An Innovative Bias Correction Method for Extreme Events for Seasonal Energy Management

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Abstract

When one is using climate simulation outputs, one critical issue to consider is the systematic bias affecting the modelled data. The bias correction of modelled data is often used when one is using impact models to assess the effect of climate events on human activities. However, the efficacy of most of the currently available methods is reduced in the case of extreme events because of the limited number of data for these low probability and high impact events. In this study, a novel bias correction methodology is proposed, which corrects the bias of extreme events. To do so, we extended one of the most popular bias correction techniques, i.e., quantile mapping (QM), by improving the description of extremes through a generalised extreme value distribution (GEV) fitting. The technique was applied to the daily mean temperature and total precipitation data from three seasonal forecasting systems: SEAS5, System7 and GCFS2.1. The bias correction efficiency was tested over the Southern African Development Community (SADC) region, which includes 15 Southern African countries. The performance was verified by comparing each of the three models with a reference dataset, the ECMWF reanalysis ERA5. The results reveal that this novel technique significantly reduces the systematic biases in the forecasting models, yielding further improvements over the classic QM. For both the mean temperature and total precipitation, the bias correction produces a decrease in the Root Mean Square Error (RMSE) and in the bias between the simulated and the reference data. After bias correcting the data, the ensemble forecasts members that correctly predict the temperature extreme increases. On the other hand, the number of members identifying precipitation extremes decreases after the bias correction.

Methodology

$$y = h(x) \;\rightarrow\; CDF_y\,(y) = CDF_x\,(x) \qquad (1)$$

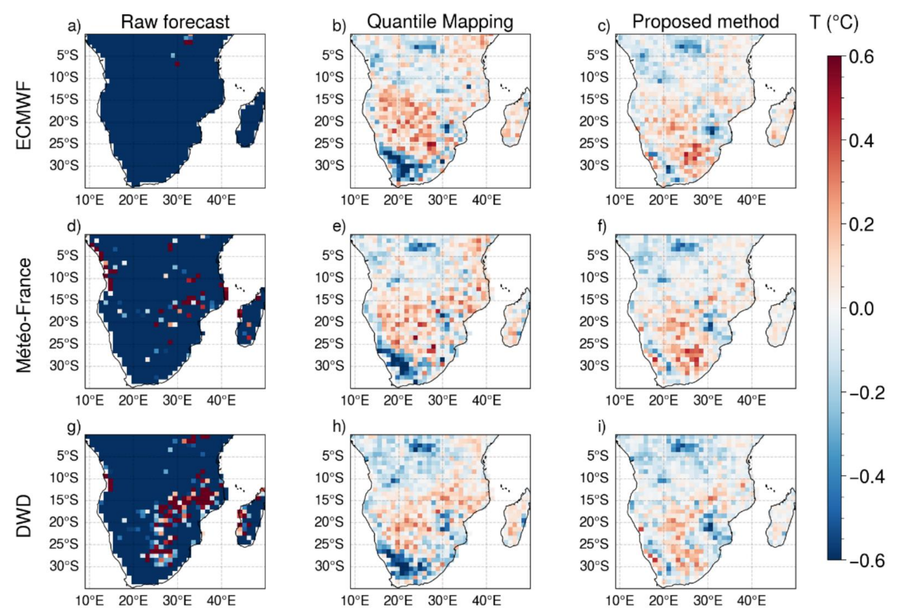
$$y = {CDF_y}^{-1}\,(CDF_x\,(x)) \qquad (2)$$

$$CDF(x;\mu;\sigma;\xi) = exp\left\{-\left[1+\xi\left(\frac{x-\mu}{\sigma}\right)\right]^{-1/\xi}\right\} \qquad (3)$$

Table 1. The three forecasting systems in the Copernicus Climate Change Service (C3S) and their original configurations.

