Added Value and Errors Ranges: Results from the Convection-Resolving Climate Simulations Intercomparison Project LocMIP

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R e L o C l i m

1 Motivation

Convection resolving climate simulations (CRCSs) have a large potential to improve the results of regional climate models (RCMs) by avoiding errors arising from the use of convection parameterization schemes and by better representation of surface boundary forcing due to high spatial resolution. However, CRCSs are far from being established and their added value compared to coarser simulations could not be sufficiently demonstrated, to justify the enormous costs associated with CRCS.

In the **L**ocal **C**limate **M**odel **I**ntercomparison **P**roject (LocMIP) two seasons were simulated with 4 different RCMs over the eastern Alpine region with 10 km (convection parameterized) and 3 km (convection resolving) grid spacing in order to:

- exploring the **error ranges** of CRCSs in hilly and mountainous regions
- detect **potential added value** of CRCSs compared to coarser simulations

2 Data and Methods

This study focuses on the **eastern Alpine region** (Fig. 1) and two sub regions: a hilly area in the foothills of the Alps (D4a) and one around the highest peaks of Austria (D4b). Four RCMs were used: **CCLM 4.0**, **MM5 3.7.4**, and **WRF 2.2.1** at the University of Graz and **CCLM 4.8** at the Brandenburg University of Technology Cottbus.

Data from the Integrated Forecast System (IFS) of the European Centre for Medium-Range Weather Forecasts (ECMWF) (25 km hor. resolution) were used to force the simulations with **10 km** grid spacing at the boundaries of D2. **Convection resolving** simulations with 3 km grid spacing (CRCS) were nested in the 10 km runs by two way coupling (WRF, MM5) and one way coupling techniques (CCLM). The evaluation is based on one summer (**JJA 2007**) and one winter season **(DJF 2007-08)**.

As **reference data** from the Integrated Nowcasting through Comprehensive Analysis (**INCA**) model (Haiden et al. 2011) are used which provides hourly data for **2 m temperature (T2M)**, **precipitation (PR)**, **relative humidity (HUS)**, and **global radiation (GL)** on an one km grid.

The evalution is performed on the 1 km INCA grid. Box-Whisker Plots are used to depict **spatial error ranges** of the temporal averaged fields. Mean diurnal cycles give insights in **sub daily processes** and frequency **distributions** reveal model performance characteristics also in the tails of the distributions. **Fractions Skill Scores** (FSS) (Roberts and Lean, 2008) and the Structure-Amplitude-Location (SAL) method (Wernli et al., 2008) are applied for a more advanced evaluation of precipitation.

3 Results and Discussion

3.1 Error Ranges

Errors of the simulated mean seasonal fields in D3 are shown in **Fig. 2** as Box-Whisker plots. **In JJA the error ranges of T2M are smaller** in all 3 km simulationsthan in 10 km simulations and all simulations have smaller error ranges that the driving data (IFS) (Fig. 2a). In DJF T2M (Fig. 2b) and all other analysed parameters (Fig. 2c-2h) added value due downscaling simulations cannot be clearly es- tablished in seasonal mean fields.

3.2 Diurnal Cycles

Diurnal cycles are shown in **Fig.3** for D3, D4a, and D4b. The T2M cycle is well reproduced by all RCMs (Fig. 3a, 3b). Only CCLM4.0 has a remarkable cold bias in DJF especially in the mountainous D4b region (panel b right). **For PR the timing of the maximum in JJA is improved** in both CCLM 3 km simulations (Fig. 3c). In DJF the diurnal cycle of RH is not captured well by any RCMs (Fig. 3f). GL is well represented in all models with exception of CCLM4.0 which underestimates GL largely in JJA (Fig. 3g).

3.3 Distribution Properties

There are big differences in the tails of the modeled and observed distributions (**Fig. 4**). In DJF all CCLM simulations show a distinct zero degree peak in T2M (Fig. 4b). The RCMs underestimate the maximum of PR in both seasons (Fig. 4c, 4d). However, the **CRCS are able to produce more intense PR than the 10 km simulations**. The distributions of RH differ largely from those of INCA (Fig. 4e, 4f). The maximum GL is underestimated particularly in DJF (Fig. 4h). This might be related to missing reflections of sunlight from snow in the models.

