The influence of sea surface temperatures on moisture sources of Central European Storm Boris in September 2024

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Take home message

The extreme precipitation of storm Boris was primarily fueled by moisture from Eastern Europe and the Mediterranean as a thermo-dynamical response to strong SST anomalies. SST changes further lead to dynamical shifts, deflecting moisture away from the target region.

Overview

This study investigates the influence of sea surface temperatures (SSTs) of different seas on storm Boris, a slow-moving Vb-like cyclone that produced exceptional rainfall and flooding between September 12th and 16th 2024 in Central Europe.

By performing sensitivity experiments with perturbed SSTs, we aim to identify primary moisture sources and separate thermodynamical and dynamical responses.

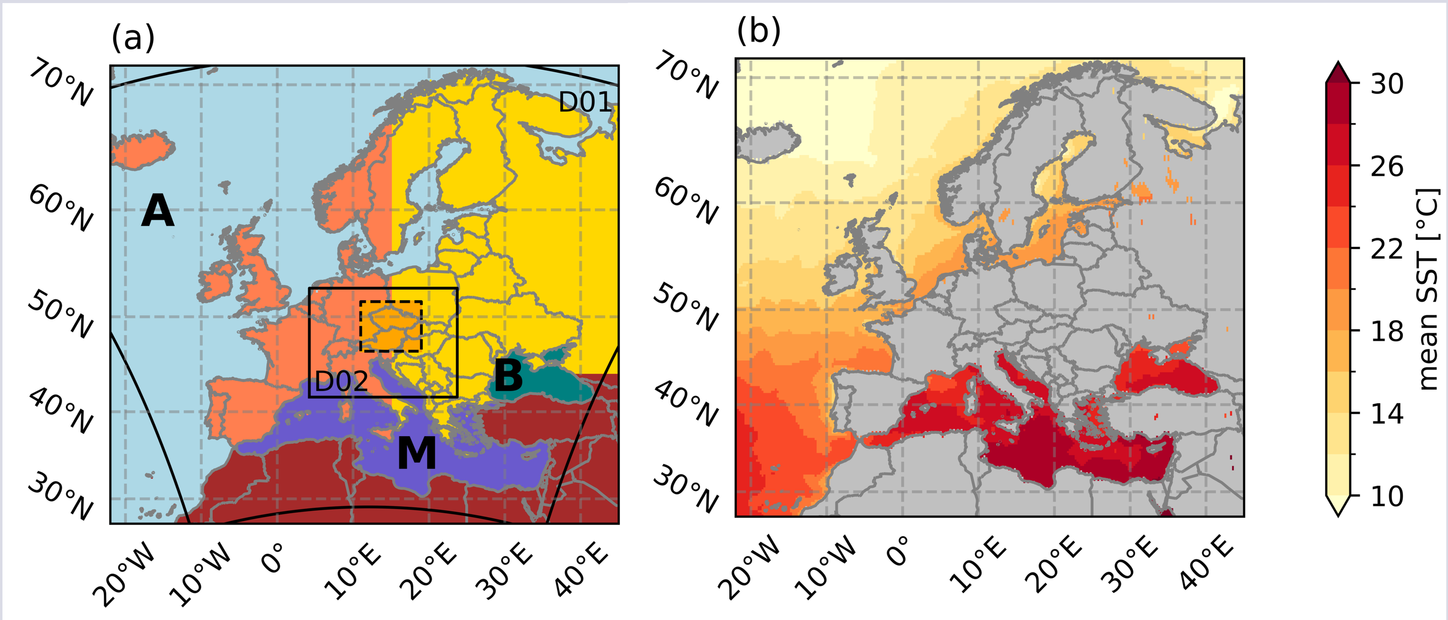


Figure 1: a) Moisture source regions and WRF domain outlines (solid lines) with 9 km (D01) and 3 km (D02) resolution and b) mean SST during the simulation period. Water basins subject to SST modifications in panel a) are marked with bold letters and colored in different shades of blue, whereas the precipitation target region is boxed in dashed lines.

