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Title: *Recent advances in understanding and parameterization of small-scale physical processes in the Arctic atmosphere*

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Small-scale physical processes in the Arctic atmosphere include turbulence in the atmospheric boundary layer (ABL), cloud physics, radiative transfer, surface fluxes of momentum, heat, and moisture, as well as small-scale orographic effects on the flow. Present-day climate and numerical weather prediction models as well as atmospheric reanalyses include large errors in small-scale processes. Hence, an improved understanding on the small-scale processes is one of the perquisites for better modelling of the Arctic climate system, including the Arctic amplification of climate change. We focus on the advances in research made since the start of the International Polar Year (IPY).

Advances related to the Arctic ABL include new results on (a) the flux-profile relationships, (b) intermittency of turbulence, (c) scaling on the basis of vertical gradients instead of the Obukhov length, (d) stability dependence of the turbulent Prandtl number, and (e) the role of friction in the generation of low-level jets. New observations have added knowledge on the properties and mutual relationships of temperature and humidity inversions, among others, the distributions of their strength, depth, and base height. Airborne observations and high-resolution model experiments have improved understanding on localized convection over leads and polynyas: the height reached by convective plumes, its dependence on the width of the lead/ polynya, wind speed, surface-air temperature difference, and the background stratification. New results on Arctic clouds are related to (a) cloud top heights with respect to the inversion layers, (b) cloud condensate content and its division between liquid water and ice, (c) cloud growth and persistence, and (d) condensation nuclei, including their marine biological sources. Modelling of Arctic clouds continues to be a major challenge, in particular with respect to temporal evolution of cloud properties, vertical distribution of cloud condensate, presence of liquid water in low temperatures, and radiative transfer through clouds. Recent field campaigns and model experiments have also demonstrated the complexity of interactions between orographically affected mesoscale dynamics and ABL physics over partly ice-covered fjords.

Despite of the recent advance, uncertainty will remain in parameterization of small-scale processes. This calls, among others, for more extensive use of stochastic physics in ensemble prediction systems. Also, we need to understand how strongly the remaining errors are related to the following aspects: (i) lack of understanding of the processes, (ii) lack of possibility to parameterize them using grid-resolved variables, and (iii) most recent findings on small-scale physics are not yet fully implemented in parameterizations.