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EVALUATION OF MODEL PERFORMANCE USING NEW DEPOSITION SCHEMES IN THE RANDOM DISPLACEMENT PARTICLE MODEL PELLO USING FUKUSHIMA POWER PLANT ACCIDENT DATA

Pontus von Schoenberg[1], Håkan Grahn[1] and Peter Tunved[2]

[1]Dispersion modelling group, CBRN Environment and protection, Swedish Defence Research Agency, FOI, Sweden
[2]Department of Environmental Science and Analytical Chemistry, ACES, Stockholm University, Sweden

Abstract: The nuclear power plant accident in Fukushima 2011 emitted large quantities of radioactive nuclides into the atmosphere. This accident stimulated extensive measurement efforts using different techniques all over the globe, especially in Japan and in the northern hemisphere. This data is highly valuable for testing the performance of dispersion models. In this study, the performance of a random displacement particle model PELLO, Particle model in an Etha Lat LOng coordinate system, (Lindqvist, 1999), has been evaluated against this data. The radionuclide Xenon, Xe, has been continuously observed within the CTBTO network, Comprehensive Nuclear-Test-Ban Treaty Organization, (CTBTO, 2016) especially on the northern hemisphere since 1996. The radioactive decay of Xenon is well known and other atmospheric sinks are of small importance, which means that Xe may be used as an inert tracer in dispersion models, allowing for evaluation of applied transport schemes. Conjunctly released cesium-137, ^{137}Cs, is however assumed to attach on ambient aerosols during and after release. On contrary to Xe and other noble gases, particles are not stable in the atmosphere, but instead subjected to aerosol dynamical ageing as well as wet and dry deposition. While comparison of modelled and measured Xenon suggest that the dispersion across the northern hemisphere is satisfactory described in terms of order of magnitude and timing of the plume arrival to the different locations (P. von Schoenberg & Grahn, 2013), modelled ^{137}Cs calculations offers a larger challenge. This highlights the requirement of more detailed representation of dominating sinks, i.e. wet and dry deposition. First steps in this direction have been taken, and this presentation explores more in depth the role of these two processes. The results presented suggest a need of more rigorous treatment of dominant aerosol sinks in the atmosphere to be represented in dispersion models, and different approaches to make such implementations are discussed.

***Key words:** Wet deposition, deposition, precipitation, dispersion modelling, PELLO, CALM.*

INTRODUCTION

Dispersion modelling constitutes a powerful tool to study the fate of emitted radioactive nuclides during and after a radiological event (e.g. after releases from nuclear power plant accidents, radiological dispersion devices and fallout after nuclear detonations).

In order to accurately describe transport and dispersion of different pollutants and hazardous substances in the atmosphere, meteorological aspects as well as compound specific dynamical processes must be taken into account. On one hand, temporal and spatial variability of wind and turbulence is responsible for the actual transport of the tracer (the substance of interest that undergoes atmospheric processes), while on the other hand the tracer itself is subjected to dynamical processes acting on its chemical and physical properties. The approach in modeling these two different aspects, however, is fundamentally different.

While the actual transport requires knowledge about boundary layer dynamics, turbulence and wind, the dynamical processes do require a broad physical and chemical knowledge and a firm understanding of the importance of different processes in different environments. To complicate matters these two aspects of transport and dispersion are largely entwined. The dynamical processes strongly determine the transport efficiency (e.g. wet removal), while at the same time the dynamical processes are influenced by meteorology and boundary layer processes.

Today, a wide range of different models addressing either of these aspects exist. However, models describing actual transport and dispersion (e.g. a Lagrangian dispersion model) usually, due to computational limitations, put less effort in describing dynamical processes affecting the tracer (may it be in aerosol or gaseous form) while detailed dynamical process models for the same reason simplify the horizontal and vertical dispersion.

At the Swedish defence research Institute (FOI), scientists have for a long period of time used Lagrangian dispersion models, e.g. PELLO (Lindqvist, 1999), as part of the work with accident preparedness and basic research. The model is implemented together with the Swedish meteorological and hydrological institute (SMHI) in the radiological emergency preparedness system at the Swedish radiation authority (SSM). This regional to global, high resolution, random displacement particle model solves the equations governing atmospheric transport of different tracers in the atmosphere. The model can be applied to study transport and dispersion of gaseous emissions, radionuclides from nuclear accidents, radioactive material from nuclear explosions as well as other, accidental, releases of toxic compounds.

