Project: **1064**

Project title: **Atmospheric Drivers of Extreme Events (ADEE)**

Principal investigator: **Bodo Ahrens**

Report period: **2025-11-01 to 2026-10-31**

Within ADEE, the focus is high-resolution, km-scale regional climate modelling of extreme events and their atmospheric drivers. ADEE results are used in the ongoing projects DFG CRC TPChange (TRR 301) SP-B3 and EU DISTENDER, and contribute to WCRP CORDEX South Asia, WCRP CORDEX FPS CPTP and WCRP Med-CORDEX. All simulations use the regional climate model ICON-CLM; in this period, it was for the first time run two-way coupled with the wave model ICON-WAVES-LAM. Here, we briefly report on **tasks 1–3** of the 2026 resource request.

Task 1: Climate simulations in the CORDEX South Asia domain

For the ERA5-driven 13 km simulation over the CORDEX South Asia domain (extended to Central Asia), 20 years up to 1965, including spin-up, have been completed. Progress was delayed by shutdowns of the computing resources and by interruptions of the reanalysis data archive, which slowed ERA5 downloads and data transfers. Within TPChange, the km-scale (3.3 km, CPTP domain) and 13 km simulations were used to study extreme events, their meteorological drivers and their impact on water vapour in the upper troposphere and lower stratosphere (UTLS).

Singh and Ahrens (2026a) combined the decade-long (2011–2020) km-scale simulation with MODIS/VIIRS fire detections, GFED5 emissions and ERA5. Himalayan fires above 1000 m peak in the pre-monsoon season (March–May) and occur under warm, dry and windy conditions; fires at 2500–3000 m occur under cooler and more humid conditions than at 500–1000 m. ICON-CLM depicts the fire environments warmer and drier than ERA5, showing the added value of km-scale modelling in complex terrain.

Singh and Ahrens (2026b) simulated three extreme precipitation and snowfall events at 3.3 km and 13 km grid spacing with different convection parameterisation settings (Fig. 1). The km-scale runs represent the extremes and the convective water vapour transport into the upper troposphere substantially better than the 13 km runs and the reanalyses ERA5 and IMDAA; the events moisten the upper troposphere but rarely penetrate into the lower stratosphere. These multi-scale experiments show what is gained at km scale and what is lost at the 13 km grid spacing chosen for the extended South Asia set-up. In addition, ICON-CLM simulations of Nepal's first recorded tornado (31 March 2019) were used to assess its effect on UTLS moisture (Singh et al., in review).

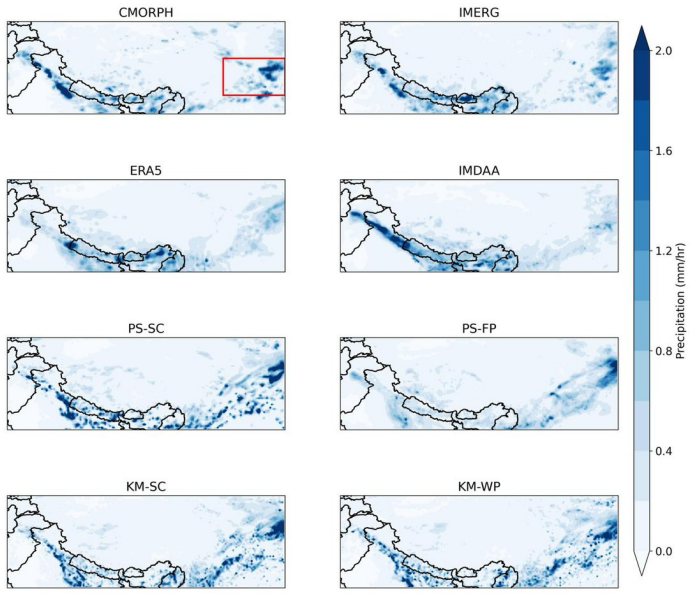


Fig. 1: Two days' average precipitation (mm/h) of event E1 (mesoscale Tibetan Plateau vortex, July 2008) from satellite-based observations (CMORPH, IMERG), reanalysis (ERA5, IMDAA) and ICON-CLM at 13 km (PS-SC: shallow convection scheme only; PS-FP: full convection parameterisation) and 3.3 km (KM-SC: shallow convection scheme only; KM-WP: no convection parameterisation). The red box shows E1's heavy precipitation region. From Singh and Ahrens (2026b).

Task 2: Coupled km-scale climate simulations over Europe in the Med-CORDEX domain

As a first step towards the atmosphere–ocean–wave set-up planned in the 2026 request, we implemented two-way atmosphere–wave coupling in ICON-CLM on the Med-CORDEX domain: ICON-NWP-LAM is coupled via YAC to ICON-WAVES-LAM (both 3.9 km; 24 directions, 30 frequencies). The atmosphere passes 10 m wind and sea-ice fraction, the waves return the roughness length z_0. This required local fixes to run ICON-WAVES in limited-area mode, an ocean-only wave grid with bathymetry cut from the atmosphere grid, and lateral wave boundaries from an analytic JONSWAP spectrum.

