Project: **474,** Project title: **Laptev**
Project lead: **Günther Heinemann,** Report period: **2024-01-01 to 2024-10-31**

The project focuses on simulations with the atmospheric climate model COSMO-CLM (CCLM) adapted for the polar regions (Heinemann et al. 2022) with 15km (C15), 5km (C05) and 1km (C01) for the Arctic (C15 being part of Arctic CORDEX).

In the report period, we used the C15 data for the study of the dynamics of low-level jets (LLJs) for the MOSAiC drift of Polarstern for the period 2019-2020 (Heinemann et al. 2024). In addition, simulations for the MOSAiC drift were performed with 5km and 1km resolution for different configurations and parameterizations. C01 was nested in C05 for case studies during winter 2019/20 using 1km sea ice data to investigate the impact of sea ice leads on the atmospheric boundary layer. Another focus was the study of topographic flows near Greenland (Kohnemann and Heinemann 2021) with C15, C05 and C01 for case studies covering periods of an aircraft-based field experiment (Heinemann 2018).

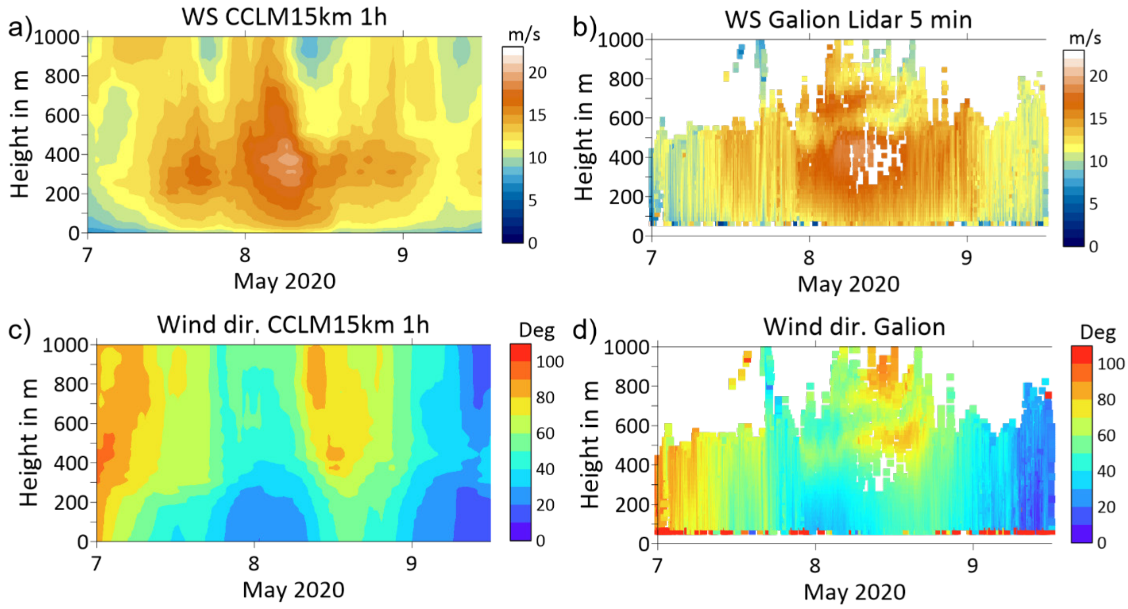

Fig.1: Time-height cross-sections for 7-9 May 2020 for the wind speed from C15 simulations a) and wind speed from lidar b), and for the wind direction from C15 simulations c) and lidar d). Interpolated fields are shown for the simulations, while observations are shown as pixels. Missing data are white. From Heinemann et al. (2024).

Fig.1 shows results of C15 simulations compared to wind LIDAR observations for an LLJ event on 7-8 May 2020.The LLJ developed at the end of 7 May and had the highest intensity in the first half of 8 May. The simulations (Fig.1a) show an LLJ at about 300 m height with maximum speeds of about 20 m/s. The simulated wind direction (Fig.1c) shows a vertical shear from north-north-easterly flow at low levels to north-easterly flow at the LLJ height, while the flow is easterly above 400 m before and after the event. The wind lidar data (Fig.1b,d) show the full jet with a few missing data in the jet core and confirm the simulated structures and evolution of the LLJ.

The average of all LLJs profiles for the lowest 1000 m is shown in Fig.2. The mean wind profile (Fig.2a) shows a pronounced maximum at about 250 m. The mean geostrophic wind decreases with height, which corresponds to a mean baroclinic forcing for the LLJs, and it is larger than the mean wind above the mean LLJ height. The mean directional shear profile (relative to the lowest level) shows the turning of the wind with height due to friction of about 30° (Fig.2b). A mean temperature profile was not computed because of the large seasonal variation of the temperature. Instead, the mean stability is described by the average of the potential temperature anomaly in the lowest 1500 m for each level and for each profile. The profile of the mean potential temperature anomaly shows the stable stratification for the LLJs with an increase of the potential temperature by 8°C in the lowest 500 m. The mean scaled wind profile (height scaled with the LLJ height and wind scaled with the LLJ speed) is shown in Fig.2d. In contrast to Fig.2a, the nose-like shape of the wind profile is present and the variability given by the 25%- and 75%-tiles is relatively small.

