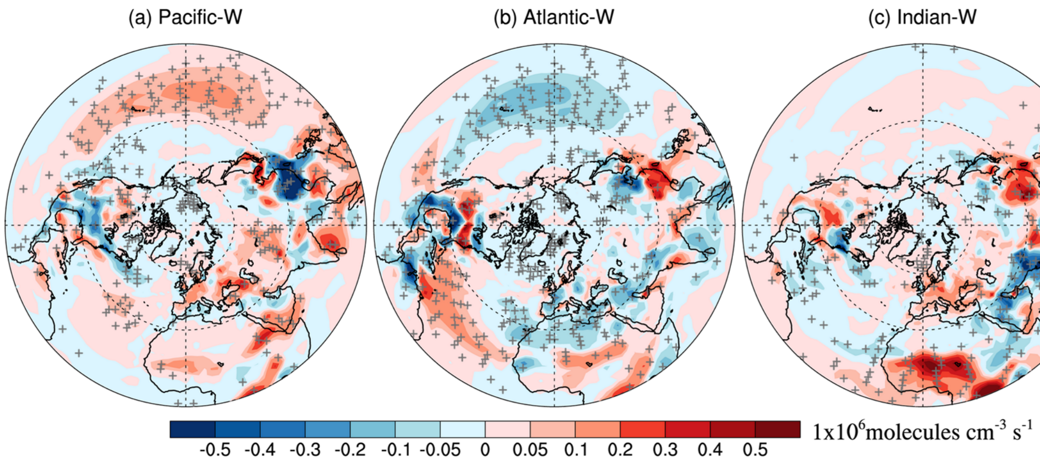

Figure 3. Perturbations of surface O_3 net-production rate (1x10^6 molecules cm^{-3} s^{-1}) for (a) Pacific-W, (b) Atlantic-W, and (c) Indian-W relative to CTRL in boreal summer. The + symbols denote areas where results are significant at the 0.05 level as evaluated with a Student t-test using 20 years of data. (Plots using the Mercator projection are shown in Figure S14 in the supplementary material)

Figure 4: The panels are small and it's hard to see the continents. Please use Mercator projection.

Thanks for this suggestion. As we discussed previously (see our response to major comment 2), we compared the performance of different projections and decided to consistently use polar projection since it is easier to interpret the hemispheric flow patterns although it is true that it's hard to see continents. We realized that the difficulty of reading the original Figure 4 were mainly caused by the low figure quality and blurry continental outlines. In the revised version, high-resolution figure is provided. In addition, the continental outlines are thicker and darker than before. Please see the revised Figure 4 below:

