Sensitivity study of the WRF model for regional climate modeling of the Carpathian Basin region

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EMS Annual Meeting: European Conference for Applied Meteorology and Climatology 2018 | 3–7 September 2018 | Budapest, Hungary

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1 Abstract

The WRF model is one of the most tunable models not only based on the sheer number of available parameterizations but several other modeling aspects can be set by the user to create the most efficient and accurate model simulations.

Therefore, in this study **the WRF-ARW non-hydrostatic mesoscale model is used to produce short-term regional climate simulations with various configurations in order to analyze the effect of different physical parameterizations and horizontal resolution on simulated variables**. Planetary boundary layer and cumulus schemes are tested and the one-year-long **simulations are carried out with 50 km and 10 km grid spacing** using a nested domain. The geographical setup of the model is in accord with the Med-CORDEX region, so comparison with other model simulations could be done in the future. **For input data the ERA5 reanalysis database was chosen** which has a resolution of about 30 km, updated in the model every 6 hours. In the validation process **the WRF output is compared with the 25 km E-OBS gridded observational dataset**. This presentation focuses on the abilities of the WRF model to reproduce **precipitation patterns** of the year 2013. The geographical area of investigation includes the Carpathian Basin region, the Alps, the Carpathian Mountains and the Dinaric Alps.

Initial results show that summer precipitation is well represented in the model, but in other seasons the precipitation is overestimated and in parallel the temperature is underestimated. According to our evaluation presented here, the simulations are sensitive to the different parameterization configurations and horizontal resolution used in the model.

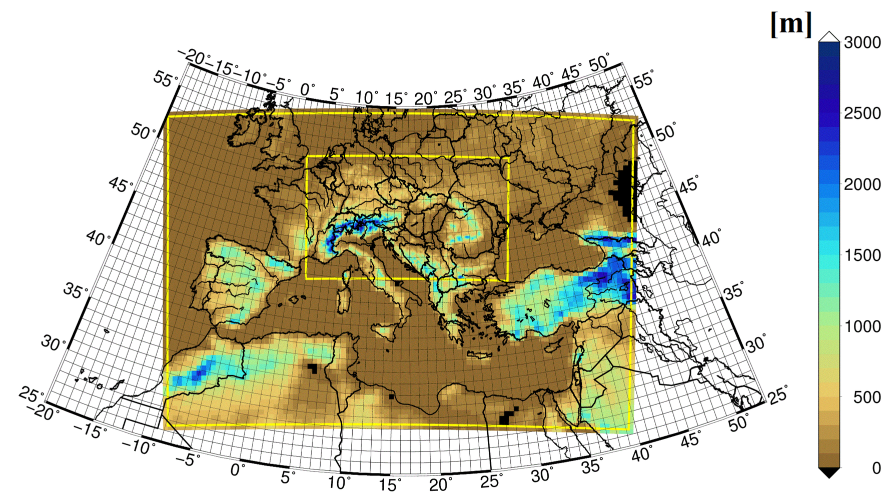
2 Motivation

- In the Hungarian climate modeling community so far **the REMO, ALADIN-Climate, PRECIS and RegCM models were adapted** out of which currently the ALADIN and the RegCM are used.
- Because of Hungary's geographical location **the most problematic climatic factor is the precipitation**, there is **no agreement on its foreseeable change** according to the existing simulations especially in terms of summer precipitation.
- Given that the predecessor of the WRF, the MM5 was developed with the intention of creating more accurate precipitation simulations, **we began the adaptation of the WRF model for regional climate modeling purposes**.

3 Model (WRF v3.8[1]) setup and configurations

3.1 Domains

- **Two domains** using one-way nesting.
- Horizontal resolution is **50 km** for the outer, and **10 km** for the inner domain.
- 44 vertical levels.
- Outer domain is in accord with the MED-CORDEX region.
- Inner domain includes the Carpathian Basin region, the Alps, the Carpathian Mountains and the Dinaric Alps.
- Area of investigation: 42°–52° N; 4°–30° E.



