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Interactive comment on "The success of emissions control legislation in mitigating air pollution is higher than previously estimated" *by* N. Daskalakis et al.

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We would like to thank the reviewer for the careful reading and the pertinent comments that helped improving this manuscript.

Here-below we provide a point-by-point reply to the comments by the reviewer. Text that corresponds to new text in the manuscript is provided in *"quotes and italics"*.

Comment: Review of the paper "The success of emissions control legislation in mitigating air pollution is higher than previously estimated" by Daskalakis et al., acpd, 2016

The paper by Daskalakis et al. (2016) deals with the assessment of emission control

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measures in improving global air quality through the development of hindcast simulations over the past 30 years. The authors performed simulations using 3 sets of anthropogenic emissions, corresponding to different scenarios:

1) CL: current legislation data based on the ACCMIP database till the year 2000 and then using projections till 2010

Answer: The CL scenario uses the ACCMIP dataset as described in Lamarque et al., 2013. We did not produce a new dataset for performing the simulations.

Indeed, the available on the web ACCMIP data used here as is and contain historical data till 2000 and projections afterwards.

These are monthly global emissions, that are constructed based on the RCP6.0 emissions among others and provide (monthly) data from 1850 to 2100 (Lamarque et al., 2013). Any relevant comparison of these emissions has been performed by the groups that developed them, and is outside the scope of the present manuscript.

To clarify this point, we have modified the text in the manuscript in page 5 lines 10 and onwards, which now reads:

"Monthly anthropogenic and biomass burning emissions for the hindcast current legislation(CL) simulation are from the Atmospheric Chemistry and Climate Model Intercomparison Project (ACCMIP) database (Lamarque et al., 2013) until the year 2000 and RCP6.0 (van Vuuren et al.,2011, Fujino et al., 2006) projections afterwards, also provided by ACCMIP (http://accmip-emis.iek.fz-juelich.de/data/accmip/gridded_netcdf/accmip_interpolated/README.accmip_interpolated.txt). "

Comment: 2) AE1980: anthropogenic emissions of 1980 are assumed constant over the years

3) BA1980: business as 1980 accounts for constant per capita emissions per region. Emissions are then calculated following the observed population changes reported by the World Bank. No technological improvement, mitigation policy and change in per

capita energy demand are taken into account.

The authors also show the comparison of their simulations with surface measurements of O3, CO, SO4 and BC obtaining a relatively good agreement.

General comments

Comment: Even though population growth is one of the drivers of emissions, the emissions are not directly scaled with population growth but with human activity. Human activity is more directly scaled with mainly global population growth (not as such with local population growth because of the globalization of industry and trade). Looking into the population growths in different parts of the world and comparing this with the emissions growth, one sees clearly huge differences for different regions. Let us have a look at the population growth rate and the CO2 emissions growth rate (which excludes the effects of technology and end-of-pipe measures) for different parts of the world:

- Whereas China and the USA show similar population growth rates (of respectively 0.012 /yr and 0.011 /yr), CO2 emissions in China increased much stronger than in USA (0.099/yr and 0.051/yr respectively).

- Moreover China showed an acceleration in emissions increase (more than 10% in average) in 2002-2010, the period with flattening of the population growth rate (only 0.0047 /yr).

- Africa and the Middle East show a fast population growth rate (0.037 /yr) but modest emissions growth rate of 0.047/yr (similar to USA).

- EU showed only a very small population growth rate of in average 0.0030%/yr which is difficult to link with the emissions decrease rate (of -0.0035/yr in average). This exercise illustrates that a constant emissions per capita factor has different meanings for different regions and as such, it is unclear what the meaning of a BA1980 scenario with constant per capita emissions is.

Answer: The numbers and statistics presented by the reviewer (unfortunately without reference) are representative of the current legislation (CL) simulation and cannot be used for the BA1980.

Our hypothetical scenario BA1980 neglects (in purpose) the globalization of industry that happened the last decades, since it is constructed as a business-as-1980 scenario. BA1980 assumes that nothing has changed, other than the population itself (including regional information).

The scenario that we describe in section 2.2 specifically states that no energy demand, industrial growth or technological improvement is taken into account. This is a hypothetical scenario where, as the name states, all human activity, technological status and energy demand were the same as in 1980, but the population increased the way it actually did. The changes take into account the regional population changes, as described in the submitted manuscript in page 5, section 2.2, lines 23-29.

