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Discussions

Interactive comment on "Xenon-133 and caesium-137 releases into the atmosphere from the Fukushima Dai-ichi nuclear power plant: determination of the source term, atmospheric dispersion, and deposition" *by* A. Stohl et al.

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We would like to thank Chino (2011) for the comments on our paper. Our a posteriori estimate does not attribute emissions to the various units of the damaged FD-NPP. At this stage, inferences concerning the ultimate source of the emissions can only be drawn by a comparison of our emissions with documented events at the site. At some point in time, when it is possible to remove the fuel assemblies from the pools, direct evidence will become available. Until then, analyses taking into account more nuclides (e.g., iodines and caesium-134) may help to bring additional clarification, provided sufficient measurement data are available. However, this is beyond the scope of our current study. But as suggested by Dr. Chino, sensitivity studies help to explore to what extent our inversion result relies on a priori assumptions.

We have performed two sensitivity studies:

1) Burnup changend in our calculations for the a priori from 30000 MWd/tU to 23000 MWd/tU, thus addressing also earlier comments by de Rosa et al. (2011). As analyzed in our earlier comment (Stohl et al., 2011a), this leads to a 27% reduction of the a-priori Cs-137 emissions from units 1-3, but leaves unit 4 emissions unchanged.

2) In addition, all emissions from unit 4 removed from our a priori.

The results of these sensitivity calculations are shown in Figures 1 and 2, respectively, and can be compared directly to Fig. 5 in Stohl et al. (2011b). Surprisingly, the reduced a priori emissions with revised burn-up do not lead to a reduction of the a posteriori emissions but instead increase them from 35.8 PBq to 38.1 PBq (Fig. 1). This overall increase is due mainly to small increases on 13-14 March and after 20 March, which are obviously required to compensate small emission decreases at other times. The fact that emission increases are possible with a reduced a priori is also related to the fact that we have changed the uncertainties of the a priori emissions as well, in proportion to the emissions. Overall, however, there is little change in the a posteriori emissions.

The removal of unit 4 emissions from the a priori on top of the changes in sensitivity test 1 has greater consequences (Fig. 2). There is a reduction of total emissions to 29.4 PBq, which however is still a rather modest decrease from our reference estimate of 35.8 PBq (about 15%) given the fact that a priori emissions are reduced by more than 50%. The reductions occur mainly on 15 March and later when unit 4 made a large relative contribution to the a priori emissions. However, the overall shape of the emissions required to satisfy the observations remains largely the same. Most notably, the drop in emissions from 19 to 20 March remains virtually unchanged. However, the maximum in emissions on 16 March around 0-3 UTC seen in our earlier estimate (Fig. 5 in Stohl et al., 2011b) is obviously sensitive to the assumed a priori emissions. Emissions from this maximum are redistributed partly to slightly different times with the modified a priori (Fig. 2). Notice the very low uncertainties from 15 March in this revised a priori data set. This makes it difficult for the inversion to sustain high emission fluxes. We expect that increasing them to an extent that would permit emissions as high as in our original a priori would lead to higher a posteriori emissions, possibly similar to our original results.

We hope that these sensitivity calculations help to clarify the role of the a priori assumptions in the inversion. A completely unconstrained inversion, as Chino (2011) seems to suggest (arbitrary a priori values, but with infinite uncertainty) is not very meaningful because of the sparse data situation for this problem, which makes it ill-conditioned. Even when setting the emissions to a constant value, there is still the question of how to specify the uncertainties, which are at least as important for the inversion as the emissions themselves. If they are made very large, spurious emissions can result at times with poor observation constraint. If they are made small, then the inversion will not allow substantial changes to the a priori emissions even when the observation constraint is good. Unless sufficient data can be added to this problem to constrain the source term well for all times, some a priori guidance is needed to obtain reasonable results.

