Different aerosol forcing in the historical simulation of NorESM2 and CESM2

June 10, 2020

1 Modification to the document

1. CESM2 aerosol ERF has been corrected (-0.864 $\mathrm{W\,m^{-2}}$ $\rightarrow$ -1.325 $\mathrm{W\,m^{-2}}$).

2 Introduction

Main points

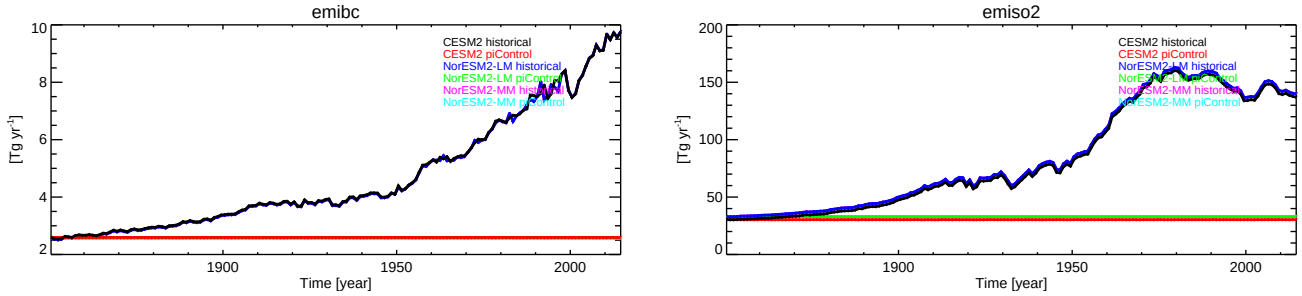
1. The emissions of SO_2, SO_4, and BC (OM not checked) are very similar between CESM2 and NorESM2.
2. The increase in SO_4 load over the historical period, is considerably larger in NorESM2 than in CESM2 (around 20 %).
3. The increase in total aerosol optical depth over the historical period is considerably larger in NorESM2 than in CESM2. Especially the optical depth of SO_4 and OM are considerably larger in NorESM2 than in CESM2.
4. The increase in BC optical depth is smaller in NorESM2 than in CESM2. The total aerosol absorption optical depth is smaller in NorESM2 than in CESM2.

Remarks

1. Not all data was available for NorESM2-MM. Therefore it is not included in all the plots.
2. Optical depth data in NorESM2-LM for the piControl is only available from equivalent year 1710 onwards.

3 Emissions

Figure 1 shows the evolution of the global mean emission strength over the historical period. From the figures shown it is clear that the anthropogenic emissions are very similar in CESM2, NorESM2-LM, and NorESM2-MM. DMS emissions in CESM2 are considerably lower, possibly contributing to the lower SO_4 burden in the piControl.



