Dear Editor,

below we describe the changes to the manuscript.
Since the new manuscript is quite different from the previous one, we do not highlight the differences in the text, but rather we specify the changes using the notation: [PAG XX LL XX]. Please, note that the references to pages and lines refer to the new version of the manuscript (differently from the replies to Referees).

Changes summary:

1. The Introduction is basically the same, with only minor changes.

2. The Methodology is basically the same, although minor changes have been implemented and the last paragraph for the description of the vertically integrated tracer transport vector computation has been added.

3. Section 3 has been partially modified to introduce the new analysis.

4. Section 4 has been largely changed. Now there are two subsections in order to include the new analysis performed to satisfy the Referees' comments.

5. The Conclusions and the Abstract have been modified accordingly to the new analysis.

6. Now there are 8 figures in total (please, note that only 3 figures out of 4 of the previous version are included in the new manuscript).

In order to facilitate the work of the Editor, below the Referees' comments are listed (as *[...]*) followed by the notes about our changes.

- - - - - - - - - - - - - - - - - - - - **REFEREE #1** - - - - - - - - - - - - - - - - - - - - -

*[...it lacks of a proper discussion where their results are contextualized within the outcome of previous studies.]*
In the conclusions we have contextualized better our results and mentioned the previous studies cited in the introduction [PAG 10 LL 3-5 and LL 11-13].
*[I think the authors never mentioned the aerosol scenario adopted (MFR, CLE?).]*
We have specified better that the simulation uses a climatology of aerosols in the Methodology section [PAG 4 LL 26-28] and conclusions [PAG 9 L 32].

**Major Comments**

1. *[...How can they possibly say that just through a correlation analysis? Could the authors explain why an increased correlation between PC1 and CO means that there will be more extremes? ...]*
   We have explained the role of the correlation computation in our analysis at PAG 7 LL 17-21.

   *[An analysis of the extreme should be done to make that point and would also add more strength to the study.]*
   We have added a new analysis of the extremes. We have defined "high NAO" and "low NAO" as (winter) periods with PC1 higher than 0.5 and lower than $-0.5$, respectively,

1

and we have computed the temporal averages of CO_25 winter surface mixing ratio. This analysis has been included in the new Subsection 4.2 [PAG 9 LL 2-16] together with the new Figure 7. Please, note that the old Section 4 now has two subsections: "4.1 Correlation and regression analysis" and "4.2 Tracer concentration and transport changes".

*[Also a regression analysis can also provide some insights on changes in the relationship between the PC and CO concentrations.]*
We have computed the regression between the PC1 and CO_25 mixing ratio in the recent past and in the future. Thus, we have added the new regression analysis and the new Figure 6 after the correlation analysis [PAG 8 LL 12-27].

*[... there is a shift of the centers of action but the PC/CO correlation pattern doesn't change. This should be discussed and possibly explained.]*
We answered in the Referee reply that the investigation of the NAO shift falls outside the scope of our study, which focuses on NAO effects on tracer transport.

2. *[Another question that I think it would be interesting to address is how the intercontinental transport of pollution changes in the future.]*
We have computed the vertically integrated tracer transport vector in order to study the pollutant transport changes in the future and we have added this new analysis in the Subsection 4.2 [PAG 9 LL 17-27] together with the new Figure 8. The description of the computation has been written in the Methodology section [PAG 5 LL 11-15].

3. *[I would suggest plotting the PC1 time series for the entire 1950-2100 period. However, the EOF analysis should be done after removing the climatological SLP climatology (e.g. 1980-2010, or 1950-1979).]*
We have added the new Figure 2 of the entire PC1 (1950-2100) series, computed after subtracting the SLP climatology of 1980-2010, in the Subsection 3.1 [PAG 6 LL 13-14].

*[The authors could also plot a pdf of the NAO/PC1 events to see how the distribution (extreme) changes.]*
We have included the new analysis of the NAO phase distribution and the new Figure 4 at the end of the Subsection 3.2 [PAG 6 LL 32-34 and PAG 7 LL 1-6], after the trend analysis. As we wrote in the Referee reply, we preferred to describe the distribution through an histogram instead of computing the PDF given the low statistics.

