Supplement of

Projections of shipping emissions and the related impact on air pollution and human health in the Nordic region

Geels et al.

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1 Trend in emissions and overview of model setup

	% change 2015 to 2030	% change 2015 to 2050
d01/Northern Hemisphere		
SO_x	-3	16
NO_x	-5	19
NH_3	17	34
$PPM_{2.5}$	-2	11
d02/Europe		
SO_x	-12	-5
NO_x	-28	-33
NH_3	2	5
$PPM_{2.5}$	12	29
d03/Nordic area		
SO_x	-3	7
NO_x	-25	-23
NH_3	0	3
$PPM_{2.5}$	13	24

Table S1: Development in land based ECLIPSE V5a emissions as a %-change in the total emissions in the three DEHM domains.

Year	Emissions - land	Emissions - shipping	Run name
2015	**ECLIPSEV5a CLE**	**BAU**	**2015BAU**
2015	**ECLIPSEV5a CLE**	**As above and reduced shipping**	**2015BAU_70%**
2030	ECLIPSEV5a CLE	BAU	2030BAU
2030	ECLIPSEV5a CLE	As above and reduced shipping	2030BAU_70%
2030	ECLIPSEV5a CLE	BAU incl. Arctic div. routes	2030BAU_PolarDiv
2030	ECLIPSEV5a CLE	As above and reduced shipping	2030BAU_PolarDiv_70%
2030	ECLIPSEV5a CLE	SECA incl. Arctic div. routes	2030BAU_SECA_PolarDiv
2030	ECLIPSEV5a CLE	As above and reduced shipping	2030BAU_SECA_PolarDiv_70%
2030	ECLIPSEV5a CLE	HFO ban incl. Arctic div. routes	2030BAU_HFO_Ban_PolarDiv
2030	ECLIPSEV5a CLE	As above and reduced shipping	2030BAU_HFO_Ban_PolarDiv_70%
2030	ECLIPSEV5a CLE	HiG traffic incl. Arctic div. routes	2030HiG_PolarDiv
2030	ECLIPSEV5a CLE	As above and reduced shipping	2030HiG_PolarDiv_70%
2050	**ECLIPSEV5a CLE**	**BAU**	**2050BAU**
2050	**ECLIPSEV5a CLE**	**As above and reduced shipping**	**2050BAU_70%**
2050	**ECLIPSEV5a CLE**	**BAU incl. Arctic div. routes**	**2050BAU_PolarDiv**
2050	**ECLIPSEV5a CLE**	**As above and reduced shipping**	**2050BAU_PolarDiv_70%**
2050	**ECLIPSEV5a CLE**	**SECA incl. Arctic div. routes**	**2050BAU_SECA_PolarDiv**
2050	**ECLIPSEV5a CLE**	**As above and reduced shipping**	**2050BAU_SECA_PolarDiv_70%**
2050	**ECLIPSEV5a CLE**	**HFO ban incl. Arctic div. routes**	**2050BAU_HFO_Ban_PolarDiv**
2050	**ECLIPSEV5a CLE**	**As above and reduced shipping**	**2050BAU_HFO_Ban_PolarDiv_70%**
2050	**ECLIPSEV5a CLE**	**HiG traffic incl. Arctic div. routes**	**2050HiG_PolarDiv**
2050	**ECLIPSEV5a CLE**	**As above and reduced shipping**	**2050HiG_PolarDiv_70%**

Table S2: Overview of the emissions included in the different model runs carried out with the DEHM model. The MATCH model has been run for a subset.

2 Evaluation of the DEHM model

The DEHM model is continuously evaluated against observations from international monitoring networks. In Fig. S1 and S2 an overall evaluation of DEHM against observations from the EMEP network within Europe is given as an average over all the available data for 2015. The comparison between model and observations are shown for the components that are included in the health assessment ($PM_{2.5}$, NO_2, and O_3).

