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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Particle number concentrations over Europe in 2030: the role of emissions and new particle formation" *by* L. Ahlm et al.

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Response to comments by reviewer 2

We thank reviewer 2 for comments and suggestions for improvement of our manuscript. The comments from the reviewer followed by our responses to the comments can be seen below.

Comment 1: In section 3.2, authors mention that the Pan–European anthropogenic Particle Number Emission Inventory (Kulmala et al., 2011) is used for the particles whose diameters range 10-300 nm, and for the larger particles, the Pan-European

Carbonaceous Aerosol Inventory (Kulmala et al., 2011) used for PM2.5 emissions. Is this applied regardless of types of PM2.5 species? How authors treat particle distribution from boundary condition. This might be important when dust emissions play an important role in Europe.

Response: The inventory used in this study merges the mass and number inventories produced during EUCAARI (Kulmala et al., 2011) producing a number emissions inventory covering the 10 nm to 10 um size range and a consistent mass composition-resolved inventory also covering the complete size range. Boundary conditions include consistent number and composition distributions based on the corresponding aerosol types (remote continental, free tropospheric and marine).

Comment 2: From Fig. 1 and Fig. 3, the west Spain and East Europe including Bulgaria and Greece are staying higher level of Ntot while emission levels are reduced. I think that authors mention that it is due to reduction of condensational sink, and they relate this to the receptor sites of Ispra and Cabauw. I think that it is good and strong points of this paper. Readers can understand well about the results of Ntot. But I am curious about why high level of N100 is kept to be maintained around the area of the south east England, Belgium, and Netherland while emission is reduced. It looks this area is high-lightened while other area N100 level went down along the reduction of emission level. Is this because there are strong sea-salt emissions whose diameter is bigger than 100 nm around these region or any other direct PM2.5 emissions? I hope authors also discuss the N100 patterns shown in the Figures.

Response: It is correct that the three scenarios (and the 2008 simulation) have maximum N100 concentrations in south-east England, Belgium and Netherlands. However, N100 concentrations are predicted to decrease also in these areas. The percentage reductions in these countries are in fact similar to other countries in Western Europe (Fig. 2g-i). However, the predicted decrease in N100 is smaller over Western Europe than in south-eastern Europe. As discussed in Sect. 4.1.2 the reason for this is that in south-eastern Europe nucleation will shift from having a positive contribution to

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having a negative contribution on N100 for the baseline scenario (see Fig. 6c). Over Western Europe (apart from Portugal) nucleation has a very low impact on N100 concentrations, meaning that the reduced N100 concentrations in these areas must be due to the reduced primary emissions and the reduced condensational growth when SO2 emissions have been reduced according to the different scenarios.

Comment 3: From Fig. 4 (median diurnal cycle) and Fig. 5 (total number distribution probability distribution curves), authors relate the nucleation events indirectly. They address impact of nucleation to the budget of Ntot, N10, and N100 in Fig. 6. To dig out further the role of emissions of each species, authors report Table 3 and conclude that SO2 contributes most of particle number concentrations followed by PM2.5 in Europe. This result is a quite contrast to the sensitivity result of Gaydos et al. (2005). Authors in the paper found that reducing SO2 increases a number of nucleation events in Pittsburgh, PA in July as it reduces ammonia by forming ammonia sulfate. They saw that NH3 plays an important role in the nucleation events in summer in Pittsburgh, PA. It looks most of Europe has abundant ammonia than Pittsburgh from this work. I hope authors mention the general level of ammonia in Europe so that readers can get a sense of why nucleation in Europe is different from Pittsburgh, PA, United States.

Response: Gaydos et al. (2005) argued that the response of the formation of new particles by nucleation to changes in sulfur dioxide concentrations can be nonlinear during photochemically active periods (see for example Figure 5a of that paper. For areas with high sulfur dioxide concentrations, reduction of the corresponding emissions can lead to increased frequency of nucleation. However, as the sulfur dioxide availability is reduced the nucleation frequency reaches a maximum and additional emission reductions lead to decreasing nucleation. The response of nucleation to sulfur dioxide depends according to Gaydos et al. (2005) to the position of each area in this nonlinear curve. The details of this curve depend on the ammonia level, levels of other aerosol components (determining the condensational sink), temperature, etc. Our work indicates that most of Europe is currently in the left half of this curve (the part where

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nucleation frequency decreases with sulfur dioxide levels). The Eastern US is moving in that direction as its sulfur emissions are decreasing.

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