Final Preport for Project 958

Project title: Weddell Sea Ice

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The regional climate model COSMO-CLM (CCLM) was used for hindcast simulations for the Weddell Sea region of the Antarctic with a horizontal resolution of 15, 5, 2 and 1 km. While the 15 and 5km runs were performed for the period 2002 bis 2020 for the whole Weddell Sea, the domain of the 2 km run covered the Antarctic Peninsula for the period 2013-2016. Runs with 1 km resolution were performed for the period of a ship-based experiment for December 2015 to January 2016. Climate runs were made using CCLM with 15km resolution for the whole Antarctic. These simulations were nested in the global climate model AWI-CM (100 km resolution for the atmosphere), and the AWI-CM sea ice data (10 km resolution) were used. The climate runs have been performed for the historical run for 2000-2014 and two time slices for the SSP3-7.0 scenario (2036-2050 and 2086-2100). The CCLM runs were part of Polar CORDEX. CCLM data were also used to drive the sea ice/ocean model FESOM. Relevant data sets were published in the DKRZ long-term archive.

In this final report, some of the publications of the project are highlighted.

A long-term verification of the 15 and 5 km CCLM simulations for the Weddell Sea was performed by Zentek and Heinemann (2020). Overall, CCLM showed a good representation of temperature and wind for the Weddell Sea region. A comparison with measurements over the sea ice of the Weddell Sea by three AWS buoys for one year showed small biases for temperature around 1 K and for wind speed of 1 m/s. Comparisons of radio soundings for 2002-2016 showed a model bias around zero and an RMSE of 1-2 K for temperature and of 3-4 m/s for wind speed. Besides the standard data sets of radiosondes and surface measurements, the study included comparisons to Doppler wind LIDAR measurements (Zentek et al. 2018). The comparison of CCLM simulations at resolutions down to 1 km with wind data from Doppler Lidar measurements during December 2015 and January 2016 yielded almost no bias in wind speed and an RMSE of about 2 m/s.

The analysis of low-level jets (LLJs) in the Weddell Sea region of the Antarctic for the period 2002–2016 of the hindcast run showed that LLJs are most frequent in the katabatic wind regime over the ice sheet and in barrier wind regions (Heinemann and Zentek 2021). The simulated LLJ frequency and the height distribution of LLJs agreed very well with the observations. During winter, katabatic LLJs occurred with frequencies of more than 70% in many areas. During climate change the LLJ frequency was found to decrease over ocean/sea ice areas. There was a slight decrease in katabatic wind areas, but an increase over the Antarctic plateau.

The effect of Antarctic katabatic winds on the surface temperature was studied by Heinemann et al. (2019) using ice surface temperature (IST) satellite data from MODIS as well as CCLM data with 5 km resolution for the winter periods 2002-2017. For appropriate synoptic forcing and/or topographic channeling, so-called katabatic surges occur, which result in warm IST signatures. IST anomaly distributions showed maxima around 10-15K for the slopes, but values of more than 25K were also found. CCLM simulations of the IST were compared to the MODIS IST, and showed a very good agreement. The model data showed that the near-surface stability was a better measure for the response to the wind than the IST itself.

CCLM hindcast runs for the Weddell Sea (2002–2017) were used to drive the sea ice/ocean model FESOM to investigate the role of polynyas for the surface freshwater flux of the southern Weddell Sea (Štulić et al. 2023). While coastal polynyas cover 2% of the continental shelf area, sea ice production within these polynyas was found to account for 17% of the overall annual sea ice production. The CCLM data yielded a more realistic polynya representation compared to a forcing using ERA-Interim reanalysis data.

CCLM runs for the SSP3-7.0 scenario were used to drive the FESOM model for the whole Antarctic (Teske et al. 2024). The focus of this study was on the oceanic Antarctic Slope Front in the southern Weddell Sea. The results indicated that a regime shift from cold to warm Filchner Trough through across-slope current before the end of the 21st century had higher potential for the CCLM forcing compared to the low-resolution atmospheric forcing by AWI-CM.

Peer-reviewed publications

Heinemann, G., Glaw, L., Willmes, S., 2019: A satellite-based climatology of wind-induced surface temperature anomalies for the Antarctic. Remote Sens. 11, 1539, 17pp, doi:10.3390/rs11131539.

Heinemann, G., Zentek, R., 2021: A model-based climatology of low-level jets in the Weddell Sea region of the Antarctic. Atmosphere 12, 1635; doi: 10.3390/atmos12121635.

Štulić, L., Timmermann, R., Paul, S., Zentek, R., Heinemann, G., Kanzow, T., 2023: Southern Weddell Sea surface freshwater flux modulated by icescape and atmospheric forcing. Ocean Sci., 19, 1791–1808, https://doi.org/10.5194/os-19-1791-2023.

Teske, V., Timmermann, R., Nissen, C., Zentek, R., Semmler, T., Heinemann, G., 2024: Regime shift caused by accelerated density reorganization on the Weddell Sea continental shelf with high-resolution atmospheric forcing. EGUsphere [preprint], https://doi.org/10.5194/egusphere-2024-2873.

Zentek, R., Kohnemann, S., Heinemann, G., 2018: Analysis of the performance of a ship-borne scanning wind lidar in the Arctic and Antarctic, Atmos. Meas. Tech., 11, 5781–5795, https://doi.org/10.5194/amt-11-5781-2018.

Zentek, R. and Heinemann, G., 2020: Verification of the regional atmospheric model CCLM v5.0 with conventional data and lidar measurements in Antarctica, Geosci. Model Dev., 13, 1809–1825, doi: 10.5194/gmd-13-1809-2020.

