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The effect of vertical velocity probability distribution shape on cloud activation of aerosols: off-line calculations

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Off-line calculations of cloud activation of aerosols using a probability density function (PDF) for vertical velocity (w) are performed. The focus is on the variation of the shape of the PDF using two functional formulations: the Normal distribution PDF and the Pearson type IV PDF. The Normal distribution provides a familiar example, as it has been widely used to approximate vertical velocity distributions in numerous applications, including climate models. Pearson type IV distribution provides an alternative that, to our knowledge, has not been employed before to describe the vertical velocity PDF. The advantage of the Pearson distribution is its versatility in representing skewed and more peaked distribution shapes compared to the Normal distribution, though this is obtained at the expense of increased mathematical complexity.

The experiments are performed using a box model, in which the environmental conditions, including the aerosol size distribution (bi-modal) and chemical composition (ammonium-sulphate particles) are prescribed as constants. Measured size distributions comprising clean and polluted cases are used. Cloud activation of aerosols is calculated by integrating over the positive side of the PDF of w, which yields the mean number of activated particles (N_{act}). The mean, variance, and skewness of the PDFs along with the type of the PDF itself are altered in order to explore the effect of the PDF shape on the activation process. All experiments are repeated for three well-documented activation parameterizations: Lin & Leaitch, Abdul-Razzak & Ghan and Fountoukis & Nenes.

The results show that for symmetric distributions of w (skewness = 0) there is a maximum difference of 10-15 % in N_{act} between the cases with w given by the Normal distribution, and the more peaked Pearson distribution. The largest differences are seen for the most polluted cases. N_{act} in clean cases will saturate rather quickly with respect to the maximum supersaturation and, hence, vertical velocity. For skewed shapes of the Pearson distribution, increasing positive skewness has the effect of eventually bringing the Pearson distribution PDF shape effectively closer to that of the Normal distribution, which results in more similar N_{act} as well. However, an opposite effect is seen with increasing negative skewness.