4. *[I am very surprised to see that the coupled simulation shows a similar NAO trend as the reanalysis. The model has its own internal variability therefore is not to be expected at all to show the positive NAO trend in the 80s and beginning of the 90s. It must be a coincidence and should not be presented as an evidence that the model is performing well because resemble the reanalysis.]*
We have removed the text regarding the NAO trend observations (and the relative plot) from the Subsection 3.2. Thus, the only figure showing the NAO trends now is Figure 3.

### Minor Comments

**Subscript** We have changed the notation to "CO_25" and "CO_50" (according to Eyring et al. 2013, pag. 48-66).

**PAG 1 LL 15-16** We have modified the text [PAG 1 LL 16-18] as: "It is a swing between two pressure systems, the Azores high and Icelandic low, which redistributes atmospheric masses between the Arctic and the subtropical Atlantic influencing weather conditions (Walker et al. 1932)."

**PAG 4 L 28** We have changed the text as requested from "data" to "scenario" [PAG 4 L 29].

**PAG 4 LL 29-34** We have preferred to leave this paragraph [now PAG 4 LL 32-35, PAG 5 LL 1-2] because here we explain that coupled models are better than GCM forced with SST to simulate the NAO phenomenon itself, besides future scenarios.

**PAG 5 LL 12-21** We have specified the years considered for the EOF analysis [PAG 5 L 25-26].

**PAG 5 L25** We have added the new reference "Pausata et al. 2015" [PAG 6 L 6].

**PAG 5 L28** We have changed the text as requested from "does not reflect" to "is not able to capture" [PAG 6 L 10].

**PAG 6 L33** We have changed the text as requested [PAG 7 LL 22-23], but we have preferred to write "Northern America east coast", instead of "North American east coast" as suggested by the Referee.

**CO_50 figure** As we have performed other plots which have been added in the manuscript (Figures 2, 4, 6, 7, 8), we have decided to leave the figures for CO_50 in the electronic supplement. The reason to show the analysis of CO_50 is explained at PAG 7 LL 13-16 and LL 25-27.

**PAG 7 L22** We have changed the text using "recent past" and "future", instead of "period A" and "period B" as requested.

**PAG 8 L8** We have improved our discussion and added the citations in the conclusions [PAG 10 LL 3-5].

**aerosols concentrations** We have specified in the text that the simulation does not account for a possible decrease of pollutant emissions and that we focus on the transport of CO-like tracers [PAG 8 LL 31-35 and PAG 10 L 23].

- - - - - - - - - - - - - - - - - - - - - **REFEREE #2** - - - - - - - - - - - - - - - - - - - - -

1. *[...It would be better to regress the NAO against the CO25 concentration during the two periods and determine differences between CO25 concentrations...]*
   We have added the analysis of the CO_25 mixing ratio future changes (Figure 7) and the regression analysis (Figure 6). Please, see also point-1 Referee #1.

2. *[...the authors should also examine changes in the tracer concentration due to changes in the NAO trend...The authors concentrated on changes in the NAO trend in the first part of the manuscript so the importance of temporal changes should be addressed.]*
   As we wrote in the Referee reply, differences in tracer concentration due to the

NAO could be due to both trends in NAO or changes in the EOF pattern. The computation of changes due to NAO trends contributes to our understanding of temporal concentrations changes by weighing the correlation results due to patterns with the results of the analysis of trends, performed in Section 3.

3. *[When computing changes in the NAO trend I assume the authors are allowing for variations in the pattern of the 1st EOF depending on the time period. This should be made very clear (in section 3.2). My feeling is it would be better to look at trends in an invariant NAO pattern.]*
   We have clarified that the trend values in Figure 3 are obtained from the PC1 computed for the entire period of 150 years [PAG 6 LL 16-18].

4. *[I am puzzled between the similarity in pattern between the slopes of the model generated PC1 and the observational generated pattern over the historical period...Why does one expect agreement?]*
   As written in point-4 Referee #1, we have removed the old text regarding the NAO trend observations (and the relative plot) from the Subsection 3.2. Thus, the only figure showing the NAO trends now is Figure 3.

5. *[...I feel the authors should try to demonstrate that this shift is not simply due to interdecadal variability.]*
   We have performed a new analysis to show that the NAO shift is climate induced and we have added it in the Subsection 3.1 [PAG 5 LL 30-31 and PAG 6 LL 1-4]. The new Figure has been included in the electronic supplement file.