Process-based modelling of the short and long-term dynamics of radiocesium in Fukushima coniferous forests

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Since Fukushima accident, a lot of field surveys have been conducted in a variety of forest stands contaminated by atmospheric radiocesium (rCs) fallouts, with a predominance of evergreen coniferous sites (eg Japanese cedars, cypresses and red pines). The thousands of observations acquired have a uniquely valuable potential for improving process-based models, although very few attempts have been published yet (Hashimoto et al. 2013, Nishina and Hayashi 2015, Calmon et al. 2015, Ota et al. 2016, Gonze et al. 2016). Such an opportunity was not given after Chernobyl because most of the surveys conducted in European forests started in the 1990’s, after short- and mid-term transfer processes had ceased to operate.

The comprehensive review of field studies of tree contamination by Gonze et al. (2017) for the period 2011-2013 was in the present research extended for coniferous forests to the period 2014-2016 and rCs profiles in soil. About 2500 spatiotemporal measurements of tree depuration fluxes, inventories or concentrations in tree and soil samples were gathered in total. To reduce spatial variability, all radioactive quantities were first normalized by the deposit estimated at each site and then log-averaged among sites to underscore the mean evolution of rCs contamination (see image), in spite of a significant residual variability likely attributed to differences in deposition conditions, forest stand and climatic characteristics and statistical inaccuracy in the measurements (due to small-scale variability in forests). The results suggest that tree vegetation intercepted up to 90% of the total deposit, under low-to-moderate precipitation, leading to initial concentrations in foliage greater than 10^{-1} m^2 kg^{-1}dw. They further suggest that: ~80% of the total deposit was progressively transferred to the forest floor during this 5-year period, according to two distinct characteristic half-lives (~50 days, ~2 years) and seasonal variations driven by climate and tree phenology. At the same time, the tree organs non directly exposed to the fallouts became rapidly contaminated, up to ~10^{-3} m^2 kg^{-1}dw in trunk wood after only 2 years, due to mainly foliage incorporation of rCs and subsequent translocation by phloem. The contribution of the root uptake in tree contamination could not be demonstrated.

In order to incorporate the new knowledge gained from Fukushima, significant improvements have been achieved in an existing model developed after Chernobyl (Calmon et al., 2015), while maintaining a reasonable level of complexity. Major efforts were invested in the refinement of the conceptual model (see image), the estimation of the forest stand characteristics and their time evolution (based on self-thinning and allometric relationships) as well as on the parameterization of root uptake and tree internal transfers (based on K cycle and biomass growth). The model relies on ~30 site-specific parameters relating to ecophysiology, climatic or soil properties, of which ranges of variability were estimated from literature. Some other generic parameters involved in the modelling of stemflow, throughfall or foliar incorporation could not be estimated otherwise than by calibrating the model against time observations. A series of numerical simulations were then performed in order to: first, ascertain the realism of the approach over the period 2011-2016; second, evaluate sensitivity of the predicted outputs to forest specificities and

atmospheric deposition conditions, including long-term prognosis until 2031.

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