3.2 Data

Input data

- **ERA5 reanalysis[2]** was used as initial and boundary conditions.
- Approx. 30 km horizontal resolution.
- Updated in WRF every 6 hours.

Validation data

- WRF model results were compared with the **E-OBS daily gridded observational dataset[3]** (v17.0).
- Approx. 25 km horizontal resolution.

3.3 Simulations – parameterizations

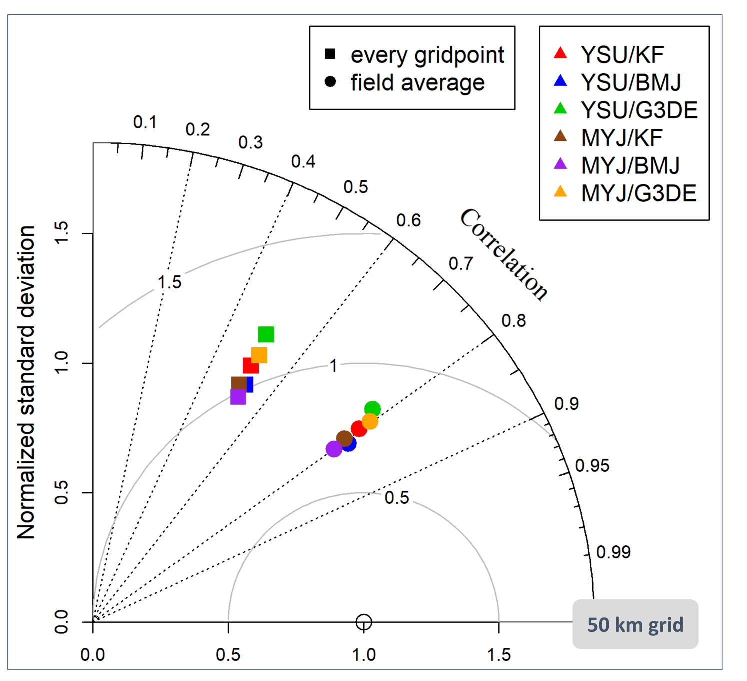
- 6 simulations with different parameterization combinations.
- The cumulus convection, planetary boundary layer and surface layer schemes were changed.
- All of the simulations were performed in non-hydrostatic mode.