After technical tests, a coupled run (CPL) and an uncoupled reference (REF) were performed under identical ERA5 forcing for the **full year 2011**. The wave component adds around 20 % to the runtime, but this can be less depending on the coupling frequency. The waves roughen the sea surface (median z_0 ratio 1.55; Fig. 2), slow the 10 m wind by 1.3 %

and increase the upward latent heat flux by 2.7 %. Results were presented at the MedCLIVAR 2026 conference and the CLM-Community Assembly 2026 (Risto and Ahrens, 2026). Further testing must be done for tuning and optimising the performance.

In the last quarter of 2026, single medicane events will still be simulated with the coupled set-up. Multi-year runs and the additional coupling to the ocean (ICON-O-LAM) are the next steps.

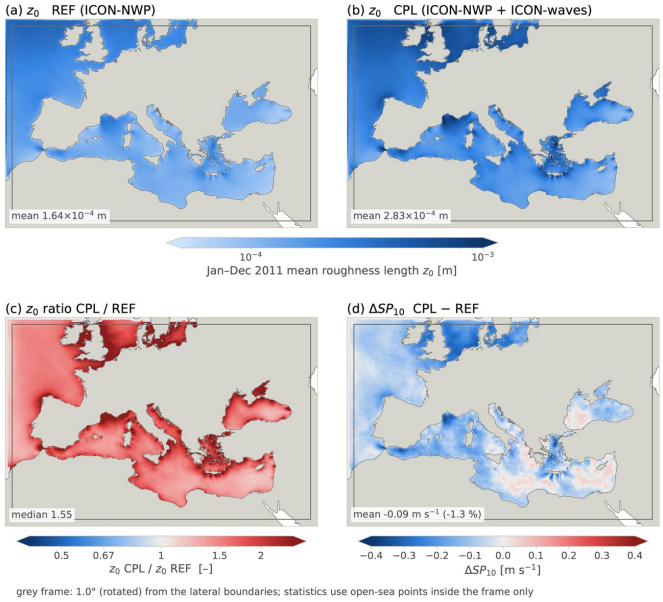


Fig. 2: Jan–Dec 2011 mean roughness length z_0 in (a) REF and (b) CPL, (c) z_0 ratio CPL/REF and (d) 10 m wind speed difference CPL − REF (Risto and Ahrens, 2026).

Task 3: Postprocessing DISTENDER simulations

In this task, we post-processed the DISTENDER simulations (EC-Earth3-Veg-driven ICON-CLM at 3.9 km) over the Med-CORDEX domain. This includes bias adjustment, validation, and inter-comparisons with low-resolution simulations, observation-based datasets, and a statistically downscaled dataset to assess the quality of the results and the added value of the convection-permitting simulations in the Mediterranean domain. We also performed a specific diagnostic on selected sub-regional scales for the latest DISTENDER reporting. The published outcomes in Essa and Ahrens (2026) and San José et al. (2026) are mainly based on these simulations and analyses. Additional analyses for further studies focusing on climate extremes are planned.

Publications

De Rovere, F., Bonino, G., McAdam, R., Scoccimarro, E., Somot, S., Parras-Berrocal, I. M., Ahrens, B., Djurdjevic, V., Li, L., and Masina, S. (2026): The added value of Med-CORDEX coupled high-resolution regional climate models in representing sea surface temperature and marine heatwaves in the Mediterranean Sea. Ocean Sci., 22, 2725–2742, https://doi.org/10.5194/os-22-2725-2026

Essa, Y. H. and Ahrens, B. (2026): DISTENDER D4.6: Interpreting climate scenarios. Zenodo, https://doi.org/10.5281/zenodo.22113239

Lohmann, R., Purr, C., and Ahrens, B. (2025): Atmospheric blocking and climate extremes in Germany in present and future climate. EGUsphere [preprint], https://doi.org/10.5194/egusphere-2025-3670

Parmar, M., Fröhlich, K., Sanna, A., Stacke, T., Benassi, M., Luo, Z., Peano, D., and Ahrens, B. (2026): Evaluation of representation of seasonally frozen ground characteristics in Land Surface Models: JSBACH and CLM. The Cryosphere, 20, 4157–4184, https://doi.org/10.5194/tc-20-4157-2026

Risto, D. and Ahrens, B. (2026): Atmosphere–waves coupling in the Mediterranean with ICON-CLM. Posters, MedCLIVAR 2026 conference and CLM-Community Assembly 2026.

San José, R., Bügelmayer-Blaschek, M., Torre, A., et al. (2026): Methodologies and tools to support climate change mitigation and adaptation actions. Clim. Change, 179, 231, https://doi.org/10.1007/s10584-026-04297-z

Singh, P. and Ahrens, B. (2026a): Fire patterns in the Himalaya and their meteorological drivers from km-scale ICON-CLM simulations. Environ. Earth Sci. Proc., 46(1), 8, https://doi.org/10.3390/eesp2026046008

Singh, P. and Ahrens, B. (2026b): Moist convection and water vapour transport into the upper troposphere over the Third Pole in multi-scale ICON-CLM simulations. MAUSAM, 77(4), 1223–1244, https://doi.org/10.54302/mausam.v77i4.7562

Singh, P., Poudel, A., and Ahrens, B. (in review): Nepal's first recorded tornado: its effect on the upper troposphere and lower stratosphere's moisture. Theor. Appl. Climatol.