3.4 FSS Analysis

In JJA all RCMs (except MM5 below 1 mm/h) have a higher Fractions Skill Score (FSS) and therefore a better representation of spatial rainfall -distribution than IFS (**Fig. 5** upper row). **All CRCSs show a larger FSS above 0.5 mm/h thres-hold**. In DJF FSSs are generally higher than in JJA (Fig. 5 lower row). Similar to JJA the CRCSs have higher FSS values than the 10 km simulations (except WRF).

3.6 SAL Evaluation

The Structure, Amplitude, Location (SAL) evaluation shows very small S values for the IFS model (**Fig. 6**i) in both seasons. This indicates to large and/or to flat precipitation objects (coarse resolution). The RCMs and particularly **the CRCSs are improving the S component** remarkably. Furthermore, especially in JJA the A component of the CRCSs are increasing. Smaller S and higher A values indicate that there is more precipitation from smaller and/or more peaked objects.

4 Conclusions

We analyzed added value of in convection resolving climate simulations (CRCSs) compared to coarser simulations and the IFS analysis. Following main conclusions could be drawn:

- CRCSs **decrease the spatial error range of T2M in JJA**, but not in DJF or other parameters
- CRCSs partially **improve the diurnal cycle** of PR in JJA
- CRCSs are more **realistic at higher precipitation** intensities
- The **structure** of PR objects is represented **more realistic** in CRCSs
- Increasing resolution needs adjustments in RCM physics (e.g., CRCSs have higher global radiation values)
- RCMs show **larger errors in mountainous region** (D4b) but potential added values of CRCS is higher