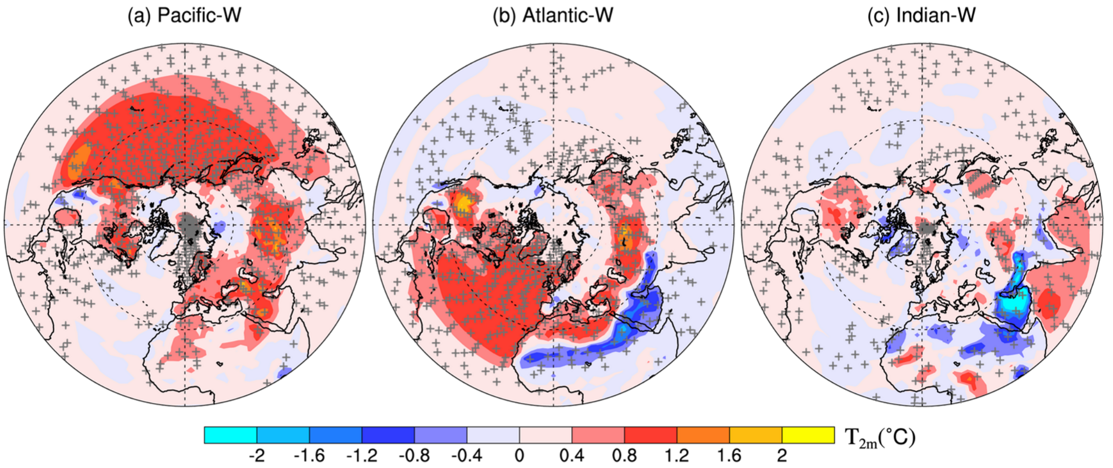

Figure 4. The difference in surface air temperature (ºC) for (a) Pacific-W, (b) Atlantic-W, and (c) Indian-W relative to CTRL in the Northern Hemisphere in boreal summer. The + symbols denote areas where results are significant at the 0.05 level as evaluated with a Student t-test. (Plots using the Mercator projection are shown in Figure S15 in the supplementary material)

On the other hand, plots using the Mercator projection are also provided in the supplementary material. Please see Figure S15 below:

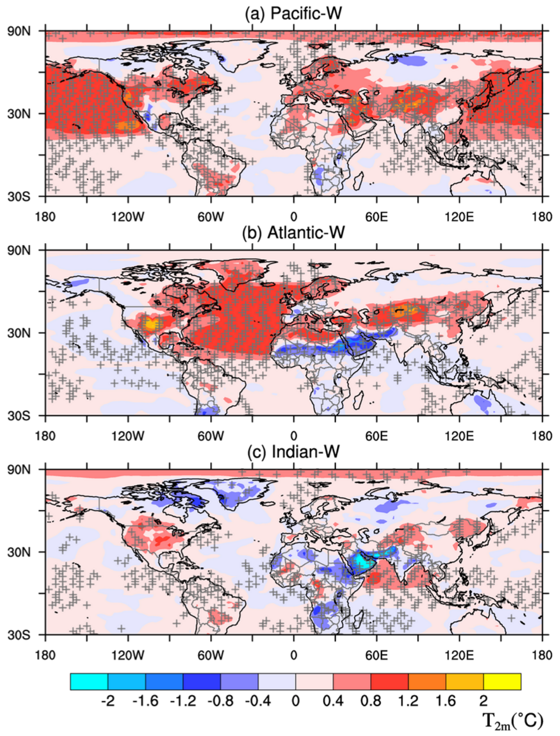

Figure S15. The difference in surface air temperature (ºC) for (a) Pacific-W, (b) Atlantic-W, and (c) Indian-W relative to CTRL in boreal summer. The + symbols denote areas where results are significant at the 0.05 level as evaluated with a Student t-test.

Figure 5: I think it would be better to show both the upwind and downwind area around the basin, i.e. in panel a) please show also the western coast of North and Central America; in panel b) please show the European coast. Finally, the authors plot the wind pattern but do not specify the level: is it at the surface or 850 hPa, …? Please clarify it. Furthermore, I would suggest not to use the surface level but rather a low-middle atmosphere level (850 or 700 hPa).

Good suggestion. We have used the same map projection for Figure 5-8 that shows both the upwind and downwind area around the basin. Please refer to our response to major comment 2 for more details. The wind pattern at 850 hPa is depicted in Figure 5.

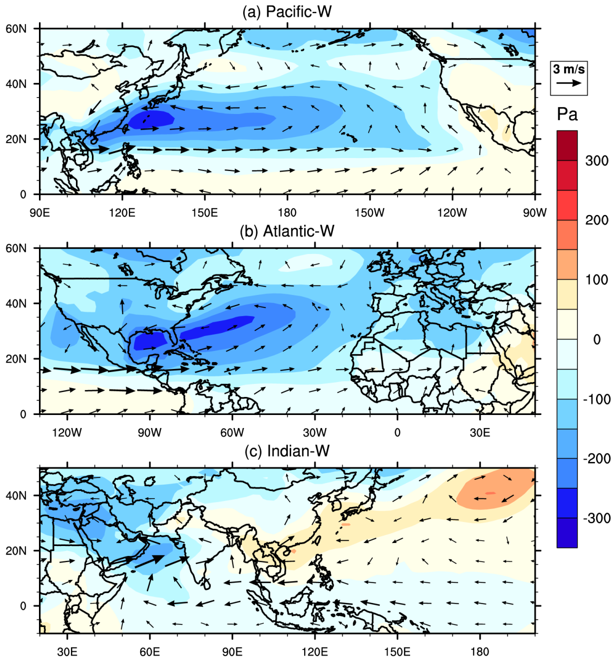

Figure 5. Changes in surface pressure (color contours, Pa) and 850 hPa wind (arrows, m/s) for (a) Pacific-W, (b) Atlantic-W, and (c) Indian-W relative to CTRL in boreal summer.