Forecasting System Name	Forecasting Centre	Hindcast Ensemble Size	Hindcast Period	Horizontal Resolution	Reference
SEAS5	ECMWF	25	1981–2016	1° × 1°	[34]
System 7	Météo-France	25	1993–2018	1° × 1°	[35]
GCFS2.1	DWD	30	1993–2019	1° × 1°	[36]

Temperature extreme identification



Temperature extreme value corresponding to the difference between the 99th percentile for the three seasonal forecast systems SEAS5 (a–c), System7 (d–f) and GCFS2.1 (g–i), and the 99th percentile of ERA5. The columns refer to the type of data: raw seasonal forecasts (a,d,g), seasonal forecast data corrected with quantile mapping (b,e,h), and seasonal forecast data corrected with the proposed bias correction method (c,f,i). Maps refer to January and lea

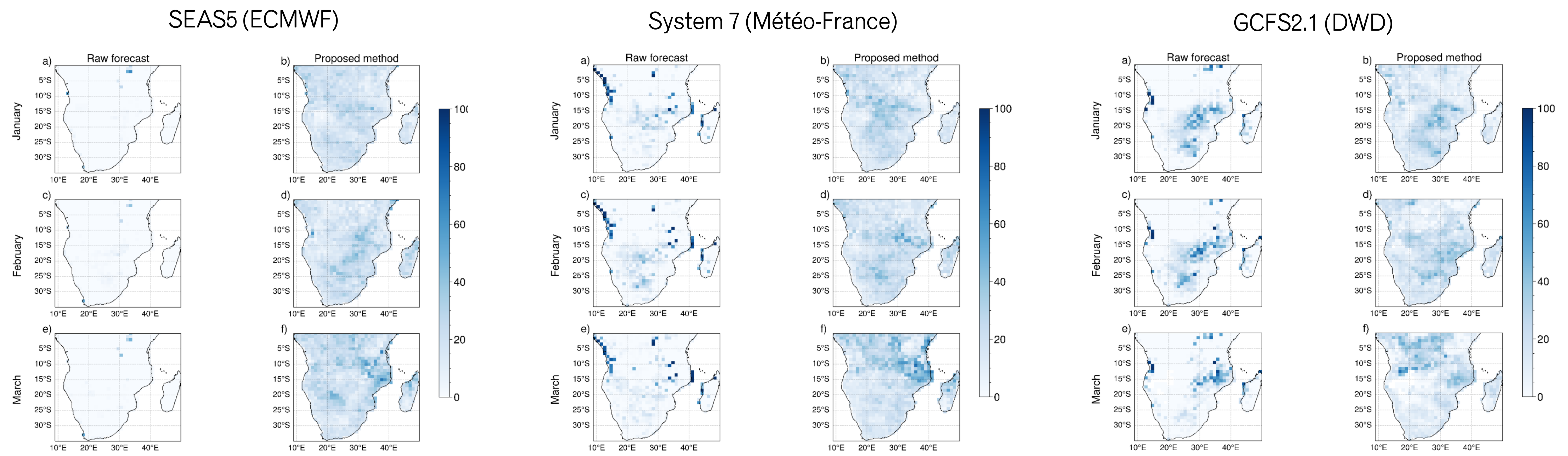
Extreme Temperature spatialization

Spatial distribution of average percentage of ensemble members that correctly predict extreme events defined as the values of 2 m mean temperature exceeding the 99th percentile:

