Interaction of cirrus clouds and gravity waves: towards a coupled representation in coarse resolution model

Alena Kosareva[1], Stamen Dolaptchiev[1], Ulrich Achatz[1], and Peter Spichtinger[2]

[1]Goethe University Frankfurt, Institute for Atmospheric and Environmental Sciences, Frankfurt am Main, Germany (kosareva@iau.uni-frankfurt.de)

[2]Gutenberg University Mainz, Institute for Atmospheric Physics, Mainz, Germany

Cirrus clouds have a notable influence on radiation and, consequently, the energy balance. Therefore detailed understanding of ice physics processes is one of the keys to improving climate representation. Major drivers of the physical processes in ice clouds such as nucleation, freezing, sedimentation etc. are mostly triggered by local dynamical causes. The variability in vertical velocity, along with temperature and pressure fluctuations induced by gravity waves (GW), significantly impacts the formation and life cycle of cirrus clouds. However, conventional climate models and Numerical Weather Prediction (NWP) systems typically limit ice formation mechanisms to turbulent forcing.

This study is focused on the interaction between ice clouds and gravity waves, aiming to enhance the representation of these processes within coarse-grid model. Building upon a double-moment scheme for ice particles, a prototype parameterisation for the nucleation process induced by gravity waves was previously proposed in [1] and has been implemented in the ICON model for numerical verification and assessment. The current approach is targeting a comprehensive coupled description of ice physics and gravity wave interaction.

Information on subgrid-scale dynamical fields impacting cirrus formation is retrieved from Multi-Scale Gravity Wave Model (MS-GWaM) [2-5]. This gravity-wave parameterisation relies on WKB-theory and employs a raytracing-based technique. It allows for the consideration of transient wave dynamics and horizontal wave propagation. The chosen approach for joined description seeks to refine the physical representation of cirrus formation associated with both convectively generated gravity waves and gravity waves generated by sources other than orography and convection.

Preliminary results, incorporating an artificial periodic forcing term, demonstrate a good agreement of ice physics parameterisation with results from an explicitly integrated double-moment scheme, where processes such as nucleation are resolved in time. Ongoing efforts involve further coupling with the MS-GWaM parameterisation, with the goal of achieving a more physically accurate representation of ice formation zones. Additionally, an analysis of time-averaged characteristic quantities is planned for a comprehensive understanding of the system.

References

[1] S. I. Dolaptchiev, P. Spichtinger, M. Baumgartner, and U. Achatz. Interactions between gravity waves and cirrus clouds: Asymptotic modeling of wave-induced ice nucleation. Journal of the Atmospheric Sciences, 80(12):2861 – 2879, 2023.

[2] G. Bölöni, Y.-H. Kim, S. Borchert, and U. Achatz. Toward transient subgrid-scale gravity wave representation in atmospheric models. Part I: Propagation model including nondissipative wave–mean-flow interactions. Journal of the Atmospheric Sciences, 78(4):1317–1338, 2021.

[3] Y.-H. Kim, G. Bölöni, S. Borchert, H.-Y. Chun, and U. Achatz. Toward transient subgrid-scale gravity wave representation in atmospheric models. Part II: Wave intermittency simulated with convective sources. Journal of the Atmospheric Sciences, 78(4):1339–1357, 2021.

[4] U. Achatz, Y.-H. Kim, and G. S. Voelker. Multi-scale dynamics of the interaction between waves and mean flows: From nonlinear WKB theory to gravity-wave parameterizations in weather and climate models. Journal of Mathematical Physics, 64(11), 2023.

[5] Y.-H. Kim, G. S. Voelker, G. Bölöni, G. Zängl, and Ulrich Achatz. Crucial role of obliquely propagating gravity waves in the quasi-biennial oscillation dynamics. EGUsphere, 2023:1–18, 2023.