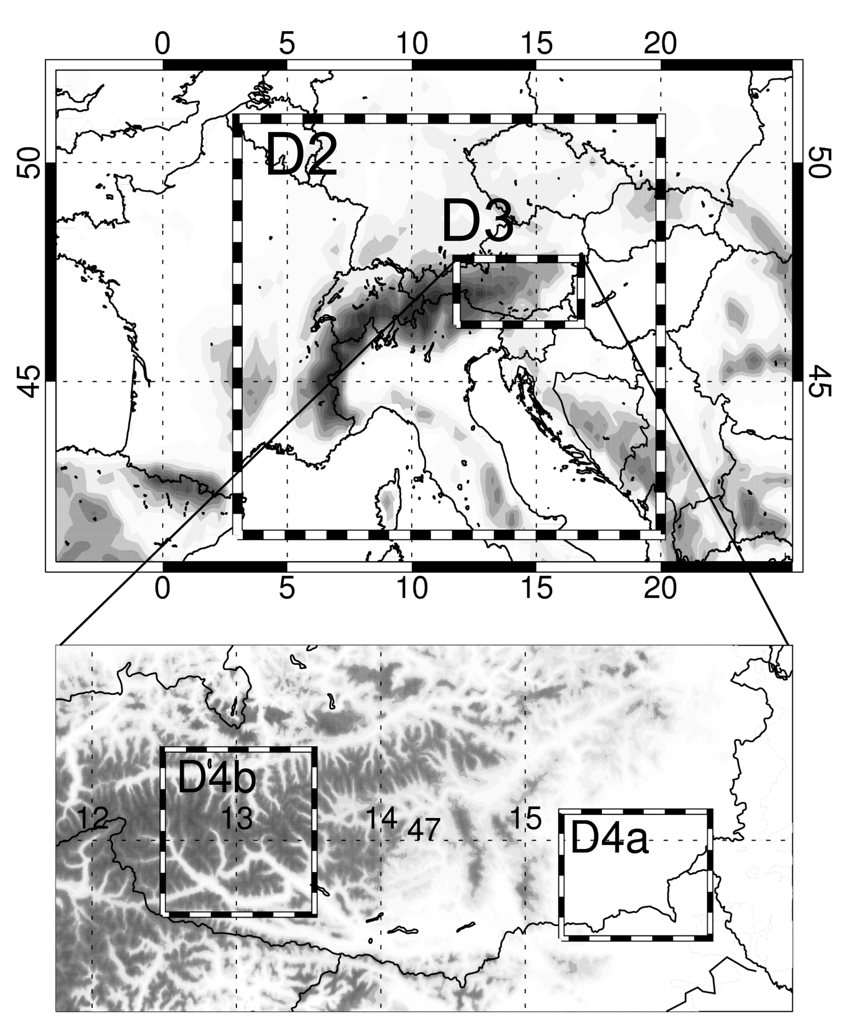

Fig. 1: In the upper panel the minimum coverage of the 10 km and the 3 km simulations are depicted. The lower panel shows the domain D3 and the two sub-domains D4a and D4b.

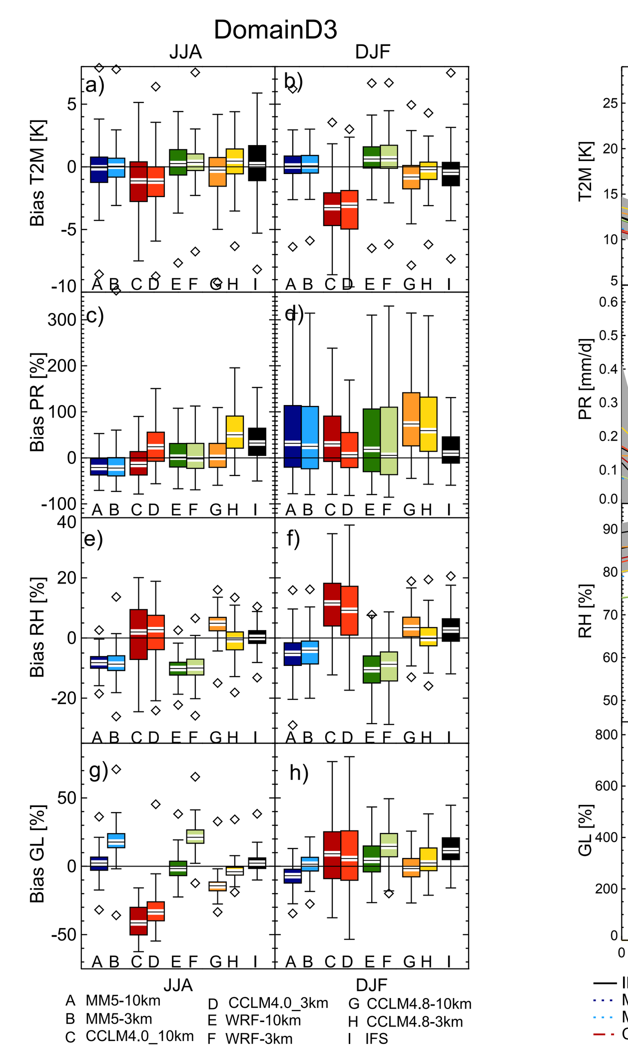

Fig. 2: Spatial Box-Whisker plots of the seasonal mean bias fields of simulations on 10km and 3km grids in D3for T2M, PR, RH, and GL (top down). Left column shows results of JJA and right column those of DJF.