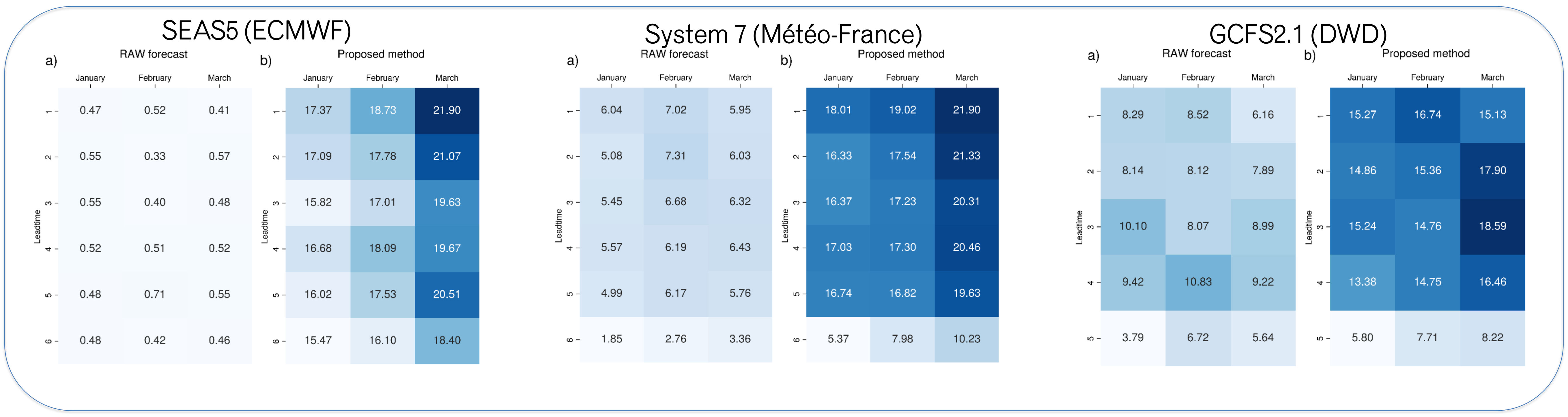
a, c, e :raw data

b, d, f: bias-corrected data

Results are shown for the three months (row-wise) and lead time one.

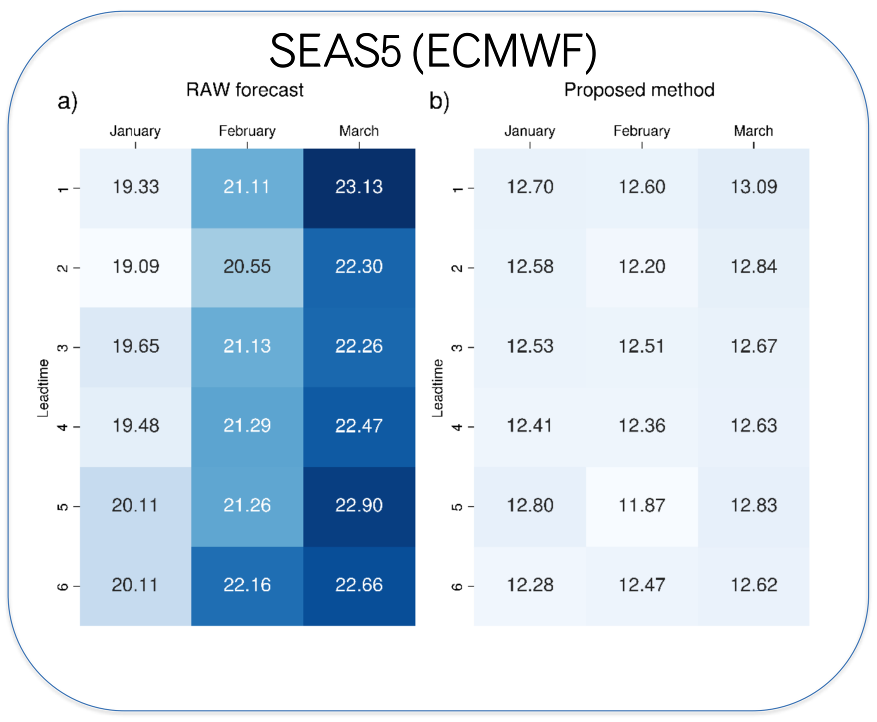


Temperature Validation



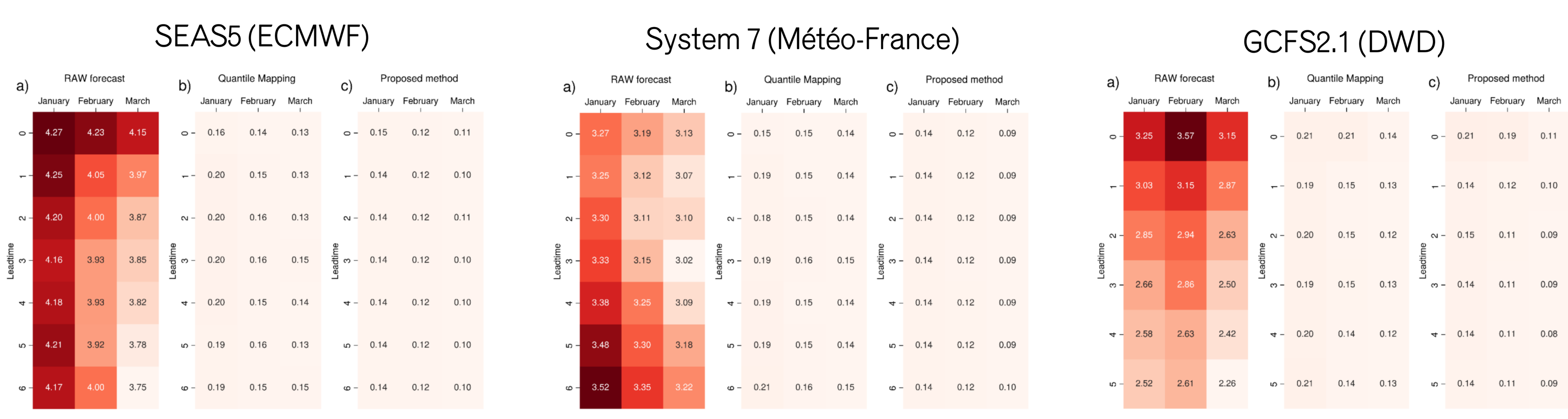
Mean percentage of ensemble members correctly predicting 2 m mean temperature over the 99th percentile value for seasonal forecast: (a) raw data and (b) data corrected with the proposed bias correction method. The colour scale ranges from white (0%) to dark blue, increasing in intensity as the percentage increases.