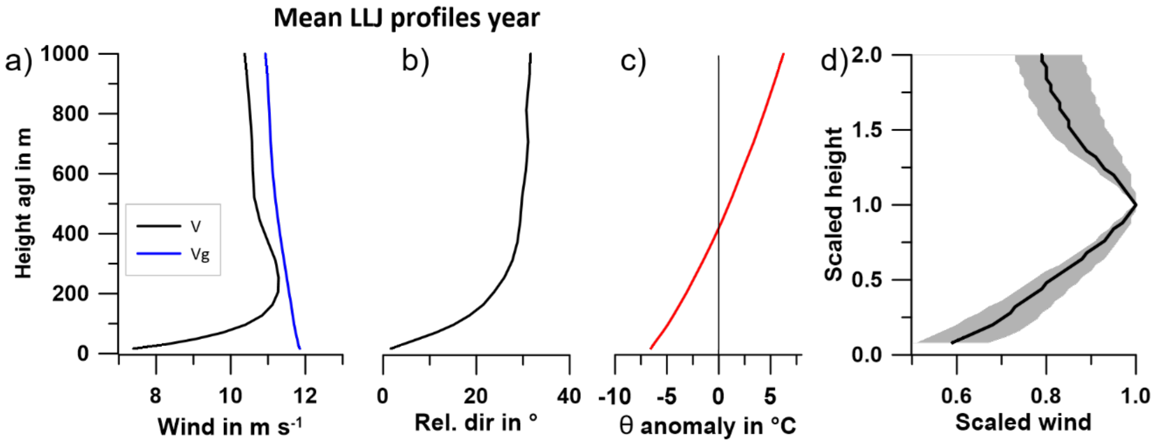

Fig.2: Mean vertical profiles for all LLJs of the a) wind speed (black) and geostrophic wind speed (blue), b) wind direction difference to the lowest level, c) potential temperature deviation (see text) and d) the mean wind profile scaled with LLJ height and LLJ speed (the shaded region marks the 25%- and 75%-tiles, respectively). From Heinemann et al. (2024).

Improvements for the parameterizations of sea ice and the ABL are shown in Fig.3. C15 was run with sea ice concentration (SIC) from AMSR (C15), with SIC from MODIS data with thin ice thickness in leads computed within CCLM (C15MOD0, see Heinemann et al. 2022), and a new parameterization of SIC within leads and the impact of leads on the TKE (C15MODep). Overall, C15MODep shows the best results. C15 has a strong cold bias for Dec.-Feb., C15MOD0 is better for these months, but has a large positive temperature bias for March, which was a month with strong lead activity.

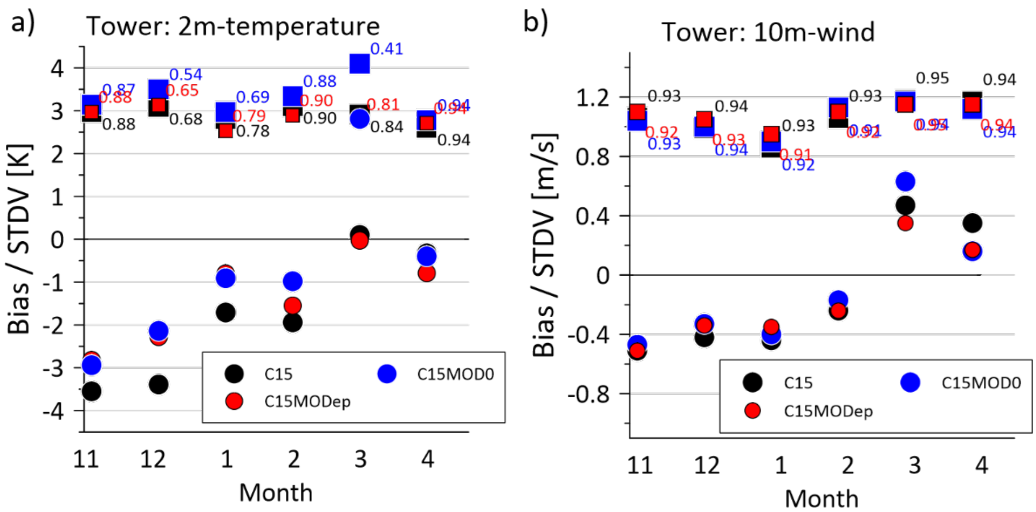

Fig.3: Comparison of simulations and tower observations for monthly data for the MOSAiC winter.
Bias (dots) and STDV (squares) for the comparison of C15 (black), C15MOD0 (blue) and C15MODep (red) with tower observations for Nov. 2019 to Apr. 2020 based on hourly data. Correlation coefficients (detrended data) for each month are shown as labels at the STDV data. a) 2m-temperature, b) 10m-wind.

Literature

Heinemann, G., 2018: An aircraft-based study of strong gap flows in Nares Strait, Greenland. Mon. Wea. Rev. 146, 3589-3604, doi:10.1175/MWR-D-18-0178.1. Plain language summary and photos from the field campaign: https://goo.gl/NDmPDg.

Heinemann, G., Schefczyk, L., Willmes, S., Shupe, M., 2022: Evaluation of simulations of near-surface variables using the regional climate model CCLM for the MOSAiC winter period. Elem. Sci. Anth., 10 (1). DOI: 10.1525/elementa.2022.00033.

Heinemann, G., Schefczyk, L., Zentek, R., 2024: A model-based study of the dynamics of Arctic low-level jet events for the MOSAiC drift. Elem. Sci. Anth. 12: 1. DOI: https://doi.org/10.1525/elementa.2023.00064.

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