The total $PM_{2.5}$ in the model is calculated as the sum of the species: primary emitted mineral dust, black carbon (fresh and aged), organic carbon, sea salt, and the secondary formed particles and secondary formed organic aerosols. The overall variability of $PM_{2.5}$ is seen to be captured by the model, with a correlation coefficient of 0.79. The model tends to underestimate the level during the summer months and the overall fractional bias is slightly negative. For NO_2 the seasonal pattern with lower values in the summer is reproduced by the model (with a correlation of 0.73), but the model over predicts some of the peaks, which leads to a slightly positive bias (FB of 0.03). For O_3 the comparison is made for daily, hourly as well as daily maximum values, as these maximum values are relevant for the health impacts. They all show a pronounced seasonal variation with highest values in the warmer months. This is replicated by the model and correlations above 0.90 are seen for all three components. The DEHM models is seen to underestimate the daily maximum slightly, while a small overestimation is seen for the daily and hourly mean values.

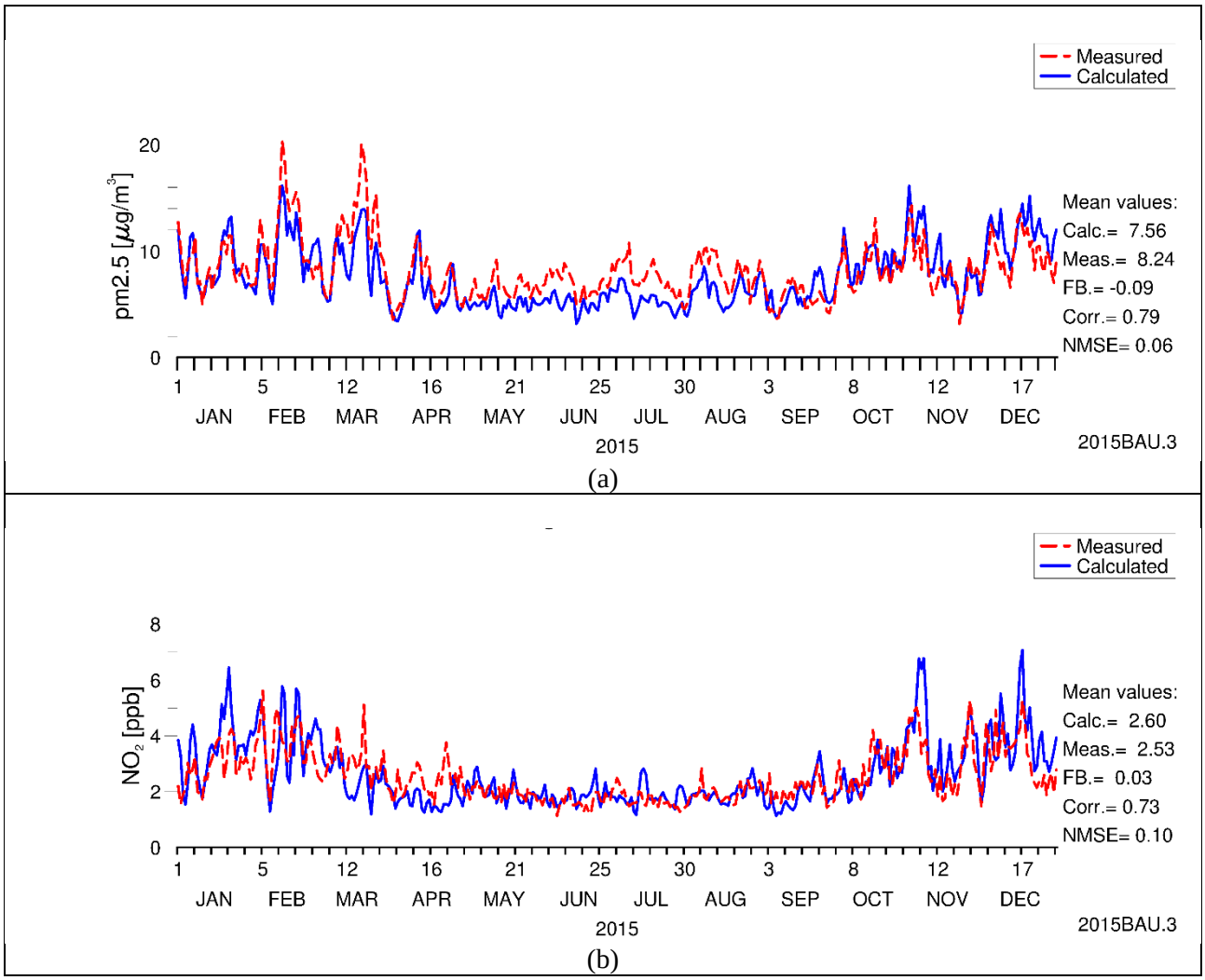

Figure S1: A comparison between DEHM results and observations as daily mean values for the year 2015. Shown as average values in space over all the available observations from the EMEP network. Here for the total $PM_{2.5}$ and NO_2 in µg/m^3. Standard statistical values are given to the right: the mean values, the Fractional Bias (FB), the correlation coefficient (Corr) and the Normalised Mean Square Error (NMSE).