Today, the model PELLO does not address aerosol dynamical processes sufficiently. Instead, the aerosol is assumed to be static, which may both underestimate or overestimate aerosol sinks, depending on transport conditions. Since the Fukushima accident in 2011 the dispersion model PELLO has been evaluated towards observations of nuclides performed during the time around the accident. These comparisons has been published in FOI reports (P. von Schoenberg & Grahn, 2013, 2014) and in conference proceedings (Pontus von Schoenberg et al., 2014). The results show that the model has good possibilities to calculate the horizontal dispersion of an aerosol in relative terms and that the magnitude of concentration and deposition is much more difficult to get accurate. To include aerosol processes during the transport is an important next step to improve model behavior.

METHOD

A first step to improve the aerosol dynamic processes is to look in to the wet deposition parameterisations. The efficiency of wet deposition of particles is depending on the size, concentration and composition of the particle. The current wet deposition parameterization in PELLO only considers washout (i.e. below cloud scavening) of aerosol particles as outlined in (Baklanov & Sørensen, 2001). Furthermore, this parameterisation considers only size dependent scavenging efficiency for different particles with diameter above 2.8um, while being held constant for particles smaller than 2.8 μm in diameter. Thus, the current treatment overestimates below scavenging in the accumulation mode size range, while at the same time neglects in-cloud scavenging. In this study we test the sensitivity to the washout parameterisation by comparing the current one with a more rigorous but computationally more heavy deposition parameterization comes from (Seinfeld & Pandis, 1997).

To evaluate the different routines in PELLO the Fukushima nuclear power plant accident was used as a scenario. The release of ^{137}Cs from the power plant was assumed to be spherically attached to the surrounding aerosol, i.e. the activity size distribution is equal to a surface size distribution of spherical aerosols.

RESULT

In Figure 1 the variation of ^{137}Cs activity in Swedish filter measurements after the Fukushima NPP accident is visualized. The measurements are compared with PELLO simulations with the two different washout parameterizations.

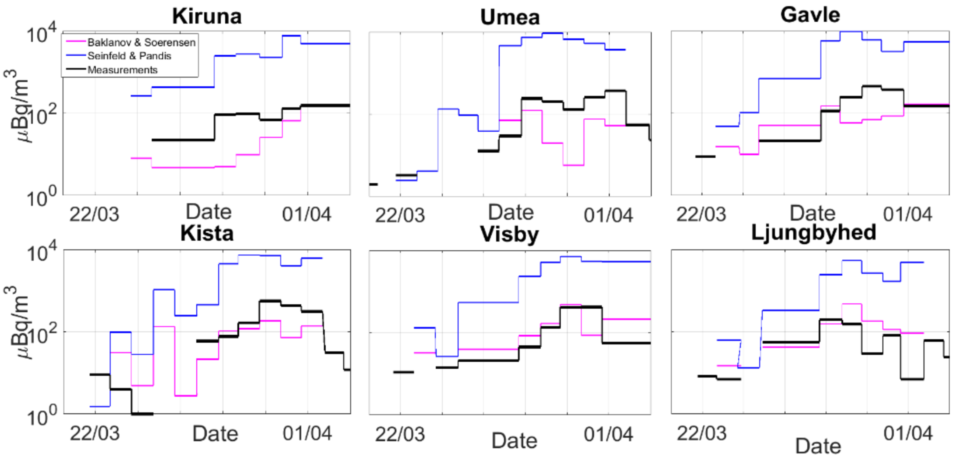

Figure 1. Radioactivity variation in time in Sweden after the Fukushima NPP accident. Comparison between measurements (black line) and model calculations with PELLO for the old wet deposition parameterization by Baklanov and Sørensen (purple line) and the new parameterization by Seinfeld and Pandis (blue line).

Hiba! A hivatkozási forrás nem található. shows the ground level deposition patterns from wet deposition with the two different parameterization schemes. It is visible that the new wet deposition scheme gives lower deposition resulting in substantially overestimated air concentrations in Sweden. As the new scheme better captures the size dependence of scavenging efficiency for accumulation mode particles, a lower washout is to be expected. The result also highlight that there is a strong need to implement a physically based representation of in-cloud scavenging, which in turn is the most efficient removal mechanism for the rather persistent accumulation mode.