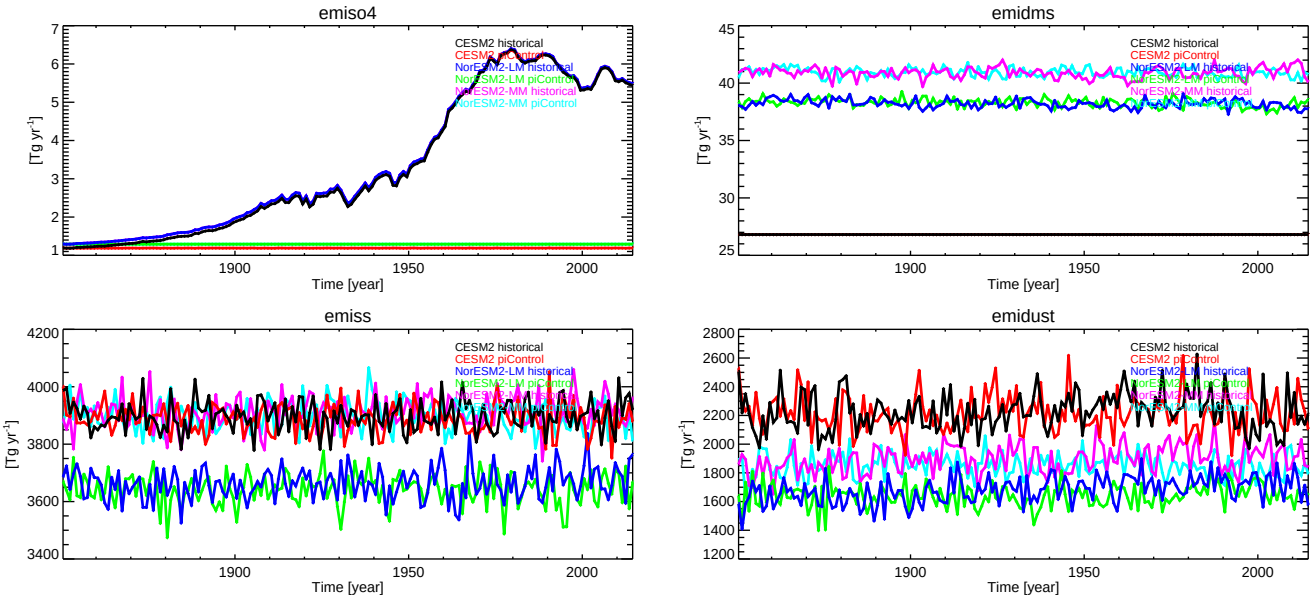


Figure 1 : Emission strenght of BC, SO_2, SO_4, DMS, sea-salt, and dust. The shown models are CESM2, NorESM2-LM, and NorESM2-MM. The experiments are historical and piControl.

4 Aerosol loads

Figure 2 shows the evoluton of the global total aeosol load of SO_4, sea-salt, and dust (not all data was downloaded to show also OM). The historical increase in SO_4 burden is around 20 % larger in NorESM2-LM than in CESM2.

