CMIP6 emissions in NorESM2 (version1.0)

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Abstract

We describe how the CMIP6 emissions for NorESM have been made.

1 Introduction

We describe here shortly how the emissions from input4MIPs are converted into emission files for NorESM. The emissions from input4MIPS treated here are anthropogenic emissions, aircraft emissions, and biomass burning emissions. The emissions from volcanoes (they are not provided by input4MIPS but taken from Dentener et al. [2006], are also described.

The emissions of oceanic POM, DMS, sea-salt, dust, and biogenic emissions of isoprene and monoterpenenes are described interactively in the model, and should not be provided by files in NorESM.

The emissions of H_2O (from CH_4 oxidation) should also be taken into account in NorESM2. Therefore, the standard CESM emission files should be used.

The next table gives an overview of the different activities and sectors treated.

Table : overview of the different activities and sectors.

Activity	Sector	Description
Anthropogenic	AGR	Agriculture
	ENE	Energy
	IND	Industrial
	TRA	Transportation
	DOM	Residential, Commercial, Other
	SOL	Solvents production and application
	WST	Waste
	SHP	International Shipping
Biomass burning	AGRI	agricultural waste burning
	BORF	boreal forest fires
	DEFO	fires used in deforestation
	PEAT	peat fires
	SAVA	savanna, grassland, and shrubland fires
	TEMF	temperate forest fires
Volcanoes	CONT	Outgassing from continuously outgassing volcanoes
	EXPL	Outgassing from explosive volcanoes
Aircraft	ALL	Aircraft emissions

The next table shows an overview of the species emitted in NorESM for different activities/sectors.

Table : overview of the emissions in NorESM. (sb.) indicates that part of the emissions come from solid biofuel.

Activity	Sector	# levels	SO_2	SO_4	BC_N	BC_AX	BC_NI	OM_NI	Remark
Anthropogenic	AGR	–	SO_2	SO_4	BC_N	BC_AX		OM_NI	
	DOM	–	SO_2	SO_4	BC_N	BC_AX		OM_NI	(sb.)
	ENE	8	SO_2	SO_4	BC_N	BC_AX		OM_NI	(sb.)
	IND	8	SO_2	SO_4	BC_N	BC_AX		OM_NI	(sb.)
	SHP	–	SO_2	SO_4	BC_N	BC_AX		OM_NI	
	SOL	–	SO_2	SO_4	BC_N	BC_AX		OM_NI	
	TRA	–	SO_2	SO_4	BC_N	BC_AX		OM_NI	(sb.)
	WST	–	SO_2	SO_4	BC_N	BC_AX		OM_NI	
Biomass burning	AGRI	6	SO_2	SO_4			BC_NI	OM_NI	
	PEAT	6	SO_2	SO_4			BC_NI	OM_NI	
	SAVA	6	SO_2	SO_4			BC_NI	OM_NI	
	DEFO	6	SO_2	SO_4			BC_NI	OM_NI	
	TEMF	6	SO_2	SO_4			BC_NI	OM_NI	
	BORF	6	SO_2	SO_4			BC_NI	OM_NI	
Volcanoes	CONT	30	SO_2	SO_4					
	EXPL	30	SO_2	SO_4					
Aircraft		25	SO_2	SO_4	BC_N	BC_AX		OM_NI	

Table : overview of the conversions between emissions as given in input4MIPs, and emissions in NorESM.

Activity	input4MIPs	NorESM					
		SO_2	SO_4	BC_N	BC_AX	BC_NI	OM_NI
Anthropogenic	SO_2	97.5 %	2.5 %				
	BC			90 %	10 %		
	OC						100 %
Biomass burning	SO_2	97.5 %	2.5 %				
	BC					100 %	
	OC						100 %
Volcanoes	SO_2	97.5 %	2.5 %				
Aircraft	SO_2	97.5 %	2.5 %				
	BC			90 %	10 %		
	OC						100 %

2 Main characteristics

Resolution : 0.9x1.25 and 1.9x2.5 As te emission reading routine is not mass conservative in NorESM (CESM), emissions have been generated on two different resolutions.

Emissions of BC as BC_N/BC_AX versus BC_NI Currently, emissions of BC from the surface anthropogenic activity and aircraft, are emitted as BC_N (90 %) and BC_AX (10 %). Emissions from biomassburning are emitted as BC_NI. **Shouldn't part (coming from solid biofuel) of the anthropogenic emissions also be emitted as BC_NI?**

OM emissions In general we apply a factor of 1.4 for the conversion of OC→OM when it is fossil fuel burning, and a factor of 2.6 when it is biomass burning. **However, should for some of the anthropogenic acitivies (coming from solid biofuel) also not a factor of 2.6 be used?**

NorESM_c1.2 and NorESM-dev NorESM_c1.2 assumes that emission files contain OC, and applies in the model the 1.4 and 2.6 factors. The factor 1.4 is always applied when the species is OM_NI. An additional increase from 1.4 to 2.6 is applied when the name in the emission files is '**emiss_awb**' (for surface emissions), '**grassfire**', or '**forestfire**' (for profile emissions).