Returning to the question of unit 4 emissions, we find that the 19-20 March emission drop is real, even though the magnitude and detailed temporal shape of emissions during the period 15-19 March is quite sensitive to the a priori emissions. To remove any misunderstandings, we would like to reiterate that the present analysis does not claim to prove that there are substantial emissions from the SFP of unit 4. Different hypotheses may be drawn from our findings in combination with other information on the state of the nuclear power plant. We hope that nuclear engineers can eventually find the reason for this drop.

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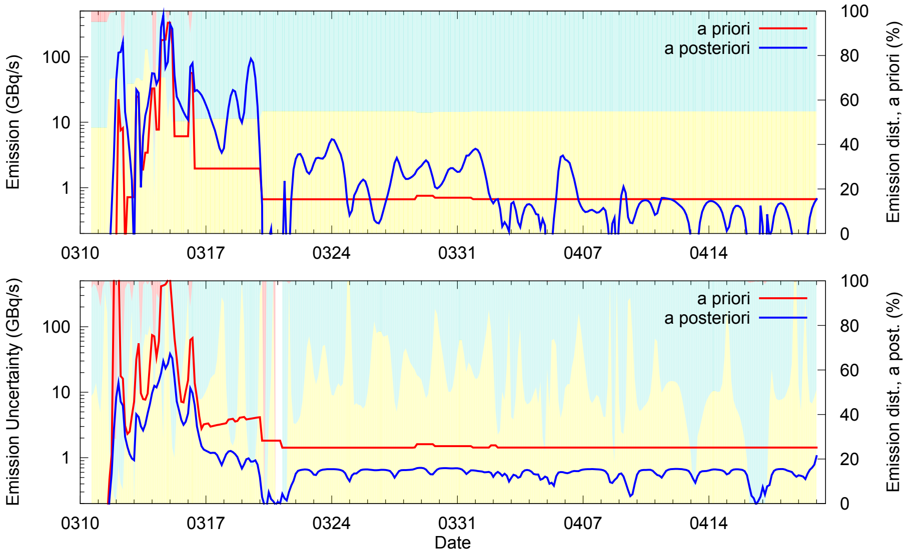

Fig. 1. Same as Fig. 5 in Stohl et al. (2011b), but with revised burn-up used to define the a priori emissions.

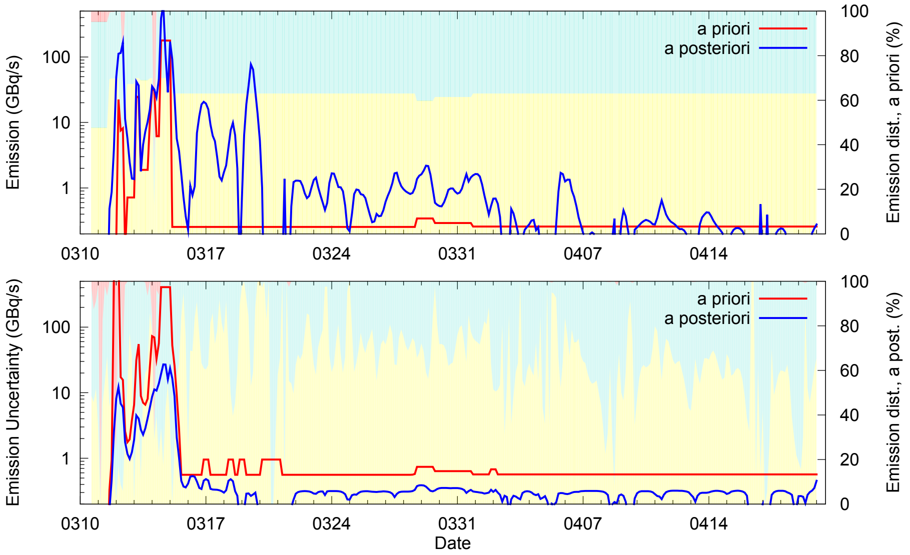

Fig. 2. Same as Fig. 1, but in addition the emissions from unit 4 were set to zero in the a priori data set.