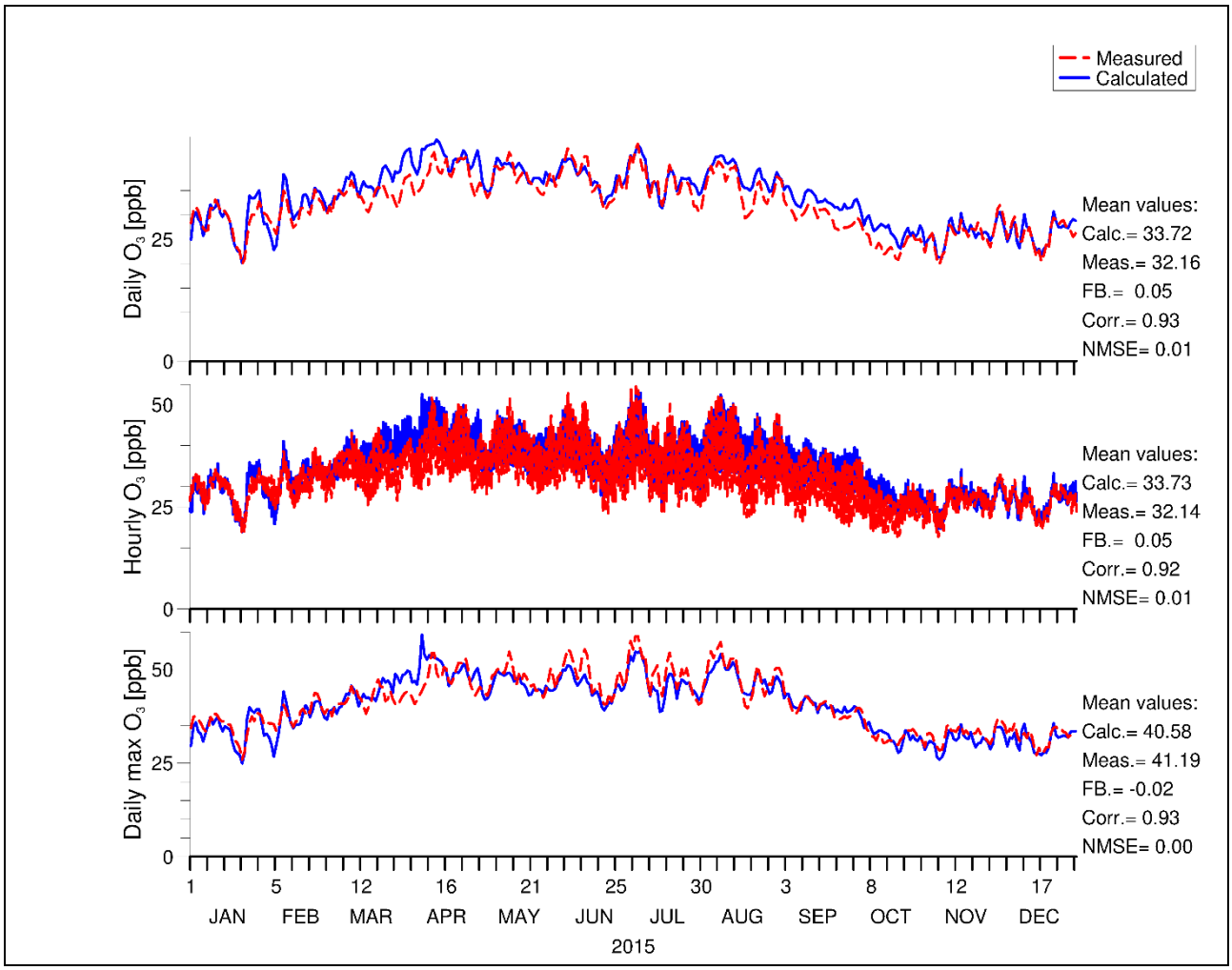

Figure S2: A comparison between DEHM results and observations for the year 2015. Shown as average values in space over all the available observations from the EMEP network. Here for O_3 as both daily and hourly mean values as well as daily maximum in ppb. Standard statistical values are given to the right: the mean values, the Fractional Bias (FB), the correlation coefficient (Corr) and the Normalised Mean Square Error (NMSE).