When creating the new emissions, the namings '**emiss_awb**', '**grassfire**' and '**forestfire**' will not be used anymore. Therefore, when creating CMIP6 emissions for NorESM_c1.2, the factor 2.6 should already be applied in advance.

Vertical levels in NorESM_c1.2 NorESM_c1.2 allows only one inputfile per species (there can be multiple fields in the file). It implies that all 3-dimenisonal emissions should be on the same vertical grid. We have chosen 21 layers, with the following spacing (km) : 0.000, 0.126, 0.278, 0.454, 0.654, 0.879, 1.127, 1.398, 1.884, 2.579, 3.471, 4.548, 5.765, 6.946, 8., 9., 10., 11., 12., 13., 14., 15.

Topography For the emissions of aircraft and volcanoes, we now take into account the local topography. This implies in general that over Greenland, the Rocky Mountains, the Andes, ... emissions will end up in a lower model level than previously. The files describing the topograpghy which have been used are :
fv_0.9x1.25_nc3000_Nsw042_Nrs008_Co060_Fi001_ZR_sgh30_24km_GRNL_c170103.nc
fv_1.9x2.5_nc3000_Nsw084_Nrs016_Co120_Fi001_ZR_061116.nc

Emission years There are no emissions for the year 2015 from anthropogenic and aircraft activities – all other sectors do. Therefore, we took emissions from the year 2014 for those two sectors when creating emissions files for the year 2015.

Constants used The emissions files from input4MIPs contain emissions amounts in units of kg. As NorESM needs emission amounts in molecules, the constants mentioned it the following table have been used.

Table : values of constants.

Molar weight of SO_2	$64\,g\,mol^{-1}$
Molar weight of SO_4	$96\,g\,mol^{-1}$
Molar weight of BC	$12\,g\,mol^{-1}$
Molar weight of OC	$12\,g\,mol^{-1}$
Avogadros constant	6.022×10^{23}
Lenght of year	365.25 days

3 Overview per activity

3.1 Anthropogenic

Original resolution The original horizontal resolution is 0.5°×0.5°. The original input4MIPs data give no information on the vertical distribution of the emissions.

Solid biofuel For the contribution of solid biofuel, shouldn't we increase the OM/OC ratio to 2.6, and emit BC into BC_NI instead od BC_N/BC_AX? The next table indicates the contribution of solid biofuel emissions for OC and BC.

Table : contribution of solid biofuel emissions in OC and BC emissions in input4MIPS data set for the year 2000.

	OC total [$Tg\,yr^{-1}$]	OC biofuel [$Tg\,yr^{-1}$]	OC biofuel [%]	BC total [$Tg\,yr^{-1}$]	BC biofuel [$Tg\,yr^{-1}$]	BC biofuel [%]
AGR	0	0	–	0	0	–
DOM	9.372	8.859	94.53	3.081	2.506	81.34
ENE	0.9681	0.1364	14.09	0.6646	0.2435	36.64
IND	1.093	0.7942	72.66	0.5734	0.1401	24.43
SHP	0.1056	0	0	0.1389	0	0
SOL	0	0	–	0	0	–
TRA	0.4529	0.00006381	0.014	0.931	0.00001134	0.001
WST	2.636	0	0	0.4227	0	0
ALL	14.63	9.790	66.92	5.811	2.670	45.94

Industry and energy production Two of the eight sectors (ENE and IND) have a vertical profile. We use 8 layers equally distributed over the range 0–400 m, with emissions different from zero only in levels 4–7 (150–350 m). Dentener et al. [2006, Sect. 7] suggest to emit fossil fuel emissions from industry and power-plants (energy production) between 100 and 300 m above the surface.

Table : emission profiles for emissions from industry and energy production.

	0–50 m	50-100 m	100–150 m	150–200 m	200–250 m	250–300 m	300–350 m	350–400 m
Industry	0	0	0	1	1	1	1	0
Energy	0	0	0	1	1	1	1	0

Surface emissions The 6 other sectors have their emissions all at the surface.

3.2 Biomas burning

Original resolution The horizontal resolution for biomass burning is 0.25°×0.25°. The input4MIPs data has no information on the altitude of the emissions.

