

Supplementary material to: A model hierarchy to investigate heatwave persistence: From climate models to storm-resolving simulations

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Abstract

This document contains supplementary material to “A model hierarchy to investigate heatwave persistence: From climate models to storm-resolving simulations”. This includes additional results that complement the analysis presented in the main text: we display the ICON workflow, the full description of the variables from ICON and ERA5 and mean biases of the ICON experiments.

S1. ICON modelling system flow chart

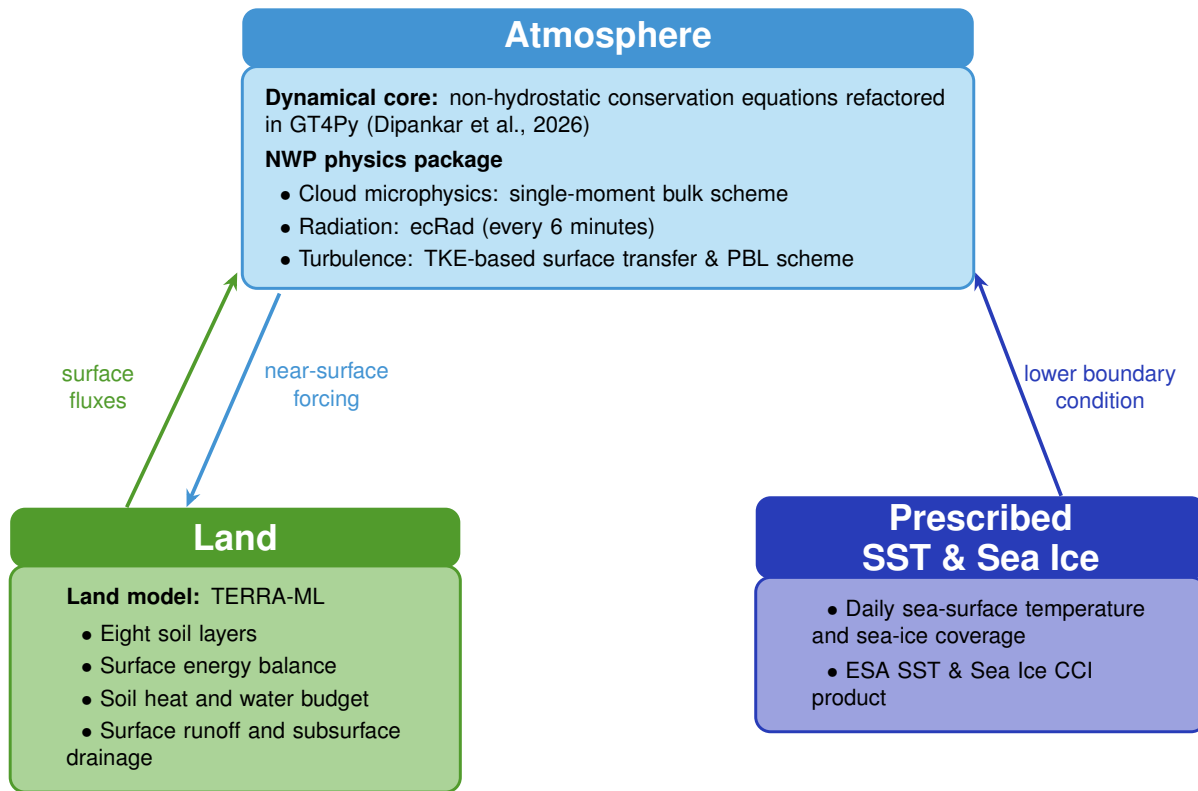


Figure S1: Schematic overview of the ICON modelling system used within the EXCLAIM framework. The diagram illustrates the main model components, physical parameterizations, and computational workflow analyzed in this study. The Tiedtke-Bechtold convection scheme is used in the parameterized simulations (Tiedtke, 1989; Bechtold et al., 2008). Further details of the model implementation are provided by Dipankar et al. (2026).