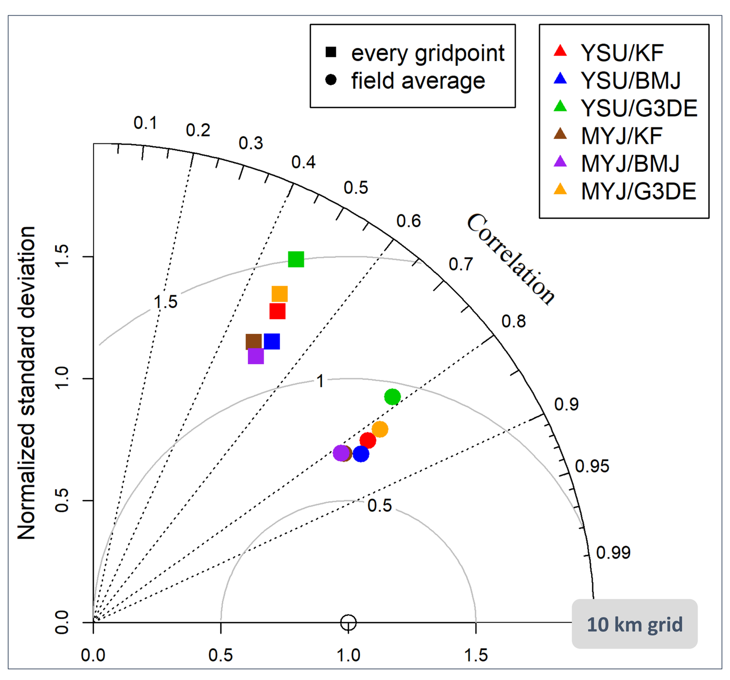
Name/Acronym	Color	PBL, Surface layer	Cumulus convection	Microphysics	Radiation	Land-surface
YSU/KF	red	Yonsei University (YSU[4]), MM5 Similarity[5]	Kain–Fritsch (KF[7])	Aerosol-aware Thompson[9]	Dudhia SW[10], RRTM LW[11]	Noah–MP LSM[12]
YSU/BMJ	blue	Yonsei University (YSU), MM5 Similarity	Betts–Miller–Janjic (BMJ[6])	Aerosol-aware Thompson	Dudhia SW, RRTM LW	Noah–MP LSM
YSU/G3DE	green	Yonsei University (YSU), MM5 Similarity	Grell 3D Ensemble (G3DE[8])	Aerosol-aware Thompson	Dudhia SW, RRTM LW	Noah–MP LSM
MYJ/KF	brown	Mellor–Yamada–Janjic (MYJ[6]), Eta Similarity[6]	Kain–Fritsch (KF)	Aerosol-aware Thompson	Dudhia SW, RRTM LW	Noah–MP LSM
MYJ/BMJ	purple	Mellor–Yamada–Janjic (MYJ), Eta Similarity	Betts–Miller–Janjic (BMJ)	Aerosol-aware Thompson	Dudhia SW, RRTM LW	Noah–MP LSM
MYJ/G3DE	orange	Mellor–Yamada–Janjic (MYJ), Eta Similarity	Grell 3D Ensemble (G3DE)	Aerosol-aware Thompson	Dudhia SW, RRTM LW	Noah–MP LSM