Overall, the scope of BA1980, explained in the manuscript in Section 2.1, page 5, lines 10-13 and Section 2.2 is to provide a picture of what the anthropogenic emissions would have been if per HTAP region the technology, the energy demand per capita and the way this energy was produced remained the same to those of the year 1980.

This was clearly stated in the manuscript. However to further emphasise this hypothesis, we have slightly modified the text in the first paragraph of section 2.2 which now reads:

"Advances in technologies are thus ignored and the energy demand per capita as well as the way energy was produced have been assumed constant with time and per region and equal to those of 1980."

Comment: A compensation with a factor 2 and 3 for China and India to account for increased energy demand seems also quite ad hoc.

Answer: As mentioned in our reply to the previous comment on the Business-As-

1980 (BA1980) scenario, we calculated anthropogenic emissions per capita in 1980 per HTAP source region since there was already in 1980 a difference on the human activities for each one of these source regions, as described by HTAP. These factors were then applied per region to the observed population growth.

The factors of 2 and 3 for India and China are not ad-hoc. They are calculated based on the energy use as equivalent of oil consumption provided by the World Bank (reference in the supplement, Table S2) for the years 2010 and 1980. This information (mean increase in energy use) is provided in Table S2b and explained in the Table caption and note in the supplement of this manuscript.

Comment: The reviewers wonder why the more elaborated retrospective emissions scenarios for 1970-2010 of the PEGASOS FP7 project (acknowledged in this work) are not used instead. Moreover the most important emissions trend, is the trend in China in the last decade 2000-2010, for which the reference case (ACCMIP) uses only a projection of emissions from RCP6.0, although the HTAP paper (cited in this work) provides monthly global emissions gridmaps for 2008 and 2010. At least a comparison of the reference case with more recent bottom-up inventories is needed.

Answer: The emissions of the PEGASOS project as stated in the Crippa et al. (2016) paper (page 3) analyse two different scenarios: "STAG_TECH, assumes after 1970 no further improvements in technologies and abatement measures. The second retrospective and lowest emission scenario (STAG_ENERGY) assumes stagnation of energy consumption since 1970, while the fuel mix, energy efficiency, emission factors and abatements are assumed as in the reference 2010 data".

None of those scenarios represents what we wanted to test, which would have been a combination of STAG_TECH (but global stagnation) and STAG_ENERGY but for 1980 fuels etc. and no increase in energy demand.

Furthermore, the emissions used here for the CL simulation have been developed and published by Lamarque et al. (2013).

The PEGASOS emissions have been constructed and are now published by Crippa et al. (2016), who state in their paper that "Historical global emissions data sets for the past decades or century have been compiled by combining several emission inventories, e.g., Lamarque et al. (2010) for 1850–2000 and Granier et al. (2011) for 1980–2010. However, an analysis of the factors driving these emissions trends is difficult because of the heterogeneity and regional differences of the original data that might show inconsistencies over the full time period and in global coverage and cause artificial variability."

So for the paper specifically:

Comment: 1)In chapter 2.2 (lines 18-20) the authors explain the data preparation for the BA1980 scenario. They say "The BA1980 inventory assumes that land anthropogenic emissions per capita remained constant from 1980 until now in major geographic regions, while population and thus overall human driven emissions changed".

The basic assumption of this scenario is that anthropogenic emissions scale with population. Although it is correct that emissions increase with population growth (e.g. due to higher energy demand, economy growth, etc.), the increasing economic activities are not always in the same place where the population grows. For example African countries have a growing population but the increase in economic activities is not happening there. On the other hand, Chinese population is stabilizing, while Chinese economy is exploding. These are just examples to highlight that population is not a driver for emissions in a certain location. This is also true for industrialized countries, having a rather stable population but increasing energy consumptions and thus increasing emissions. Therefore the assumption behind the BA1980 scenario is not correct and the authors need to reconsider how to build this scenario. One option could be to focus on certain emission sectors, for example the road transport or the residential ones, where population can possibly be considered as a driver for the emissions (the authors will need to prove it anyway). For other sectors, like the power generation or the industrial ones, population growth in a certain location is not driving the increase of such activities in

the same area. So, the population driven scenario is not applicable at all. Due to this major criticism, the authors should define a new methodology for developing hindcast simulations. Then all results should be modified accordingly and possibly the main message of the paper will change.