S2. Complete list of variables in ERA5 and ICON

Table 1 lists the ERA5 and ICON variables used in the analysis, grouped according to their corresponding diagnostic quantities. Variables were selected to provide the closest available physical counterparts between the two datasets. Nevertheless, some quantities are not defined identically because ERA5 and ICON employ different model formulations and diagnostic conventions. This is particularly relevant for soil moisture: ERA5 provides volumetric soil-water content in its uppermost soil layer, extending from the surface to approximately 7 cm depth, whereas ICON provides the total liquid and frozen water content within approximately the upper 6 cm of soil. These variables are considered suitable counterparts because both characterize the near-surface soil-water availability that influences evapotranspiration, surface-energy partitioning, and land-atmosphere coupling.

The use of correlations with near-surface temperature and precipitation emphasizes variations and coupling within each model or reanalysis while reducing sensitivity to differences in units, soil-layer thickness, and land-surface formulation. Comparisons of the resulting coupling metrics should nevertheless be interpreted as comparisons between analogous, rather than strictly identical, quantities.

Table 1: Full list of ERA5 and ICON variables used for the analysis. Variables are grouped by diagnostic quantity. Some quantities are not strictly identical between ERA5 and ICON, especially soil moisture, because ERA5 provides volumetric soil water whereas ICON provides total water content in the upper soil layer.

Diagnostic	ERA5	ICON
2-m temperature	2m_temperature ; used to derive daily mean temperature and daily maximum temperature	t_2m : used to derive daily mean temperature and daily maximum temperature
Soil moisture / soil water	volumetric_soil_water_layer_1 : volumetric soil water in the upper 0–7 cm, $\text{m}^3 \text{m}^{-3}$	w_so : total water content, ice plus liquid water, in the upper soil layer; approximately upper 60 mm
Total precipitation	total_precipitation ; accumulated precipitation, converted to mm and aggregated as needed	tot_prec : total precipitation
Geopotential height at 500 hPa	geopotential at 500 hPa; converted to geopotential height using $Z = \Phi/g$ if needed	geopot : geopotential at full-level cell centre at 500 hPa

S3. Global validation of surface temperature [local summer]