4 Results

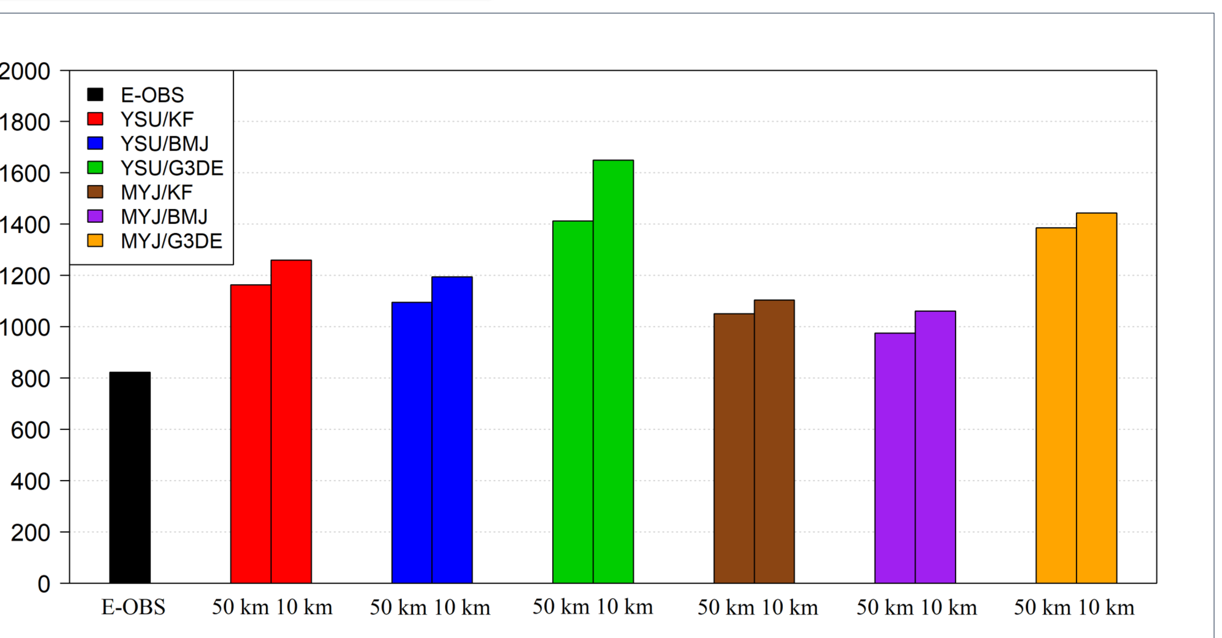
4.1 Taylor diagrams

Normalized Taylor diagrams[13] for the daily total precipitation of the 6 simulations, carried out with 50 km (left) and 10 km (right) horizontal resolution, for the year 2013. Different colors represent the different model configurations. Statistical parameters were calculated taking into account every grid point separately (squared symbols) and values averaged over the whole field (round symbols) within the area of investigation.





4.2 Annual total precipitation



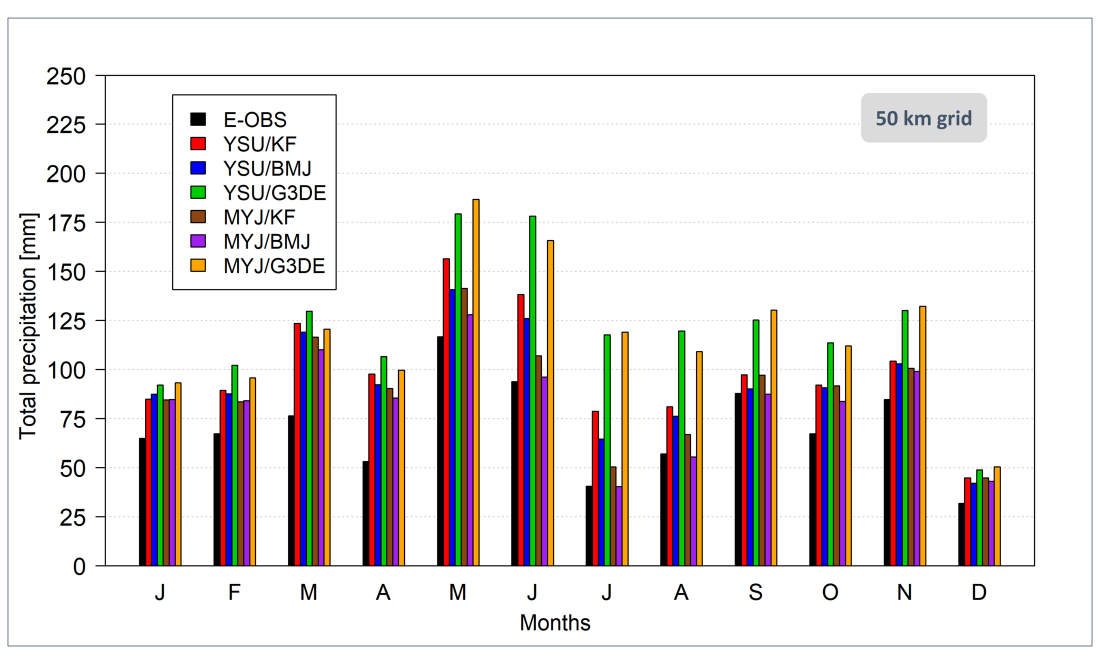
Observed and simulated total precipitation for the year 2013, with 50 km and 10 km horizontal resolution, averaged over the area of investigation.