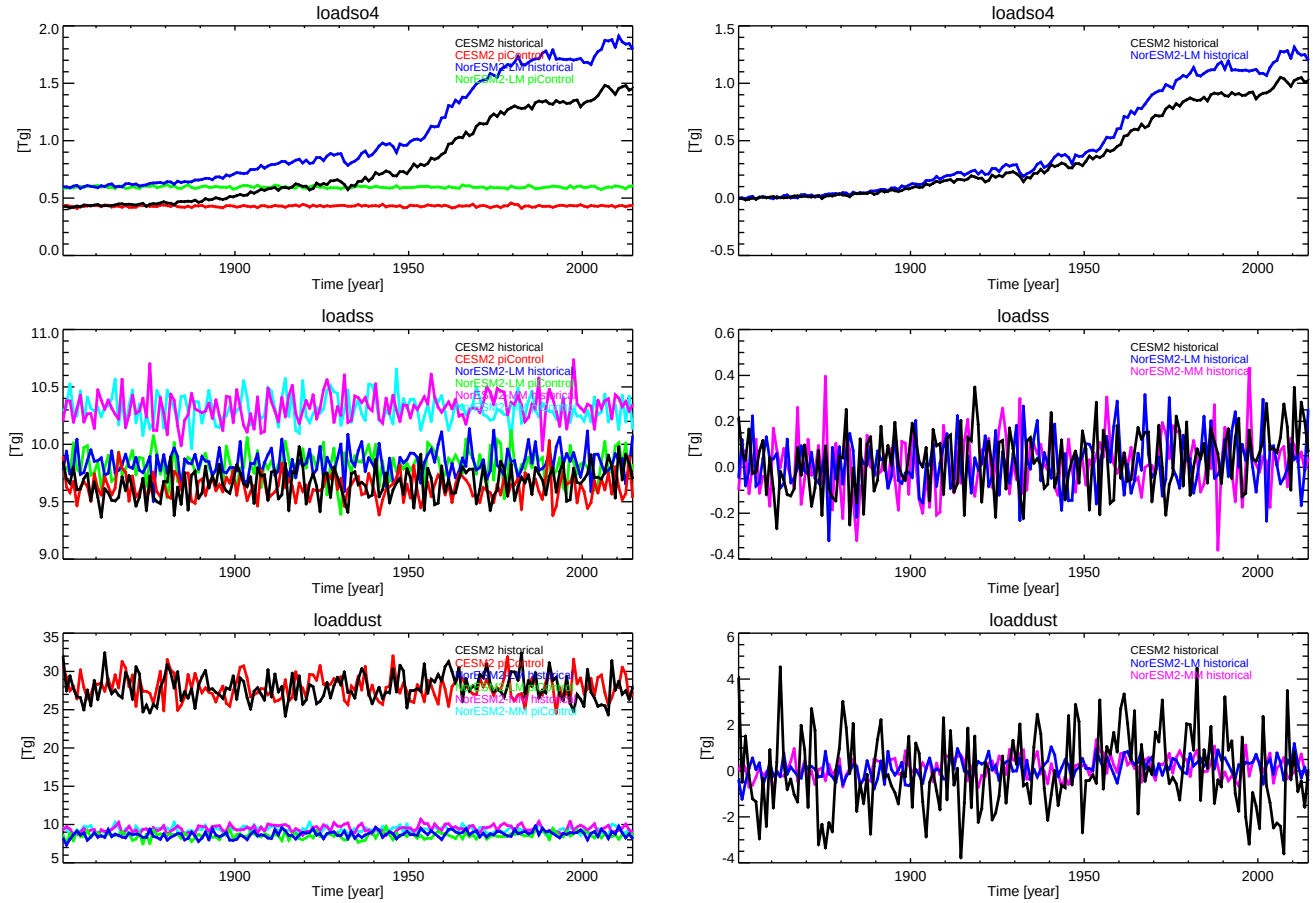


Figure 2 : Atmospheric aerosol load of SO_4, sea-salt, and dust. The shown models are CESM2, NorESM2-LM, and NorESM2-MM. Left : the experiments historical and piControl are shown seperately. Right : the difference between historical and piControl.

5 Aerosol optical depth

Figure 3 shows the evolution of the total aerosol optical depth. The aerosol optical depth is considerably larger in NorESM2-LM than in CESM2.