Answer: We understand the reviewer's reasoning about globalisation of industrial activities that moved a significant amount of industrial and energy demanding activities to regions with cheap labor. Thus the economic development did not follow the population growth.

This is the reason that in India the CL emissions in 2010 are higher than the BA1980 corresponding emissions as shown in the Figure 1 of our paper and discussed in section 3.1 (middle of first paragraph) of the ACPD version of the manuscript (page 6,line 10).

Based on our scenario the human activities in each region remain the same as in 1980- this means we do not account for globalisation of the industrial activities. This is afterwards indirectly accounted when discussing the increase in the energy demand based on Table S2b (see our earlier reply).

Of course, in another scenario, the emissions could increase with human activity and not human population. In our scenario though it is clearly stated (by the name of the scenario – Business-As-1980) that human activity does not change in any way, only number of humans per grid. This results to the population increase being the only driver for emissions increase, which we believe is the best reference scenario for one to use in order to study the impact of emissions control legislation at any region.

To further clarify this approach we have added in section 2.2. where the BA1980 scenario is described the following sentence:

"This also implies that globalisation of industrial activities leading to an increase in energy demand in developing countries disproportional to the population growth is not

taken into account in this scenario."

Comment: 2)The authors should also explain the novelty of their work compared to recent literature about hindcast scenarios published within the same FP7 project they acknowledge. For example, Crippa et al. (2015) published a paper about retrospective scenarios assessing the effectiveness air quality legislations at global scale. Turnock et al. (2016) used a composition-climate model to simulate the impacts of European air quality legislation and technology measures implemented between 1970 and 2010. They used 2 scenarios, one with actual emissions in 2010 and the other with emissions that would have occurred in 2010 in the absence of technological improvements and abatement measures.

Answer: The Crippa et al. (2015) paper stagnates specific sectors of the anthropogenic emissions, where in our case all land anthropogenic sectors remain constant per capita to the levels of 1980, so a direct comparison with their results is not possible.

The Turnock et al. (2016) paper, that was published almost a month after our initial submission, discusses the impact of the European legislation only and is a regional study, while our study is a global one not focusing on one specific region and taking into account all legislation globally.

Comment: 3)The authors should compare their CL scenario with other emission datasets since this scenario is based not only on historical data but also on projections (from 2000 to 2010)

Answer: The CL scenario emissions are the well documented ACCMIP emissions and RCP 6.0 projections not developed by us. They are documented in Lamarque et al (2013) and analyzed in Granier et al (2010). These emissions have already been thoroughly analyzed and compared to other datasets by the people that produce them. This was also mentioned in an earlier reply.

Comment: 4)The authors state: "Emission factors per species per capita per year

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for each HTAP source region were calculated for the year 1980 by dividing the 1980 anthropogenic emissions by the population of each region" (page 5, lines 31-32). When dividing emissions by population you do not get emission factors, but population weighted emissions that is a completely different concept since emission factors are calculated from activity data.

Answer: We thank the reviewer for this comment and we correct the manuscript accordingly:

"Population weighted emissions per species per capita per year for each HTAP source region were calculated for the year 1980 by dividing the 1980 anthropogenic emissions by the population of each region. These per capita emissions were then applied on the gridded population maps to construct the database of annually-varying BA1980 anthropogenic emissions."

Comment: 5)The introduction deals mainly with O3 and just in the last few lines the authors introduce their work which seems not to be related with what discussed above. Moreover, the authors state that "Traditionally, air quality assessments are performed by comparing the pollutants concentrations at present with those of a past year". They should provide literature references about this approach since usually modelers make projections for future air quality then looking at past concentrations.