3 Evaluation of the MATCH model

The MATCH model is a model used for various applications, including operational air quality forecasting and is a member of the CAMS forecasting ensemble, mapping of historical exposure to air pollution including measurement model fusion methodologies, scenario simulations, dispersion of volcanic ashes and nuclear emergency preparedness. It is has been evaluated against observations from international monitoring networks for all applications and typically perform among the best Eulerian chemistry and transport models in Europe (e.g. Otero et al., 2017; Theobald et al, 2019). The current model configuration was evaluated in the EURODELTA trends exercise as described in the main paper.

In this section we present an evaluation for the smaller grid used in this study, for the BAU2015 simulation. Hourly observations for 2015 from Norway, Sweden and Denmark were extracted from the EMEP web page and were used to evaluate the model performance at the sites. The site-specific evaluation statistics were averaged and is presented in Table A3.

	Obs (ppbv)	Mod (ppbv)	%bias	r	# stns	# values
hourly ozone	29.9	31.7	5.8	0.71	16	133817
daily mean	29.9	31.7	5.8	0.80	16	5718
daily maximum ozone	37.1	37.2	0.16	0.78	16	5718

Table S3: Evaluation of the MATCH BAU2015 simulation for Scandinavia based on measured hourly ozone at EMEP sites (Extracted from https://projects.nilu.no//ccc/emepdata.html, Mars 2019).

4 Population data

Population data used in the EVA system are based on data from EuroStat. The population distribution from 2011 have been scaled with national totals for 2015 (see table A1) within the applied 16.67 km 16.67 km grid. The Faroe Islands is not included in the Eurostat data, but the population has here been added to the grid covering the Faroe Islands. The final population distribution can be seen in Figure S3.

Country	Total population
Denmark	5645766
Norway	5151500
Sweden	9922787
Finland	5447248
Iceland	328261
Faroe Islands	49000

Table S4: The total population in the Nordic countries for year 2015.

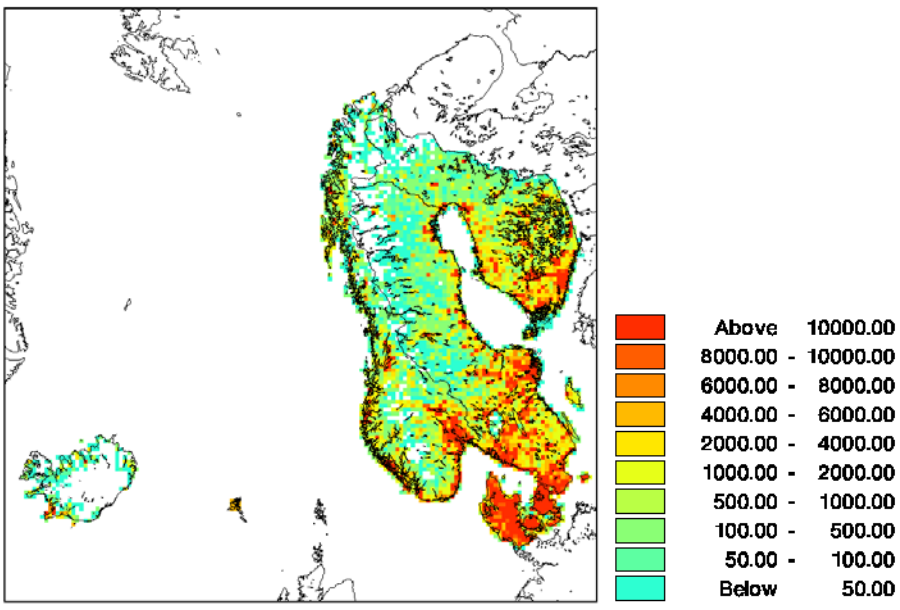

Figure S3: The population distribution in the 16.67 km x 16.67 km grid used for the health assessment.