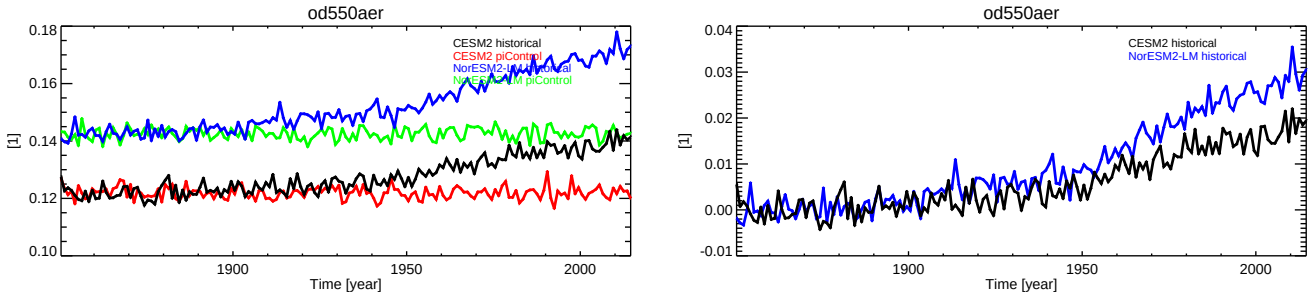
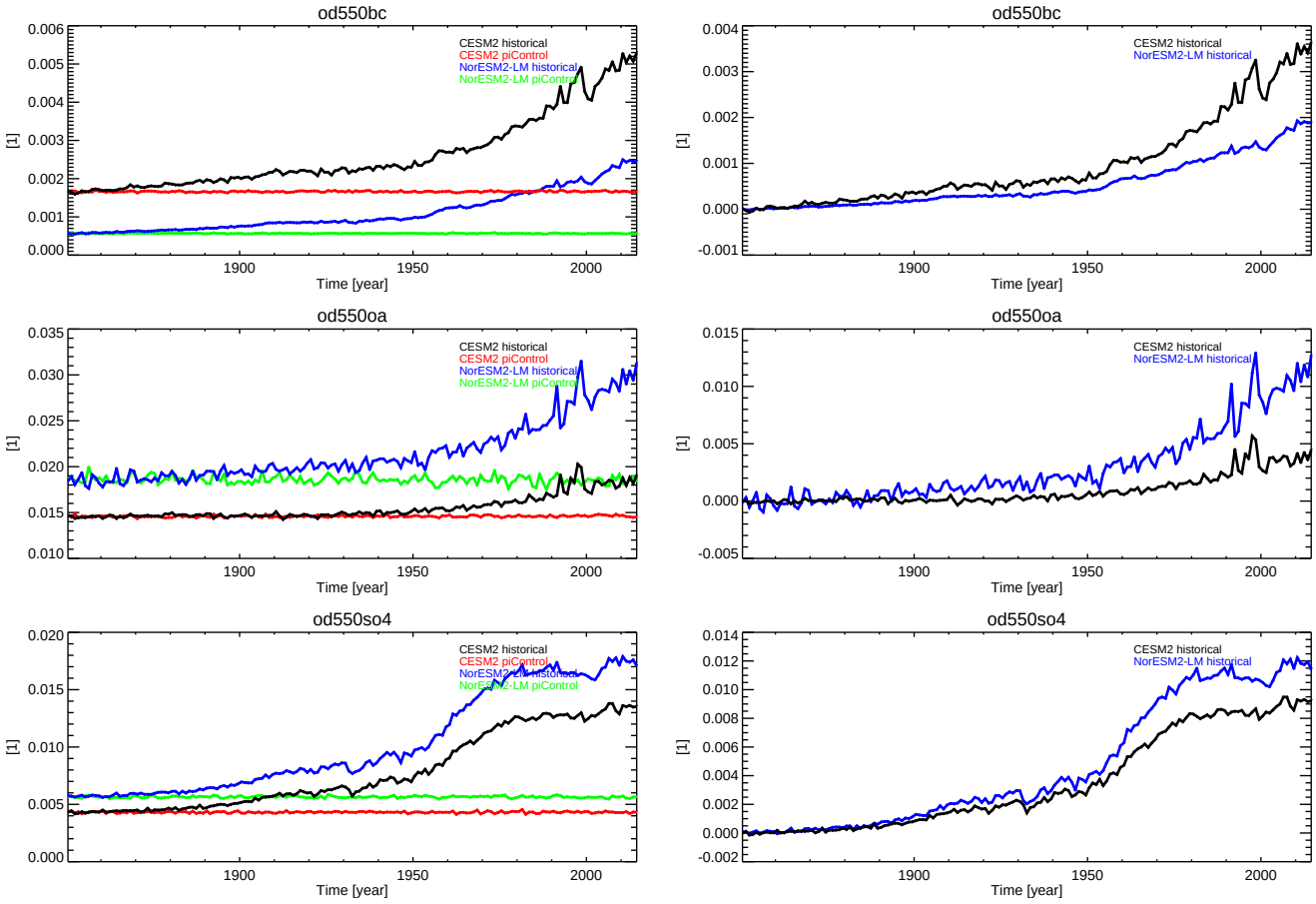


Figure 3 : Total aerosol optical depth. The shown models are CESM2, and NorESM2-LM. Left : the experiments historical and piControl are shown seperately. Right : the difference between historical and piControl.

Figure 4 shows the evolution of the speciated aerosol optical depth, i.e., for BC, OM, SO_4, and dust. It shows that BC optical depth is smaller in NorESM2-LM than in CESM2, that OM and SO_4 optical depth is larger in NorESM2-LM than in CESM2. The number for OM optical depth contains for NorESM2-LM probably the contribution from SOA, whereas for CESM2 it probably does not. However the optical depth contribution from SOA in CESM2 is probably small (see Table 1).



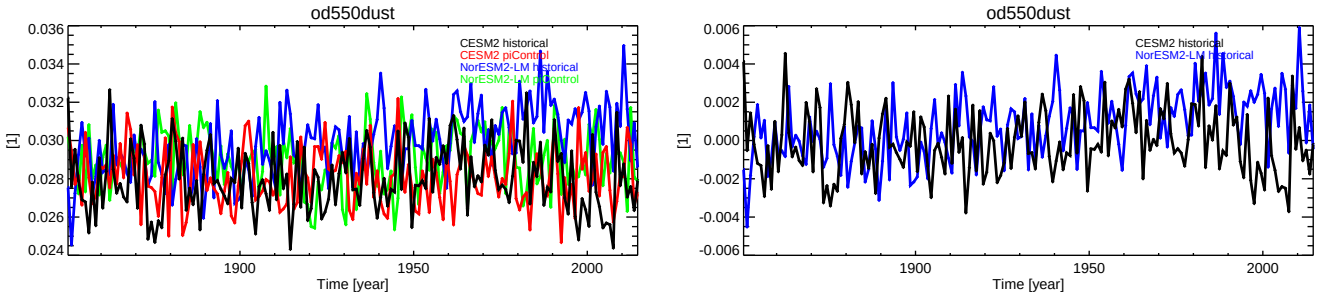


Figure 4 : Speciated aerosol optical depth of BC, OM, SO_4, and dust. The shown models are CESM2 and NorESM2-LM. Left : the experiments historical and piControl are shown seperately. Right : the difference between historical and piControl.