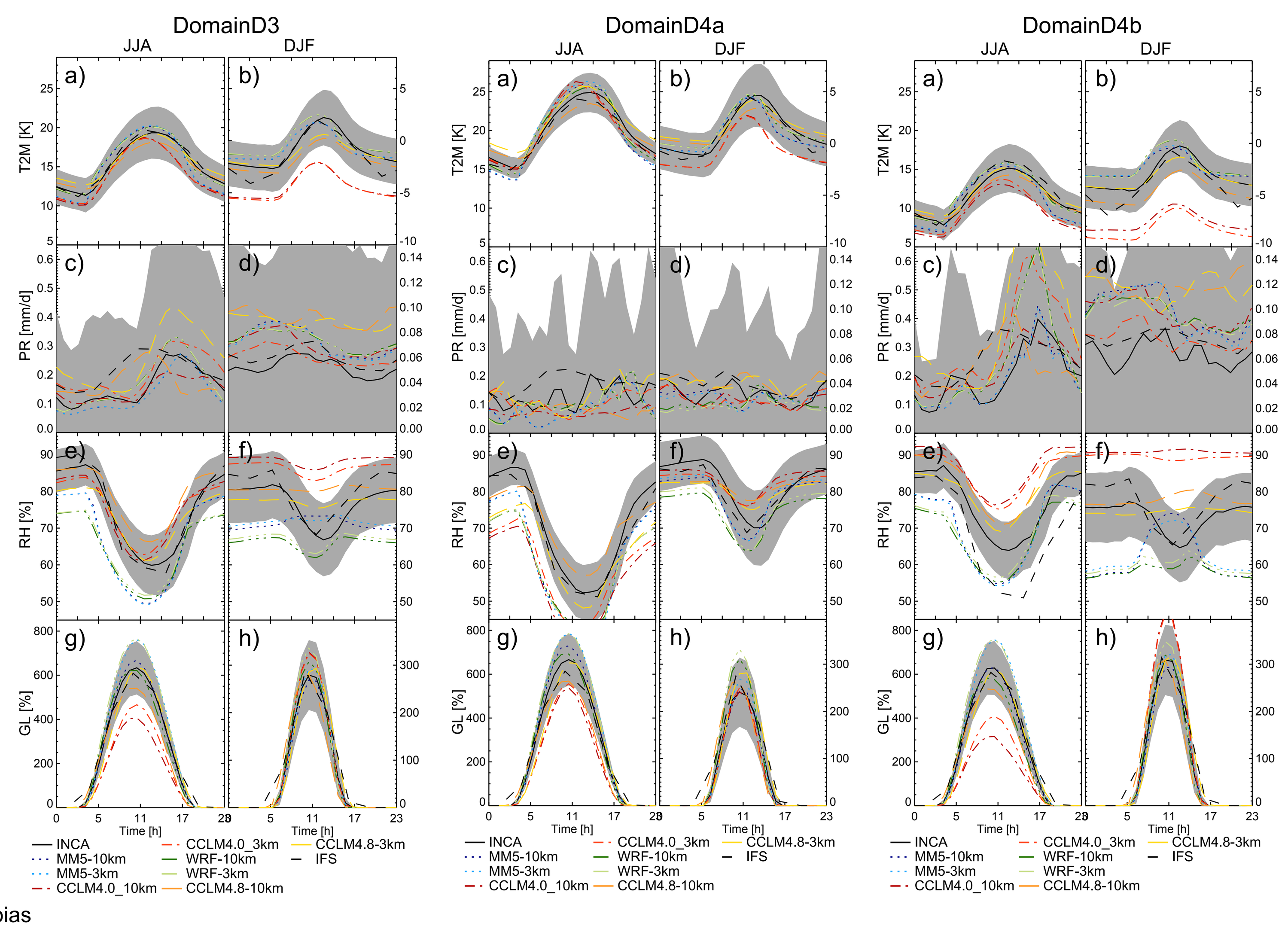

Fig. 3: Diurnal cycles of the spatial averaged simulations depicted for the eastern Alpine region D3 (left), and the sub domains D4a (middle), and D4b (right). The left panels (a, c, e, and g) show JJA and the right panels (b, d, f, and h) DJF. T2M is shown in panel a and b, PR in c and d, RH in e and f, and GL in g and h. Shadings display the 25 % and 75 % percentiles of INCA.