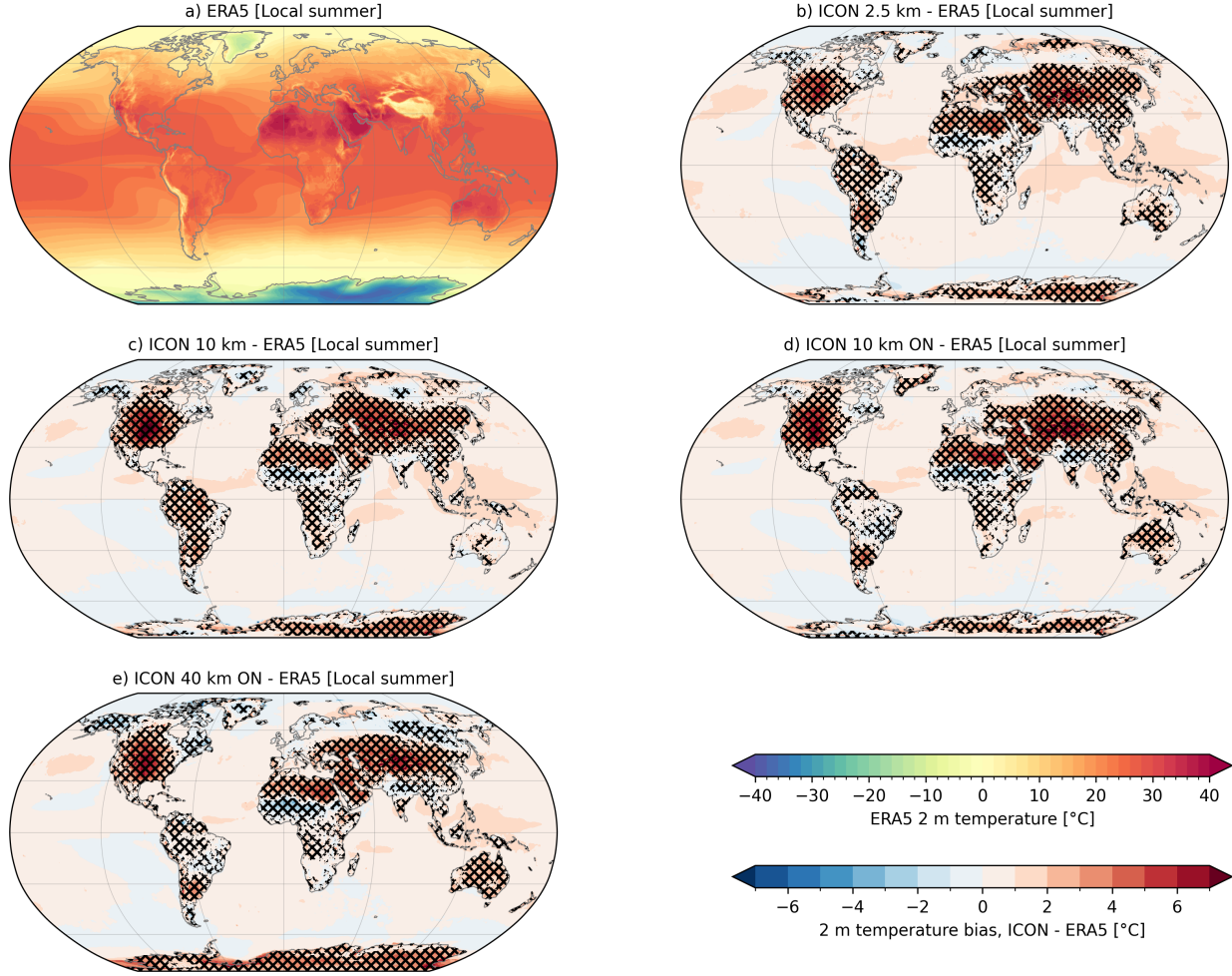


Figure S2: Seasonal mean 2m air temperature (T_{2m}) during local summer. Panel (a) shows the ERA5 climatology, while panels (b–e) show the corresponding biases relative to ERA5 for ICON-2.5 km, ICON-10 km, ICON-10 km-ON, and ICON-40 km-ON, respectively. Positive values indicate warmer conditions in the simulations than in ERA5. Crosses indicate grid points where the ICON four-season mean lies outside the central 95% of the corresponding ERA5 four-season bootstrap distribution ($p < 0.05$, two-sided test). A discontinuity near the Equator may arise from the hemispheric seasonal definition, which switches from JJA in the Northern Hemisphere to DJF in the Southern Hemisphere.

S4. Global validation of precipitation [local summer]