Figure 5 shows the evolution of the total aerosol absorption optical depth. It shows that the total aerosol absorption obtical depth is considerably lower in NorESM2-LM than in CESM2. This agrees with the lower BC optical depth seen in Fig. 4.

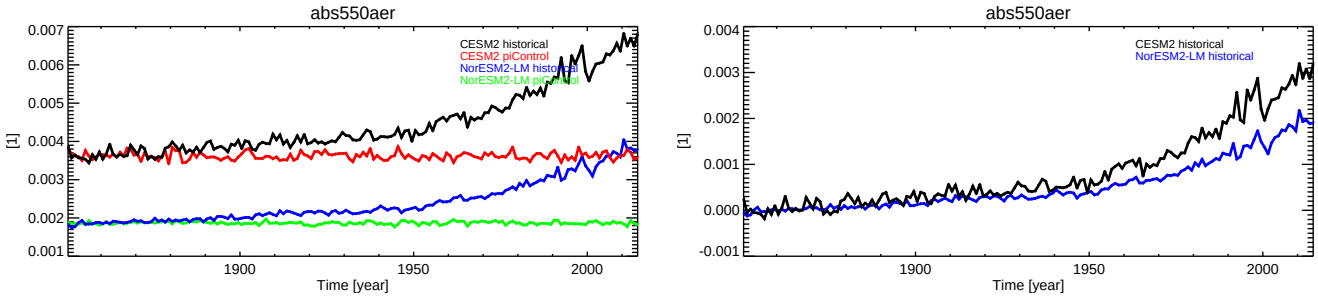
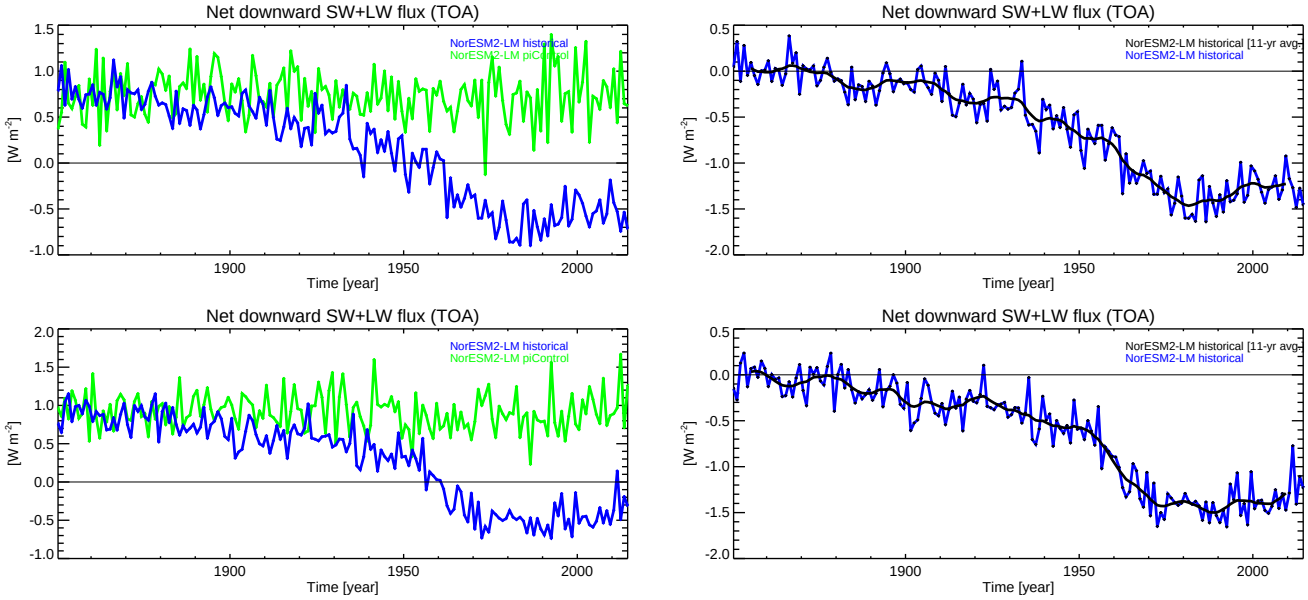