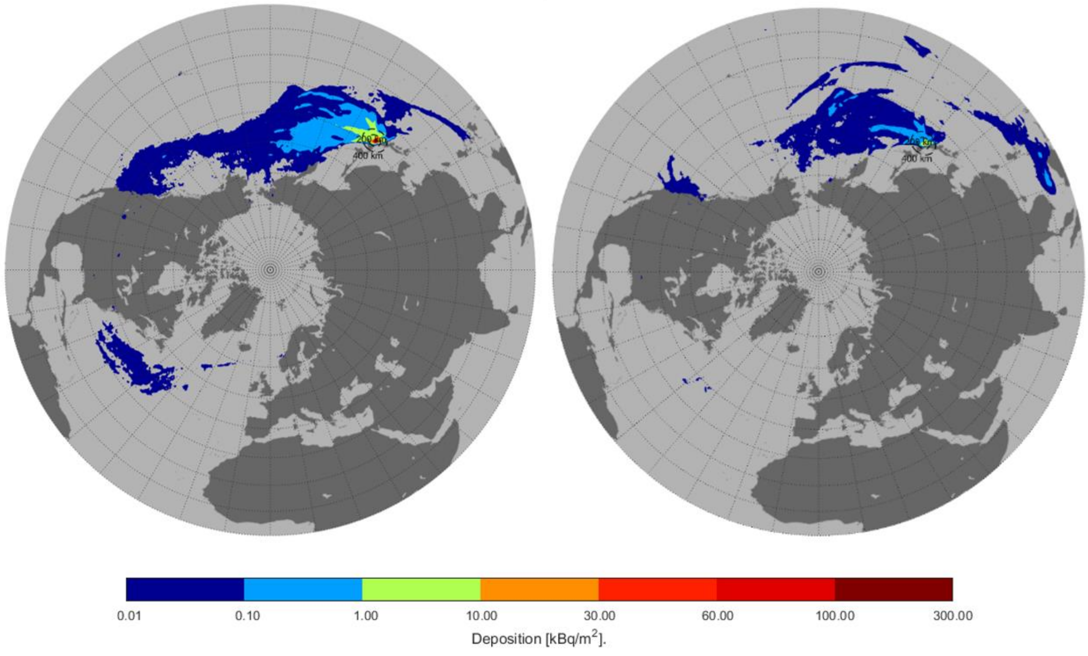

Figure 2. Wet deposition of ^{137}Cs from the Fukushima Daiichi Nuclear power plant accident. To the left the Baklanov Sørensen parameterization and to the right the Seinfeld Pandis parameterization.

CONCLUSIONS

As has been known for a long time accurate parameterization of wet deposition (both in-cloud and below cloud scavenging) is crucial for describing the long range transport since it is the major sink for these particles. It looks like the new scheme for the PELLO model over predicts the concentrations in Sweden compared to measurements and compared to the old parameterization. However there are many assumptions that are not studied here that will be the purpose of future studies. The result also highlight that in-cloud scavenging is missing in the current model setup. In the old parameterization this was partially worked around by assuming unrealistically high scavenging efficiency in the accumulation mode size range, again highlighting the need for a more rigorous treatment of aerosol processes in the atmosphere. Other questions recently actualized relates to how to best use the limited amount of precipitation parameters in the numerical weather prediction model (NWP) that PELLO uses. For example to correctly separate large scale and small scale precipitation or to separate precipitation as rain and as snow.

REFERENCES

Baklanov, A., & Sørensen, J. H. (2001). Parameterisation of radionuclide deposition in atmospheric long-range transport modelling. *Physics and Chemistry of the Earth Part B-Hydrology Oceans and Atmosphere*, ***26***, 787-799. doi:Doi 10.1016/S1464-1909(01)00087-9

CTBTO. (2016). CTBTO, Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization. http://www.ctbto.org/

Seinfeld, J. H., & Pandis, S. N. (1997). Atmospheric Chemistry and Physics From Air Pollution to Climate Change: John Wiley & Sons.

von Schoenberg, P., Boson, J., Grahn, H., Nylén, T., Ramebäck, H., & Thaning, L. (2014). Atmospheric Dispersion of Radioactive Material from the Fukushima Daiichi NuclearPower Plant. Air Pollution Modeling & its Application XXII, 345. Retrieved from https://ezp.sub.su.se/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=edb&AN=94129118&site=eds-live&scope=site

von Schoenberg, P., & Grahn, H. (2013). Dispersion of radioactive material across the northern hemisphere from Fukushima Daiichi Power Plant accident modeled with a random displacement stochastic particle model (FOI-R--3746--SE).

von Schoenberg, P., & Grahn, H. (2014). Våtdeposition av radioaktiva partiklar. Del 2. Implementation (FOI-R--3972--SE).