Figure 6: Impossible to understand it without major efforts.

Thanks for bringing this problem up. Figure 6 shows the spatial pattern of vertical velocity changes at 500 hPa. We agree that the old version was hard to read because of the low figure quality. We have optimized this figure with large improvement. We also changed the map projection of Figure 6 to make it comparable with Figures 5, 7 and 8. Please see the revised Figure 6 below:

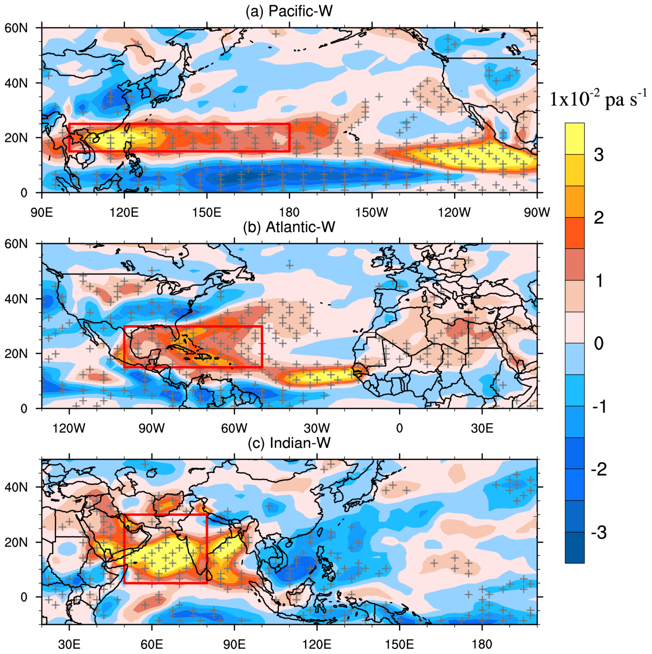

Figure 6. The spatial pattern of vertical velocity changes at 500 hPa (color contours, $1x10^{-2}$ Pa s^{-1}) for (a) Pacific-W, (b) Atlantic-W, and (c) Indian-W relative to CTRL in boreal summer. Positive values indicate upward motion. Red polygons denote the regions where the surface pressure responses to SST anomalies are significant (see Figure 5 a-c). The + symbols indicate areas where results are significant at the 0.05 level as evaluated with a Student t-test using 20 years of data.

Figure 7: as for figure 5 I don't understand the choice of the domain shown for each of the sensitivity experiment. Furthermore, panel b) should be switched with panel c). Furthermore, the authors should also here be consistent with the choice of the domain to show. I would advice to adopt the domain (or a similar one) used in figure 8.

Good suggestion! We have used the same map projection for Figures 5-8 that shows both the upwind and downwind areas around the ocean basin and revised mistakes in the original figure panel:

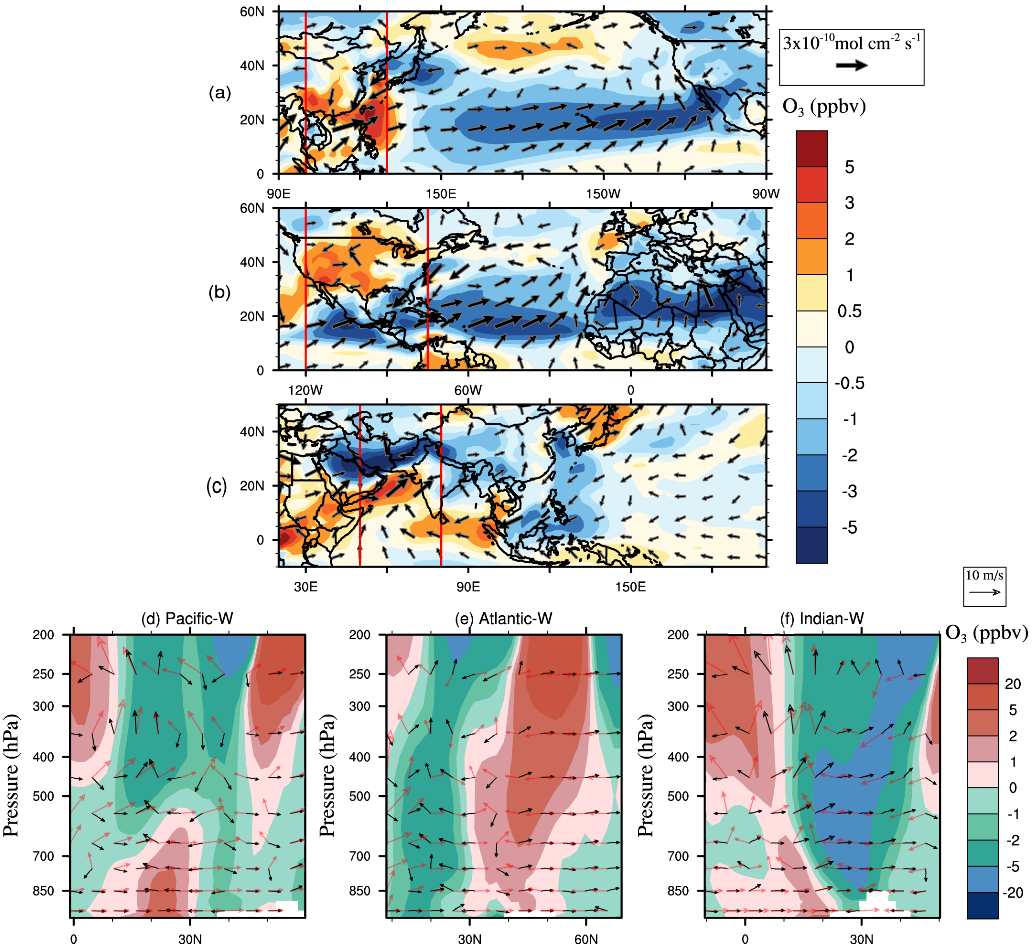

Figure 7. Top three rows: Changes in O_3 concentrations (color contours, ppbv) and horizontal fluxes (arrows, mol cm^{-2} s^{-1}) at the surface level for (a) Pacific-W, (b) Atlantic-W, (c) Indian-W relative to CTRL in boreal summer. Last row: zonally average of tropospheric O_3 changes (color contours, ppbv) and wind fluxes in CTRL (red arrows, m/s) and its perturbation (black arrows, m/s) in (d) Pacific-W, (e) Atlantic-W, (f) Indian-W relative to CTRL in boreal summer. The red rectangles in (a), (b) and (c) denote the longitudinal range used for zonal average in (d), (e) and (f), respectively. The vertical wind velocity is amplified 1000 times to make it comparable to horizontal wind velocity.

Figure S3: which season?

This Figure is referring to the boreal summer. We have revised the caption of Figure S16 (i.e., the Figure S3 in old version) and clearly clarified the relevant season.

*"**Figure S16.** Vertical-meridional distributions of air temperature differences (contours, °C) between (a) Pacific_W (zonally averaged from 100°E-90°W) (b) Atlantic_W (100°W-180°W) (c) Indian_W (30°E-100°E) and CTRL in boreal summer. Black solid and dashed lines in the contours indicate positive and negative air temperature*

anomalies, respectively (contour interval: 0.2 ^{o}C).The + symbol denotes areas where the changes of air temperature are significant at the 0.05 level evaluated with a Student t-test.”

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