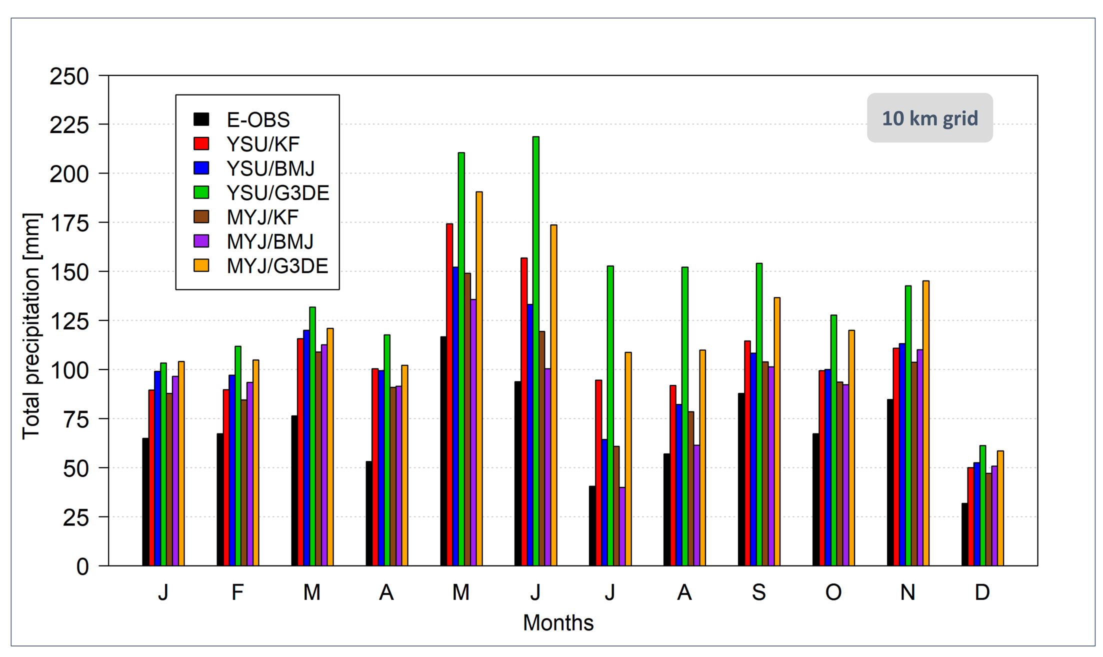
- The simulations generally overestimate the yearly precipitation.
- The runs with the coarser (50 km) grid spacing lead to more accurate results.
- Using the MYJ PBL scheme instead of the YSU scheme improves model performance.
- Out of the tested cumulus schemes the BMJ is the most accurate, and the G3DE performs the worst.

4.3 Monthly total precipitation

Observed and simulated total precipitation for each month in the year 2013, with 50 km (left) and 10 km (right) horizontal resolution, averaged over the area of investigation.

- Note the accuracy of the 50 km MYJ/BMJ simulation in the summer and in September.