Figure 5 : Total aerosol absorption optical depth. The shown models are CESM2 and NorESM2-LM. Left : the experiments historical and piControl are shown seperately. Right : the difference between historical and piControl.

6 Aerosol forcing

Figure 6 shows the TOA imbalance from the atmosphere-only simulations piClim-control and piClim-histaer in NorESM2-LM. Their difference is an estimate of the aerosol ERF. We used 3 ensemble members for piClim-aer, and only the ensemble avearge is shown. We have also plotted the 11-year running mean.

Unfortunately, the piClim-histaer experiment is not available for CESM2 (on nird, I will check ESGF again), so no equivalent plot could be made vor CESM2.



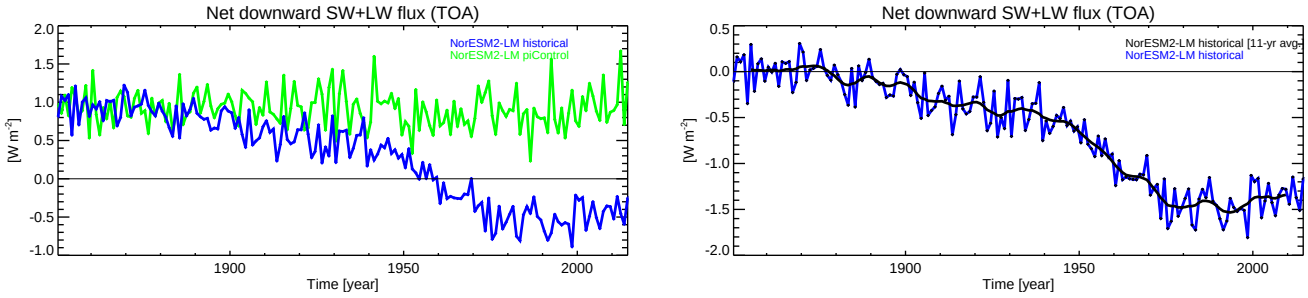


Figure 6 : Left : TOA imbalance in atmosphere-only piClim-control and piClim-histaer in NorESM2-LM. Right : aerosol ERF, calculated as difference between piClim-histaer and piClim-control.

7 Aerosol forcing and aerosol AOD in 2014

Table 1 shows the aerosol ERF and optical depths in CESM2 and NorESM2-LM, based on the 30-year piClim-control and piClim-aer simulations. The aerosol perturbation represent the 2014 conditions. It shows that the aerosol ERF is considerably more negative in NorESM2-LM than in CESM2. Also the aerosol optical depth is considerably larger in NorESM2-LM : it is mainly caused by a larger OM (more than 100 % larger) and SO_4 (33 % higher) optical depth in NorESM2-LM than in CESM2. The aerosol absorption optical depth is considerably smaller in NorESM2-LM than in CESM2.

TABLE 1 : Anthropogenic aerosol RF and anthropogenci aerosol optical depths. Values are based on the difference between the piClim-aer and piClim-control experiment. Results for CESM2 and NorESM2-LM.

	Unit	CESM2	NorESM2-LM
TOA imbalacne	[W m^{-2}]	-1.325	-1.217
od550aer	[-]	0.0127	0.0218
ad550abs	[-]	0.0031	0.0018
od550bc	[-]	0.0037	0.0018
od550oa	[-]	0.0040	0.0093
od550soa	[-]	0.0008	–
od550so4	[-]	0.0075	0.0101
od550dust	[-]	-0.0017	0.0007
od550ss	[-]	–	-0.0001

8 Indirect aerosol effect

The impact on the indirect aerosol effect is not directly related to the differences seen in optical depth. However, the larger SO_4 and OM burden might probably also lead to a stronger indirect effect in NorESM2-LM than in CESM2.