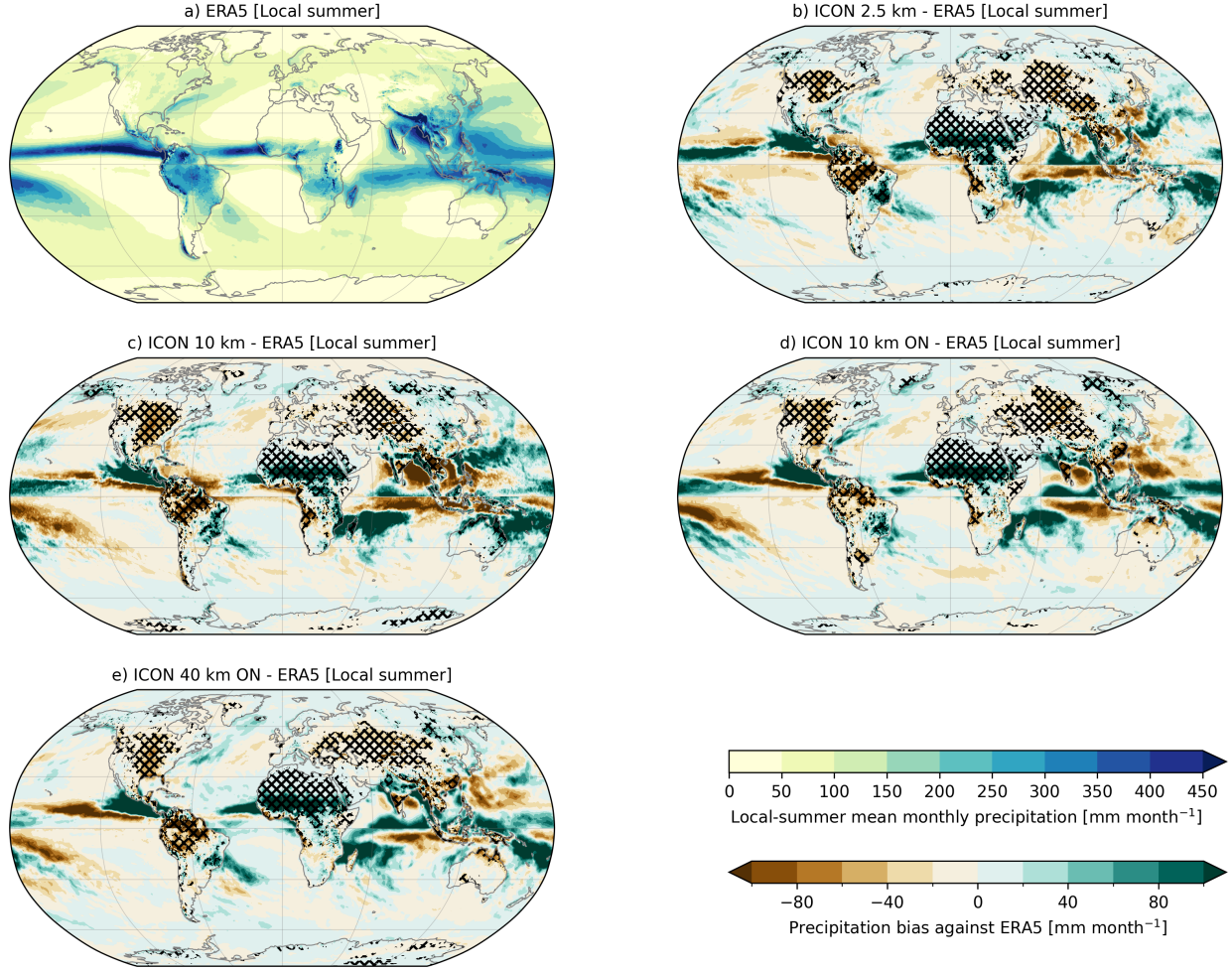


Figure S3: Seasonal monthly mean precipitation (mm month^{-1}) during local summer. Panel (a) shows the ERA5 climatology, while panels (b–e) show biases relative to ERA5 for ICON-2.5 km, ICON-10 km, ICON-10 km-ON, and ICON-40 km-ON, respectively. Positive values indicate an overestimation of precipitation relative to ERA5. Crosses indicate grid points where the ICON four-season mean lies outside the central 95% of the corresponding ERA5 four-season bootstrap distribution ($p < 0.05$, two-sided test). A discontinuity near the Equator may arise from the hemispheric seasonal definition, which switches from JJA in the Northern Hemisphere to DJF in the Southern Hemisphere.

S5. Global validation of soil moisture [local summer]