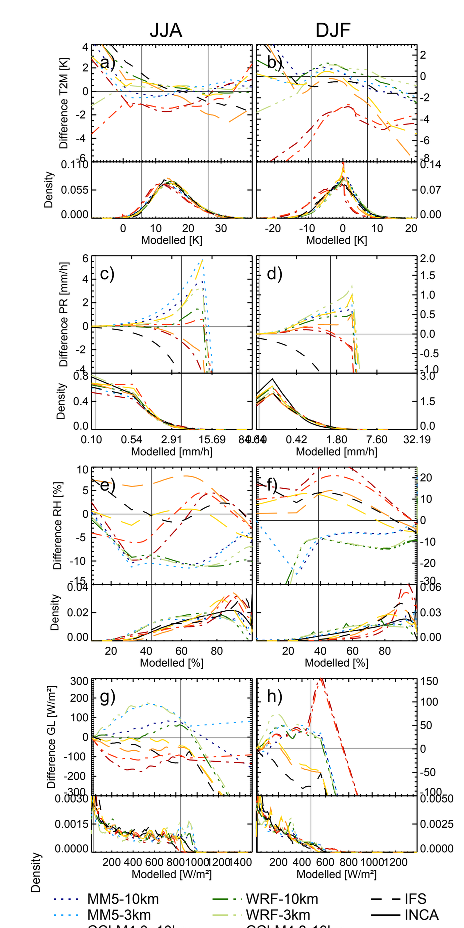

Fig. 4: Simulated minus observed quantile differences (upper sub panels) and density distributions (lower sub panels) for JJA (left column) and DJF (right column). The two vertical lines depict the 5 % and 95 % quantile of the INCA dataset.

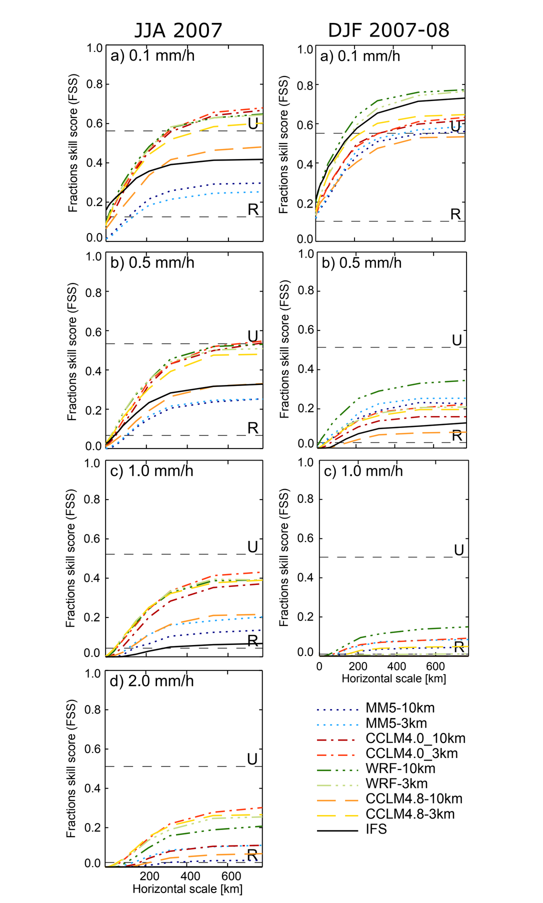

Fig. 5: Fractions Skill Skores (FSS) of the average JJA (upper row) and DJF (lower row) precipitation fields in D3 for different precipitation thresholds in each subpanel. A random forecast would have the FSS R (lower dashed line) whereas reasonable skill can be assumed by crossing the uniform (U) dashed line). A perfect simulation has a FSS of 1.

