Investigating the phase composition of mixed-phase clouds

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Aims of the project

- Modelling a typical mixed-phase Arctic layer cloud with a 2D kinematic model to investigate:
  - the impact of turbulence on phase composition;
  - how the liquid water concentration (LWC) in the cloud evolves with time.

The importance of phase composition

Changes in the phase composition of a mixed-phase cloud changes its albedo. Long-term global changes in cloud albedo cause climate feedbacks that are poorly defined in global climate models. Gaining a better understanding of phase composition will improve the accuracy of these models[1].

Model details and microphysics

The model used a bulk microphysics parameterisation with three phases of ice and two phases of liquid, based on the Met Office's Large Eddy Model. This was more advanced than the scheme used by Hill, et al. in similar research[2], with ice able to rime and precipitate, and liquid able to sediment and ventilate. No secondary ice production mechanism was included.

Simulations were performed across five different initial ice concentrations from 1 to 100 L^{-1}. A steady-state dynamical solution was used, with the peak wind-speeds scaled between 0.1 and 5 $m\ s^{-1}$.

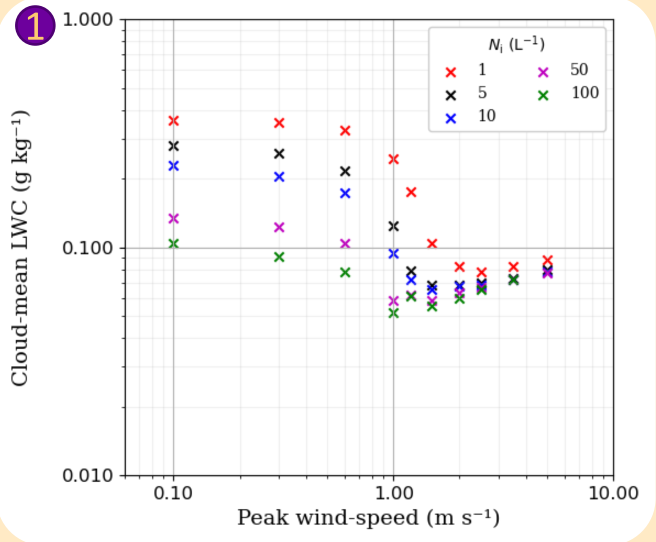

Fig. 1: Average liquid water mixing ratio in cloud simulations with different initial ice concentrations N_i. Greater peak wind-speeds correspond to greater turbulent kinetic energies.

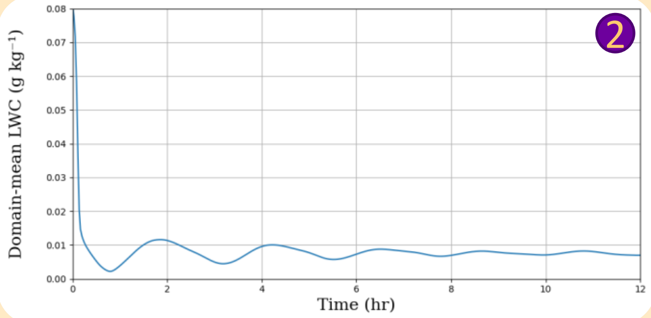

Fig. 2: Evolution of LWC over time in a low wind-speed, low-ice environment. The oscillations do not occur with high wind-speeds and ice concentrations.

Impact of turbulence

Previous research by Hill, et al. suggested that LWC increases where the turbulent kinetic energy (TKE) is largest[2]. In contrast, this work found that areas of high LWC were not well-correlated with large values of local TKE. There is also no positive correlation between TKE and LWC when averaged across the cloud, as shown in Fig. 1, where the peak wind-peed forms a proxy for TKE.

Evolution of LWC

At initial ice concentrations below 10 L^{-1} and wind speeds below 1.5 $m\ s^{-1}$ and, LWC undergoes damped oscillations about an equilibrium value (Fig. 2). This occurs since rain is produced when LWC is above a threshold value near equilibrium. Some rain evaporates before reaching the surface and returns as pockets of high water vapour concentration to the cloud in updraughts. This effect is suppressed at larger wind-speeds and ice concentrations.

Areas for future investigation

- Is the threshold value of LWC used in the rain production model appropriate and does it artificially shift the equilibrium LWC?
- The LWC oscillations stop occurring at the same wind-speeds as cloud-mean LWC reaches a minimum. Are the two related?

1. A. Korolev, *et al.*, "Mixed-phase clouds: Progress and challenges," *Meteorol. Monographs*, vol. 58, pp. 5.1–5.50, 2017.
2. A. A. Hill, *et al.*, "Mixed-phase clouds in a turbulent environment. Part 1: Large-eddy simulation experiments," *Q. J. R. Meteorol. Soc.*, vol. 140, no. 680, pp. 855-869, 2014.