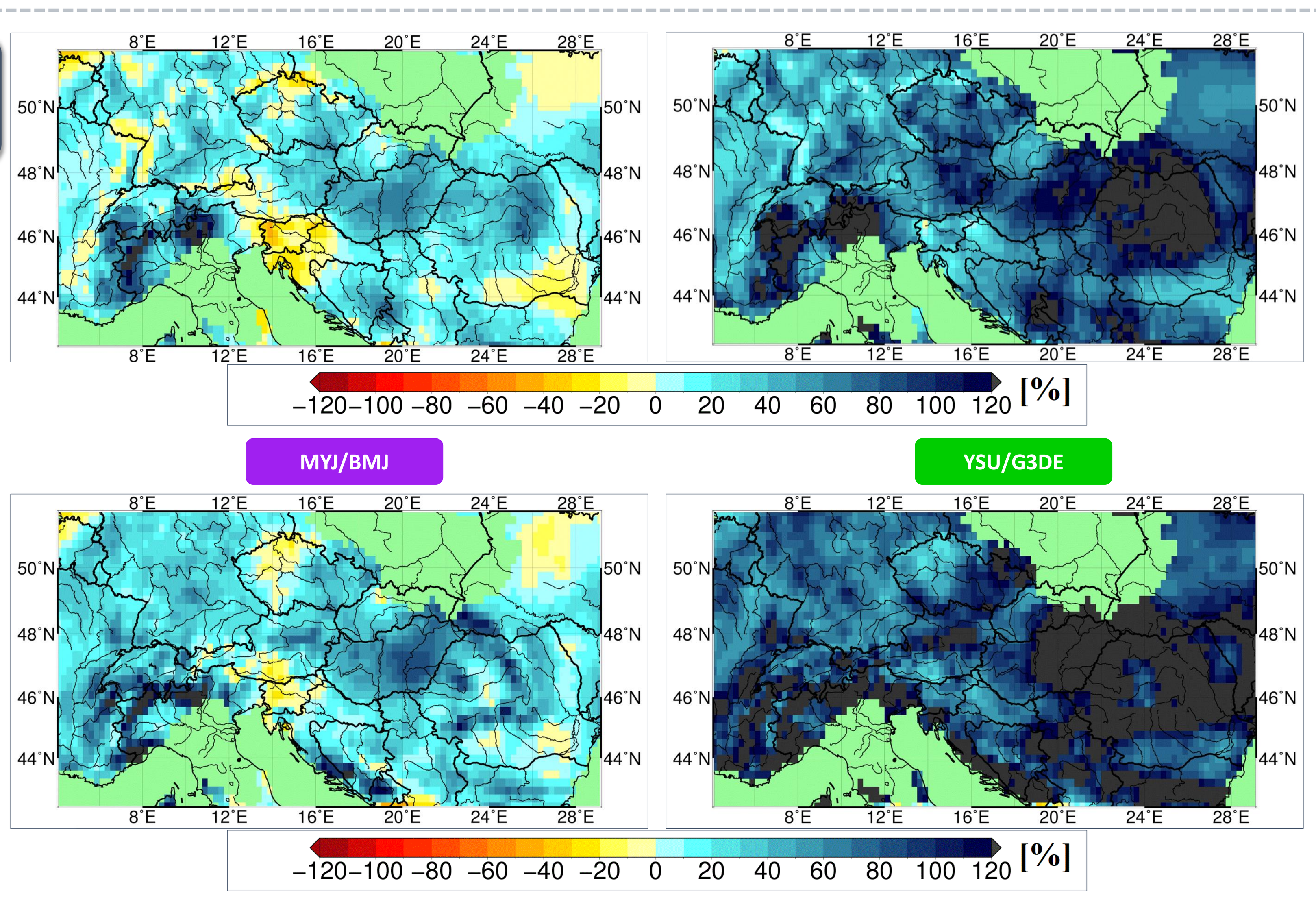
4.4 Annual precipitation bias

50 km grid

Field of annual total precipitation bias over the area of investigation between WRF–simulated and E-OBS observational variables, for the simulations rated as best (left) and worst (right) based on their performance.

10 km grid

- The 10-km-grid runs produce excess wet bias over the mountainous regions.



4.5 High-elevation precipitation

Number of days when total precipitation exceeded 5 mm, 10 mm and 15 mm in areas above 800 m sea level height.

Daily total precipitation	E-OBS	YSU/KF	YSU/BMJ	YSU/G3DE	MYJ/KF	MYJ/BMJ	MYJ/G3DE
> 5 mm	80	178	169	223	118	133	172
> 10 mm	14	53	54	91	34	40	54
> 15 mm	3	13	12	19	8	11	11

Daily total precipitation average calculated only from gridpoints above the elevation of 800 m within the area of investigation, in the year of 2013, for the finer grid (10 km horizontal resolution) simulations.

- Significant overestimation of daily total precipitation in high-elevation regions by the 10 km simulations.
- The MYJ PBL scheme combined with the KF cumulus scheme works best in mountainous areas out of the tested configurations.

5 Conclusions

- **The WRF regional climate model is sensitive to the used parameterization configurations and horizontal resolution.**
- **We found the best performing cumulus scheme to be the BMJ, while the G3DE produced the least accurate results.**
- **Out of the tested PBL/Surface layer parameterizations the MYJ/Eta Similarity scheme improved model performance compared to the YSU/MM5 Similarity scheme.**
- **The runs with 50 km horizontal resolution gave better results than the ones with 10 km grid spacing. Finer resolution led to increased overestimation in mountainous regions.**

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