Precipitation Validation



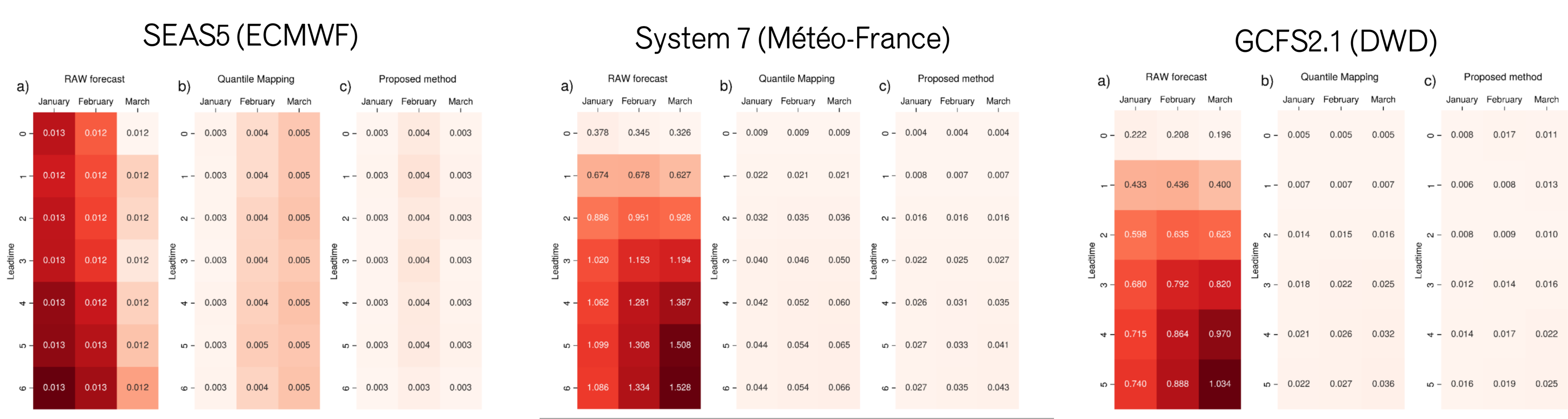
Mean percentage of ensemble members correctly predicting total precipitation over the 99th percentile value for seasonal forecast SEAS5 (ECMWF): (a) raw data and (b) data corrected with the proposed bias correction method.

RMSE analysis for 2m Temperature



RMSE (in K) of the 2 m mean temperature 99th percentile value for three seasonal forecast model compared to ERA5 reanalysis: (a) raw data, (b) data corrected with standard quantile mapping and (c) corrected with the proposed bias correction method. The colour scale ranges from white (RMSE = 0) to dark red, increasing in intensity as the metric increases. The most intense colour corresponds to the maximum value

RMSE analysis for Precipitation



RMSE (m) of the total precipitation 99th percentile value for three seasonal forecast models compared to ERA5 reanalysis: (a) raw data, (b) data corrected standard with quantile mapping and (c) data corrected with the proposed bias correction method. The colour scale ranges from white (RMSE = 0) to dark red, increasing in intensity as the metric increases. The most intense colour corresponds to the maximum value

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