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Interactive Comment

Interactive comment on "The climate penalty for clean fossil fuel combustion" *by* W. Junkermann et al.

Anonymous Referee #2

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This manuscript has the following chain of logic: 1) in plumes downwind of powerplants equipped with flue gas cleaning technology, number concentrations of 1-10 nm particles are elevated compared to plumes from old fashioned powerplants that emit much more sulfur; 2) the nm-sized particles are efficient precursors of CCN; 3) therefore flue gas cleaning leads to modified cloud microphysics; 4) the modification is such that cloud drop number concentration is increased, their size is decreased, and thus steady precipitation is suppressed while vigorous rain events become more common.

Clearly, the subject matter of the manuscript is in the area of ACP. However, the chain of logic has so many flaws and speculative assertions that I cannot recommend acceptance. Furthermore, most of the material in the ms has been published in two earlier papers, so I very much doubt whether a publishable paper can be produced even if the erroneous logic is removed. My detailed comments are below.

1) Number concentrations of 1-10 nm particles are elevated because the particles are formed from sulfuric acid already inside the smoke stack, which does not happen with old-fashioned (non-cleaned) technology. Maybe, but I would also note that the coagulational loss of these particles must be much less because (as the authors note themselves), in the old-fashioned plumes there are much more fine and coarse particles acting as a sink for the nucleation mode particles.

2) The nm-sized particles are not very efficient precursors of CCN, only a small percentage of them (if any) will grow to CCN size range. This depends not only on the growth rate of the particles but also on the coagulational loss. The authors observation, based on following a plume until the nucleation mode grew to 20nm, is that the growth rate is about 8nm/h, and therefore the particles will grow to CCN size in a few hours. However, they assume that 50 nm particles are efficient CCN. This is only true in very clean areas such as remote marine boundary layer. In Central European conditions with a lot of primary accumulation mode particles, the lower limit for CCN is likely something like 150-200 nm. Furthermore, if the growth is only caused by sulfuric acid formed from oxidation of SO2 in the plume, the growth is likely to slow down due to dilution of the plume. And in the night the growth would stop altogether. In order to show that the nucleation mode particles in the plume will enhance CCN concentrations effectively, extensive microphysical and regional modeling should be undertaken. The COSMO-ART modeling in Junkermann et al. (2011) only followed particle growth to a few tens of nm.

3) Does flue gas cleaning lead to modified cloud microphysics? Probably yes, but this is because there are less CCN available (compared to the days of no flue gas cleaning), not more. This is self evident for anyone who has been around in e.g. Central Europe in the eighties and early nineties. The visibility was in general less than today, indicating that AOD was greater, and AOD is affected by particles larger than about 100 nm in diameter. There are many papers showing that “global dimming” has been reduced in

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Europe and in North America, where effective flue gas cleaning is taking place. See e.g. Ruckstuhl et al. (2010). Note also that AOD and CCN concentrations have been shown to be correlated (Andreae 2009).

4) The matter of what happens to cloud microphysics when CCN concentrations change is something that is very complex, and has not been addressed by the authors at all. As Ruckstuhl et al. (2010) have indicated, in Central Europe, cloud optical properties have not changed much although the CCN concentrations have been reduced. This is probably because the clouds are "saturated" with respect to CCN concentrations already at current CCN levels. However, careful cloud microphysical simulations would be needed to say anything substantive regarding this matter. Note also that even if the microphysical simulations would indicate that cloud drop concentrations and sizes change, inferences about large scale precipitation changes are purely speculative without extensive large-scale modeling.

In summary: It is interesting that there are high concentrations of fast growing nm-sized particles in cleaned power plant plumes, but this was shown already in Junkermann et al. (2011). The inferences in the current ms that this will lead to clouds which have more and smaller droplets and different precipitation properties (compared to circumstances of no flue gas cleaning) are purely speculative and very likely wrong.

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Ruckstuhl, C., J. R. Norris, and R. Philipona (2010), Is there evidence for an aerosol indirect effect during the recent aerosol optical depth decline in Europe?, J. Geophys. Res., 115, D04204, doi:10.1029/2009JD012867.

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