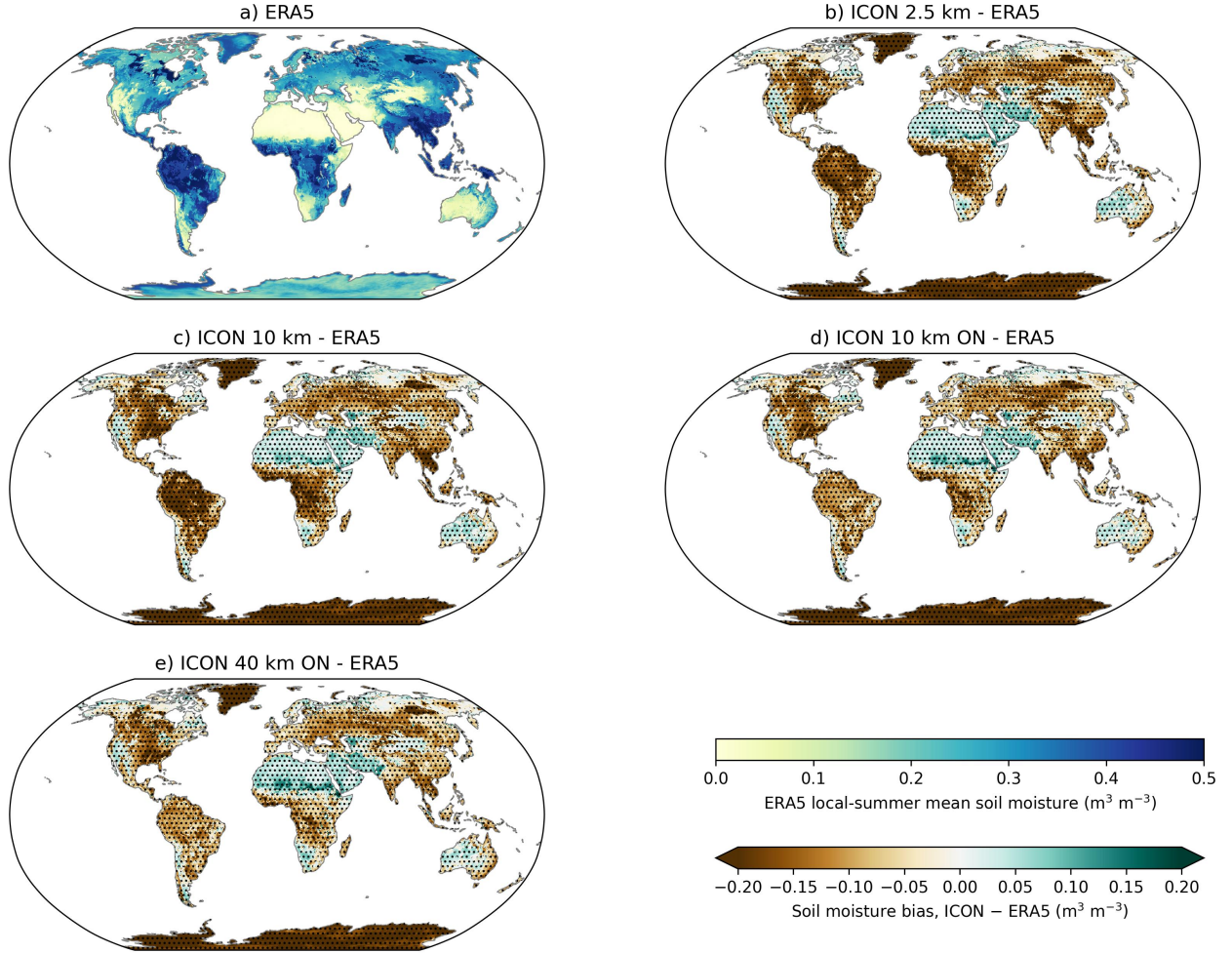


Figure S4: Seasonal monthly mean soil moisture ($\text{m}^3 \text{m}^{-3}$) during local summer. Note that the soil moisture in ICON and ERA5 are not exactly the same variables, see 1. Panel (a) shows the ERA5 climatology, while panels (b–e) show biases relative to ERA5 for ICON-2.5 km, ICON-10 km, ICON-10 km-ON, and ICON-40 km-ON, respectively. Stippling indicates grid points where the ICON four-season mean lies outside the central 95% of the corresponding ERA5 four-season bootstrap distribution ($p < 0.05$, two-sided test). A discontinuity near the Equator may arise from the hemispheric seasonal definition, which switches from JJA in the Northern Hemisphere to DJF in the Southern Hemisphere.

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