Bachelor, master and PhD theses

Kiene, V., 2016: Thermische Signaturen aus Satelliten-Daten über Gletschern und Schelfeisen der Antarktischen Halbinsel. Bachelorarbeit im Fach Umweltmeteorologie, 42pp.

Knopp, L., 2017: Topographically induced winds and foehn warming effects at the Antarctic Peninsula. Master thesis, Environmental Meteorology, University of Trier, 129pp.

Glaw, L., 2018: Thermal Signatures over Polar Ice Sheets – A Study using MODIS Data. Master thesis, Environmental Meteorology, University of Trier, 61pp.

Krautwig, T., 2020: Vergleich von MODIS-IST mit Messungen in der Antarktis. Bachelorarbeit im Fach Umweltmeteorologie, Universität Trier, 48pp.

Bär, C., 2020: High-resolution model study of atmospheric forcing on the Larsen ice shelf. Master thesis, Environmental Meteorology and Mathematics, University of Trier, 135pp.

Zentek, R., 2023: Regional climate simulations in the Weddell Sea region (Antarctic): Verifications and evaluation of low-level jets. Dissertation University of Trier, 98pp. https://ubt.opus.hbz-nrw.de/frontdoor/index/index/docId/2055

Data publications

Zentek, R. and Heinemann, G., 2019: CCLM simulation (Antarctica 2002–2016) – selected data, https://doi.org/10.5281/zenodo.3355401

Zentek, R., Heinemann, G., 2022: Low-Level-Jet and inversion statistic for Weddell Sea region of Antarctica. PANGAEA, https://doi.org/10.1594/PANGAEA.940364

Zentek, R., Heinemann, G., 2022: Weddell Sea Projekt - Uni Trier - Low Level Jet Data. DOKU at DKRZ. https://hdl.handle.net/21.14106/f5feade1129a76d5eb4f32553c54717574039a32

Zentek, R., Heinemann, G., 2022: CCLM data for 2000-2014, 2036-2050 and 2086-2100 of Antarctica. Monthly Mean. https://www.wdc-climate.de/ui/entry?acronym=DKRZ_LTA_958_ds00004

Zentek, R., Heinemann, G., 2022: COSMO-CLM 5.0 data for 2002-2019. Weddell Sea Projekt - Uni Trier - Simulation C15. DOKU at DKRZ. https://www.wdc-climate.de/ui/entry?acronym=DKRZ_LTA_958_ds00001

Zentek, R., Heinemann, G., 2022: COSMO-CLM 5.0 data for 2002-2016. Weddell Sea Projekt - Uni Trier - Simulation T15. DOKU at DKRZ. https://www.wdc-climate.de/ui/entry?acronym=DKRZ_LTA_958_ds00002

Zentek, R., Heinemann, G., 2022: COSMO-CLM 5.0 data for 2002-2018 (only Apr. till Sept. + Oct2015-Mar2016), Weddell Sea Projekt - Uni Trier - Simulation C05. DOKU at DKRZ. https://www.wdc-climate.de/ui/entry?acronym=DKRZ_LTA_958_ds00003

Zentek, R., Heinemann, G., 2022: COSMO-CLM 5.0 data for 2000-2014, 2036-2050 and 2086-2100 of Antarctica. REDOCCA Projekt - Uni Trier - All Simulation - Monthly Mean. DOKU at DKRZ. https://www.wdc-climate.de/ui/entry?acronym=DKRZ_LTA_958_ds00004

Zentek, R., Heinemann, G., 2022: COSMO-CLM 5.0 data with horizontal resolutions of 15km, 5km and 2km for 2002-2019 (and subsets) of the Weddell Sea Region (Antarctica). REDOCCA Projekt - Uni Trier - All Simulation - Monthly Mean. DOKU at DKRZ. https://www.wdc-climate.de/ui/entry?acronym=DKRZ_LTA_958_ds00005

Zentek, R., Heinemann, G., 2023: REDOCCA Projekt - Uni Trier - Core Data. DOKU at DKRZ. https://hdl.handle.net/21.14106/cb44f718061ed8e9cdeb574d51113b64ec781564

Zentek, R., Heinemann, G., 2023: COSMO-CLM REDOCCA Simulation (Version 2) Core Data 2000-2014. DOKU at DKRZ. https://hdl.handle.net/21.14106/cb44f718061ed8e9cdeb574d51113b64ec781564

Zentek, R., Heinemann, G., 2023: COSMO-CLM REDOCCA Simulation (Version 2) Core Data 2036-2050. DOKU at DKRZ. https://hdl.handle.net/21.14106/cb44f718061ed8e9cdeb574d51113b64ec781564

Zentek, R., Heinemann, G., 2023: COSMO-CLM REDOCCA Simulation (Version 2) Core Data 2086-2100. DOKU at DKRZ. https://hdl.handle.net/21.14106/cb44f718061ed8e9cdeb574d51113b64ec781564

Zentek, R., Heinemann, G., 2023: COSMO-CLM REDOCCA Simulation (Version 2) Monthly Mean Data. DOKU at DKRZ. https://hdl.handle.net/21.14106/f5e92dcc334eb2250e630cd60cd6e142dbc545cf

Zentek, R., Heinemann, G., 2023: COSMO-CLM REDOCCA Simulation (Version 2) Pressure Level Data. DOKU at DKRZ. https://hdl.handle.net/21.14106/0ad29c2f7d8bc35094b961e34048db47a3b4f4b8