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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

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This presentation will show the results of a paper currently under review in ACPD and some additional new results, including more data and with an independent box modeling approach to support some of the findings of the ACPD paper.

On 11 March 2011, an earthquake occurred about 130 km off the Pacific coast of Japan's main island Honshu, followed by a large tsunami. The resulting loss of electric power at the Fukushima Dai-ichi nuclear power plant (FD-NPP) developed into a disaster causing massive release of radioactivity into the atmosphere. In this study, we determine the emissions of two isotopes, the noble gas xenon-133 (^{133}Xe) and the aerosol-bound caesium-137 (^{137}Cs), which have very different release characteristics as well as behavior in the atmosphere. To determine radionuclide emissions as a function of height and time until 20 April, we made a first guess of release rates based on fuel inventories and documented accident events at the site. This first guess was subsequently improved by inverse modeling, which combined the first guess with the results of an atmospheric transport model, FLEXPART, and measurement data from several dozen stations in Japan, North America and other regions. We used both atmospheric activity concentration measurements as well as, for ^{137}Cs, measurements of bulk deposition. Regarding ^{133}Xe, we find a total release of 16.7 (uncertainty range 13.4-20.0) EBq, which is the largest radioactive noble gas release in history not associated with nuclear bomb testing. There is strong evidence that the first strong ^{133}Xe release started early, before active venting was performed. The entire noble gas inventory of reactor units 1-3 was set free into the atmosphere between 11 and 15 March 2011. For ^{137}Cs, the inversion results give a total emission of 35.8 (23.3-50.1) PBq, or about 42% of the estimated Chernobyl emission. Our results indicate that ^{137}Cs emissions peaked on 14-15 March but were generally high from 12 until 19 March, when they suddenly dropped by orders of magnitude exactly when spraying of water on the spent-fuel pool of unit 4 started. This indicates that emissions were not only coming from the damaged reactor cores, but also from the spent-fuel pool of unit 4 and confirms that the spraying was an effective countermeasure. We also explore the main dispersion and deposition patterns of the radioactive cloud, both regionally for Japan as well as for the entire Northern Hemisphere. While at first sight it seemed fortunate that westerly winds prevailed most of the time during the accident, a different picture emerges from our detailed analysis. Exactly during and following the period of the strongest ^{137}Cs emissions on 14 and 15 March as well as after another period with strong emissions on 19 March, the radioactive plume was advected over Eastern Honshu Island, where precipitation deposited a large fraction of ^{137}Cs on land surfaces. The plume was also dispersed quickly over the entire Northern Hemisphere, first reaching North America on 15 March and Europe on 22 March. In general, simulated and observed concentrations of ^{133}Xe and ^{137}Cs both at Japanese as well as at remote sites were in good quantitative agreement with each other. Altogether, we estimate that 6.4 PBq of ^{137}Cs, or 19% of the total fallout until 20 April, were deposited over Japanese land areas, while most of the rest fell over the North Pacific Ocean. Only 0.7 PBq, or 2% of the total fallout were deposited on land areas other than Japan.