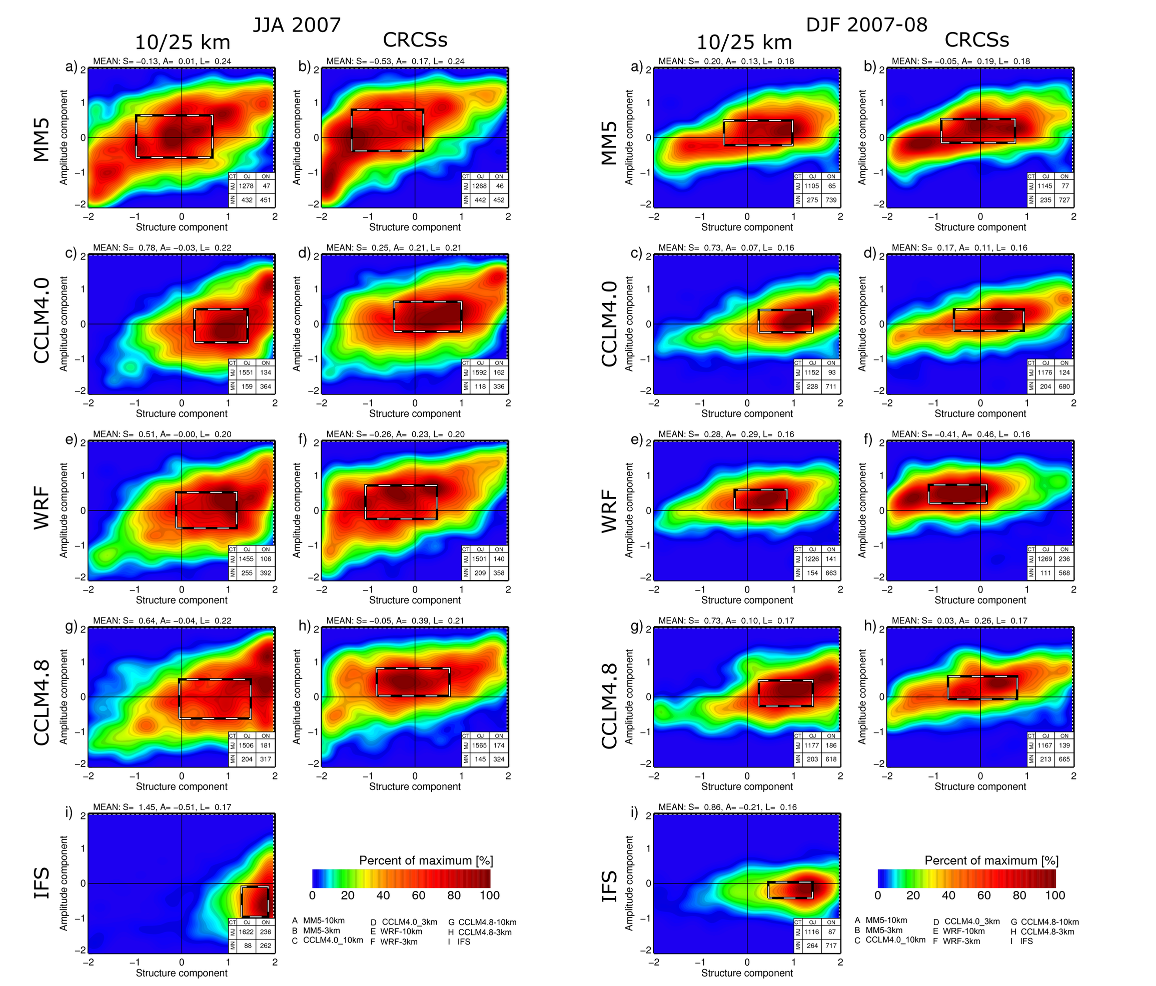

Fig. 6: Structure, Amplitude, and Location (SAL) diagrams for JJA (left panel) and DJF (right panel) precipitation. From the spatial distribution of hourly precipitation structure and amplitude values contour maps were created where red shows the maximum density of points. The mean values of SAL are written above each subplot and the box inside the plots shows the 25 % to 75 % quantile of S and A. In the lower right corner of the subplots contingency tables are depicted. A perfect simulation would have S=0, A=0, and L=0.

Acknowlegements: This work was founded by the Austrian Science Fund (FWF) under project ID P19619. The authors acknowledge the data providers at Central Institute for Meteorology and Geodynamics (ZAMG) for data of the Integrated Nowcasting through Comprehensive Analysis (INCA) dataset. This study heavily relied on computing resources. The authors are therefore grateful to the Jülich Supercomputing Centre (JSC) and the European Centre for Medium-Range Weather Forecasts (ECMWF) for providing these resources. The ECMWF receive thanks for providing operational Integrated Forecast System (IFS) analysis and short term forecasts which served as lateral boundary conditions (LBCs) for the simulations.

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