SIMULATION OF ARCTIC MIXED-PHASE CLOUDS OBSERVED DURING M-PACE USING THE GLOBAL ENVIRONMENTAL MULTISCALE MODEL (GEM): EVALUATION OF TWO BULK MICROPHYSICS SCHEMES

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State-of-the-art regional climate models are currently unable to properly simulate cloud-radiation interactions over the Arctic. One of the main challenges is to properly simulate cloud microphysical properties. Cloud thermodynamic phase seems to be particularly important in the magnitude of the cloud radiative forcing (CRF). For instance, Shupe et al. (2006) have shown that CRF can reach 40 W m^{-2} when liquid is present as opposed to 10 W m^{-2} for ice clouds. This research aims at evaluating two bulk microphysics schemes currently used in the Global Environmental Multiscale (GEM) Model. The main objective is to assess the ability of each scheme to properly simulate the partitioning of liquid and ice in mixed-phase clouds and the ability to simulate cloud persistence (in spite of the colloidal instability of the mixed-phase). The first evaluated microphysics scheme is from Sundqvist (1978) (hereafter SUN). The total water content is the only prognostic equation of this scheme. A function depending on temperature is used to discriminate between liquid and ice phases. The second microphysics scheme is from Kong and Yau (1997) (hereafter KY). It is a single-moment scheme with 4 prognostic variables: rain, cloud water, graupel and ice water (which include both cloud ice and snow). The number concentration of ice particle is determined using an empirical relationship, which depends on ice supersaturation only. Further, ice nucleation is not allowed at temperatures above -5^{0}C.

Short simulations of 36 hours including 12h spin-up are performed over the North Slope of Alaska on a small domain of 447.5 km by 137.5 km covering Barrow, Oliktok and Atqasuk, which are the 3 sites where in-situ and ground-based measurements were taken during the Mixed-Phase Arctic Cloud Experiment (M-PACE) on October 2004. A first simulation at 10 km horizontal resolution is performed over a large domain. This first simulation is then used to drive a 2.5 km horizontal resolution simulation over a smaller domain. Clouds observed on October 5th, 6th, 8th, 9th, 10th and 12th have been simulated. The first 4 days were characterized by relatively high in-cloud temperatures (-11^{0}C to -6^{0}C) (hereafter warm regime) while the two last days were colder with in-cloud temperatures down to -17^{0}C (hereafter cold regime).

Results were first compared with in-situ measurements for each day. Figure 1 shows an example of the vertical profiles of IWC and LWC measured by the aircraft and modeled on October 8th. A mixed-phase stratus cloud was present at 1000 m with a dissipating cloud above. Results show that both schemes capture the vertical structure and the persistence of the cloud. Although the mixed-phase is captured by both schemes, the partitioning between liquid and ice differs significantly when compared to observations as illustrated on Figure 1 for October 8. When all the 6 cases are gathered, it is found that SUN has a systematic negative cloud liquid water bias and a positive cloud water ice bias for all cases examined (see Table 1). It seems that the phase partitioning function of SUN is not appropriate for these Arctic stratus clouds. KY behaves differently depending on temperature. Indeed, for warmer in-cloud cases, it has a positive cloud liquid water bias and a negative cloud ice water bias. On the other hand, KY biases are substantially reduced for colder clouds (see Table 1). This bias could be related to the formulation of the scheme, which restricts the ice nucleation at temperatures below -5^{0}C.

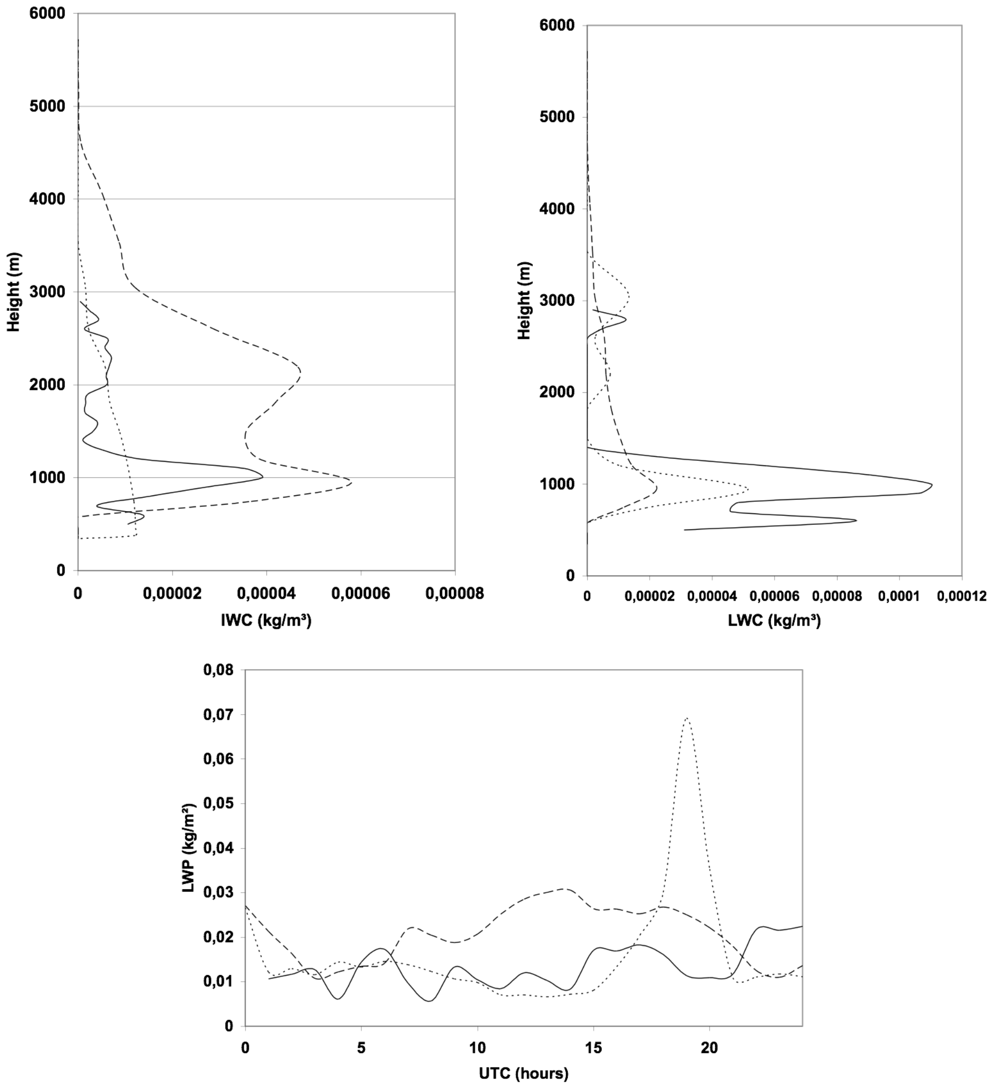

Figure 1: Vertical profile of LWC and IWC and time series of LWP at Oliktuk (modelled vs. observed) for October 8^{th}. Observations (—), SUN results (-----) and KY results (·····).

Table 1: Time averaged LWP (g m^{-2}) at Oliktok and Atqasuk for October 5^{th}, 6^{th}, 8^{th} and 9^{th} (warm regime) and for October 10^{th}, 12^{th} (cold regime at Atqasuk only)

Regime	Observations	SUN	KY
Warm	56.0	23.2	82.5
Cold	14.0	3.7	17.2

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