Vertical profile We use 6 layers to distribute the emissions vertically. We base our approach on Dentener et al. [2006]. They distinguished the following five categories

Table : emission profiles from Dentener et al. [2006, Table 4].

	0–0.1 km	0.1–0.5 km	0.5–1 km	1–2 km	2–3 km	3–6 km
	[%]	[%]	[%]	[%]	[%]	[%]
Agricultural waste	100	0	0	0	0	0
Tropical (30°S–30°N)	20	40	40	0	0	0
Temperate (30°N–60°N, 30°S–60°S	20	20	20	40	0	0
Boreal (Eurasia)	10	10	20	20	40	0
Boreal (Canada)	10	10	10	10	20	40

We attribute the following profiles to the biomass burning emissions. **We do not used the highest profile of Dentener et al. [2006] (Boreal forest in Canada), but use the Eurasian Boreal profile instead. Also for the categories PEAT and DEFO we had to choose one of the profiles of Dentener et al. [2006]**.

Table : emission profiles for emissions from biomass burning.

	0–0.1 km	0.1–0.5 km	0.5–1 km	1–2 km	2–3 km	3–6 km
	[%]	[%]	[%]	[%]	[%]	[%]
AGRI	100	0	0	0	0	0
PEAT	100	0	0	0	0	0
SAVA	20	40	40	0	0	0
DEFO	20	40	40	0	0	0
TEMF	20	20	20	40	0	0
BORF	10	10	20	20	40	0

3.3 Volcanoes

Type of volcanoes We emit both from continuous outgassing volcanoes, but also from explosive volcanoes. The emissions are based on the files continuous_volc.1x1.ascii explosive_volc.1x1.ascii from Dentener et al. [2006].

The total emission amount from continuous volcanoes is $25.2\,Tg[SO_2]\,yr^{-1}$, and $4\,Tg[SO_2]\,yr^{-1}$ from the explosive volcanoes.

The emissions from explosive volcanoes should be placed between 500 and 1500 m above the volcano peak. For continuous outgassing volcanoes, emissions should be placed in the upper third of the volcano.

Technical comment We have interpreted the emission data set as containing emissions per 1x1 gridbox, where the gridbox was called by its lowerleft corner. There was one volcano in Turkey, where the top and bottom of the emission plume were both 0 m. We have put the top of the plume at 10 m, such that the emissions will all end up in the lowest model layer.

Vertical profile We use 30 layers equally distributed between 0–7.5 km (every layer has a thickness of 250 m).

3.4 Aircraft

Original resolution 0.5×0.5 × L25

Topography The original emissions span the range 0–15.25 km. For cruise-altitude emissions, the interpretation of the vertical coordinate seems to be above sealevel : emissions in the North-Atlantic flight corridorindicate no lowering in height when flying over Greenland. However, for the low altitude emissions the interpretation of the vertical coordinates seems to be as "height above local topography" : airport emissions in Denver (US) and La Paz (Bolivia) end up in the lowest level in the data set.

The approach taken, is to interprete the original informations as "above sealevel", and use the local topography to adjust the emission height. Emissions that fall below the topography (e.g., in Denver and La Paz), are put in the lowest level.

Vertical profile The original data is on 25 levels (0–15.25 km)(vertical spacing is 610 m). We keep this vertical resolution.

4 Comparison w.r.t CESM

Some differences and similarities between the emission treatment in CESM and in NorESM

1. Vertical resolution : we use the same vertical resolution for the volcanoes (30 layers), aircraft (25 layers), and anthropogenic (8 layers). However the vertical resolution for the biomass burning emissions is different (NorESM uses 6 layers).
2. Volcanoes : CESM has not taken into account the SO_2 emissions from explosive volcanoes (4 Tg[SO_2-equivalent] yr^{-1}).
3. Topography : CESM has not taken into account the topography for volcanic and aircraft emissions.
4. OM/OC ratio : CESM uses a constant factor of 1.4 to transform OC into OM emissions.
5. SO_4 emissions : CESM puts the emissions of SO_4 in two different modes (so4(a1) and so4(a2)).
6. Aircraft : CESM uses no OM or SO_4 emissions from aircraft, only SO_2 and BC.

References

Dentener, F., Kinne, S., Bond, T., Boucher, O., Cofala, J., Generoso, S., Ginoux, P., Gong, S., Hoelzemann, J. J., Ito, A., Marelli, L., Penner, J. E., Putaud, J.-P., Textor, C., Schulz, M., van der Werf, G. R., and Wilson, J.: Emissions of primary aerosol and precursor gases in the years 2000 and 1750 prescribed data-sets for AeroCom, Atmos. Chem. Phys., 6, 4321–4344, doi:10.5194/acp-6-4321-2006, 2006.