Answer: The introduction of the manuscript is used to state the problem of the atmospheric pollution increase of the near past that is a fact since it has been observed. It is true that more weight was given to O_3 in the submitted manuscript. For that reason we extended the aerosol discussion in the introduction, following also the suggestion by reviewer #3. Page 3, lines 16 and onwards now read:

"The modelling study by Pozzer et al. (2015) also shows globally decreasing AOD trends for the period 2001–2010. Regionally the largest decrease is calculated for easern USA and western Europe, where the eastern Chinese region shows the sharpest increasing trend. Similar results are found in the multi-satellite study by Yoon

et al. (2014), where regionally western Europe and eastern USA appear to have the fastest decreasing trends in AOD, while central and east China the fastest increasing trends in AOD. In agreement with that study the analysis of the measurements of surface concentrations of several aerosol species by Leibensperger et al. (2012) shows decreasing trends in the eastern US for the period 1990–2010"

The technique modelers use, irrelevant of present or future, is to compare a time period against another. This is applicable to all aspects of modeling, including air quality. Frequently this involves studies of the future air quality, which is what the reviewer is referring to, and there are hundreds or thousands of studies about it. Also frequently though, studies involve the historical period, and how air quality is right now, compared to the past. There are also hundreds or thousands of studies about that as well. In this study we compare the method currently used to evaluate the already applied legislation to the present day conditions (comparison of what the levels of atmospheric pollutants would be if the emissions where quantitatively the same as those of a past year to the current levels) with a newly proposed method that, in our opinion, provides a better baseline scenario for comparison. Indeed, most future studies assume a business-as-usual scenario, which is a different way to say business-as-2000, if the year 2000 is the one considered as present day. Our BA1980 scenario is exactly that, for a historical analysis.

Comment: 6)it is not completely clear the scope of this paper. From the title the authors claim to have shown the success of emission control legislation in mitigating air pollution. However, most of their results focus on the quality assessment of their simulations through the comparison with measured concentrations (paragraphs 3.2 and 3.3). Only in paragraph 3.4 they want to address the legislation impacts on air quality, but they actually do not show the impact of any specific legislation, or the impact of certain abatement measures or technological advancement. Therefore the objective of the paper should be reconsidered.

Answer: The scope of this paper is to prove that in order to evaluate the effect of

applied emission control legislation, the comparison of the pollutant levels of present years to pollutant levels based on a scenario that just keeps the anthropogenic emissions constant to the levels of a past year is not correct. Scenarios that take into account population increase and migration (shown here) and energy demand (not simulated but calculated and discussed here) should be used instead. This is already stated in the title, abstract and conclusions of the manuscript.

In order to extract any results by a model simulation, a thorough validation of the model results needs to be done. Otherwise, any results produced by said model would not be credible. This leads to the current structure of the paper, which demonstrates that the model calculates realistic concentrations of pollutants, and then addresses the key point of the paper.

Comment: 7)For a more detailed review new scenarios need to be developed and more in depth analyses will be required in order to assess the role of mitigation policies on emissions.

Answer: Even though lots of different scenarios can be produced giving different results, we believe that the scenario we chose serves the purpose of this paper sufficiently. As already stated above and in the paper, our study recommends which is the best reference scenario to use, it is not proposing mitigation policies or develops new future emissions scenarios.

Specific comments

Comment: 1) In Figure 2, the BA1980 and AE1980 scenarios are not needed since the aim of this figure is to compare measured concentrations with the simulated ones (CL)

Answer: Figure 2 is also used to point the difference of the different scenarios in a more localized way than in Figure 4, thus the extra simulations (BA1980 and AE1980) are needed. The extra lines have been valorized following reviewer #1 comment 3.

Comment: 2) In figure 4 the authors should say to what they normalized the concentrations

Answer: The caption of the figure now reads:

"Annual mean surface concentrations for CO, NO_x, O_3, OC, BC, and sulphate aerosols (rows), averaged over the globe, Europe, North America, India and China (columns) and normalized to the 1982 concentrations."

Comment: 3) The authors state (page 2, line 7): "Most anthropogenic activity takes place in the northern mid-latitudes with approximately 80% of global population residing there (Kummu and Varis, 2011)". The authors should report the definition of northern-mid latitudes (degrees or countries included) and the year they are referring to, since population distribution might change in the next years (e.g. higher contribution from India?)

Answer: The sentence now reads:

"Most anthropogenic activity takes place in the Northern Hemisphere (N.H.) with 87.5% of the global population residing there, in particular 81.8% was occuring between the equator and 50^o North in 2005 (Kummu and Varis, 2011)"

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