Marine Cloud Brightening – do implementation assumptions change its effectiveness?

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We present the impacts of two implementation assumptions on the potential albedo enhancements achievable through the proposed Marine Cloud Brightening (MCB) scheme (Latham, 2002; Salter et al., 2008).

In the MCB proposal, sea water droplets would be emitted from close to the sea surface into the marine stratocumulus-topped boundary layer. These droplets would evaporate to form sea salt aerosols, which are intended to increase cloud albedo via the first and second indirect aerosol effects.

By using the WRF/Chem model in the large-eddy simulation configuration at small domain sizes, we interrogate two assumptions:

1) Emitting DRY aerosols vs. WET droplets

Previously, the emitted aerosols have been simulated as DRY aerosols. By instead simulating the emission as WET droplets, we find rapid evaporation and associated latent heat fluxes. These result in local temperature decreases and short-lived cold pools which suppress the height of the aerosol plumes by up to a third.

Omitting this plume height suppression by assuming that the emitted aerosols are DRY creates an overestimation in cloud albedo increase, producing a 94.1% increase in cloud albedo for our weakly precipitating case compared to an 88.5% increase when the emission is simulated as WET droplets.

Whilst this DRY versus WET sensitivity reduces the number of aerosols reaching the cloud base by half during the early morning, it is of less importance during the more uncoupled daytime. At this time, cloud-top-originating turbulence decreases, and poor transport of both the emitted aerosols, and moisture from the surface leads to low cloud albedo enhancement regardless of aerosol emission assumption.

2) Aerosol processes in the emitted plume

Previous studies, at a global scale, have shown that the albedo enhancement is sensitive to a combination of assumed emitted aerosol size distribution and number concentration, and the background aerosol conditions (Rasch et al., 2009; Korhonen et al., 2010; Alterskjær et al., 2012; Jones and Haywood, 2012; Partanen et al., 2012).

Here, we focus first on producing more realistic size distributions and number concentrations by using higher-resolution simulations (0.5m horizontal resolution) to capture the behaviour of the plume on emission into the boundary layer wind (figure 1).

By simulating the dynamics and aerosol processes within these plumes, we find a growth of larger aerosols, with an associated reduction in aerosol number concentration.

We then utilise these new aerosol size distributions and number concentrations in cloud simulations, in order to assess how the inclusion of this implementation detail affects the albedo perturbation under several background aerosol conditions.

These outcomes are intended to inform both future modelling work, and potential engineering design considerations.

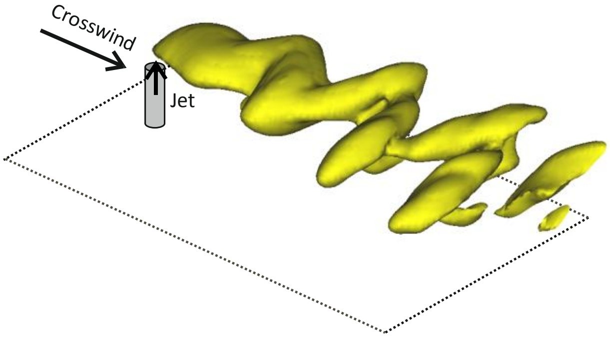

Figure 1. Annotated isosurface schematic of aerosol plume (yellow) in a crosswind

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Alterskjær, K., Kristjánsson, J. E., and Seland, Ø.: Atmos. Chem. Phys., 12, 2795-2807, 2012.

Jones, A., and Haywood, J. M.: Atmos. Chem. Phys., 12, 10887-10898, 2012.

Korhonen, H., Carslaw, K. S., and Romakkaniemi, S.: Atmos. Chem. Phys., 10, 4133-4143, 2010.

Latham, J.: Atmospheric Science Letters, 3, 52-58, 2002.

Partanen, A.-I., Kokkola, H., Romakkaniemi, S., Kerminen, V.-M., Lehtinen, K. E. J., Bergman, T., Arola, A., and Korhonen, H.: J. Geophys. Res., 117, D02203, 2012.

Rasch, P. J., Latham, J., and Chen, C. C.: Environ. Res. Lett., 4, 2009.

Salter, S., Sortino, G., and Latham, J.: Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 366, 3989-4006, 2008.