Methods

Experi-ment	Mediter-ranean	Atlantic	Black Sea	Full Nudging
CTRL	OBS	OBS	OBS	Yes
Mc	-2 K	OBS	OBS	Yes
Ac	OBS	-2 K	OBS	Yes
Bc	OBS	OBS	-2 K	Yes
MAc	-2 K	-2 K	OBS	Yes
MBc	-2 K	OBS	-2 K	Yes
ABc	OBS	-2 K	-2 K	Yes
MABc	-2 K	-2 K	-2 K	Yes
MABw	+2 K	+2 K	+2 K	Yes
$CTRL_{dyn}$	OBS	OBS	OBS	No
Mc_{dyn}	-2 K	OBS	OBS	No
Bc_{dyn}	OBS	OBS	-2 K	No
MBc_{dyn}	-2 K	OBS	-2 K	No
Mw_{dyn}	+2 K	OBS	OBS	No
Bw_{dyn}	OBS	OBS	+2 K	No
MBw_{dyn}	+2 K	OBS	+2 K	No

Table 1: Experiment definitions of SST-changed nudged (no subscript) and free-running simulations (dyn subscript).

We use a model chain of the numerical Weather Research and Forecasting (WRF) model v4.2.2 (Skamarock et al., 2019), the Lagrangian model FLEXPART-WRF (Brioude et al., 2013) and a moisture diagnostic tool (Sodemann et al., 2008) to identify air parcels transporting moisture to the precipitation target region, tracking them up to ten days backwards.

This model chain is applied to different experiments with modified SSTs and nudging settings, as visible in Table 1. Full nudging means wind and pressure nudging during the event, while the dynamical runs are free-running during the storm and only nudged before (from 31st of August to 10th of September).

Results

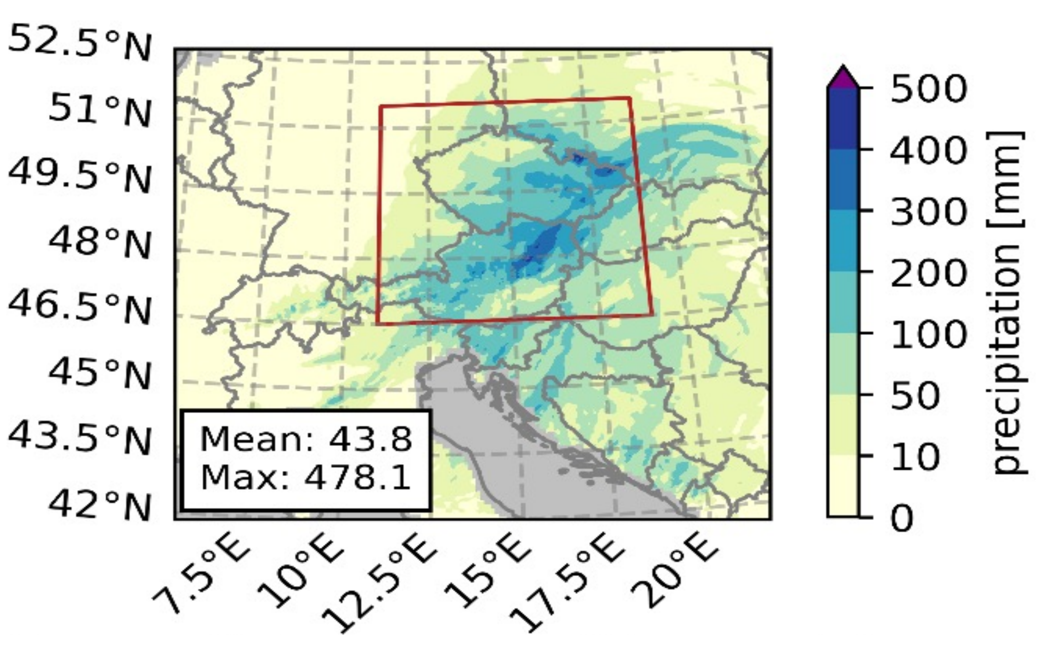
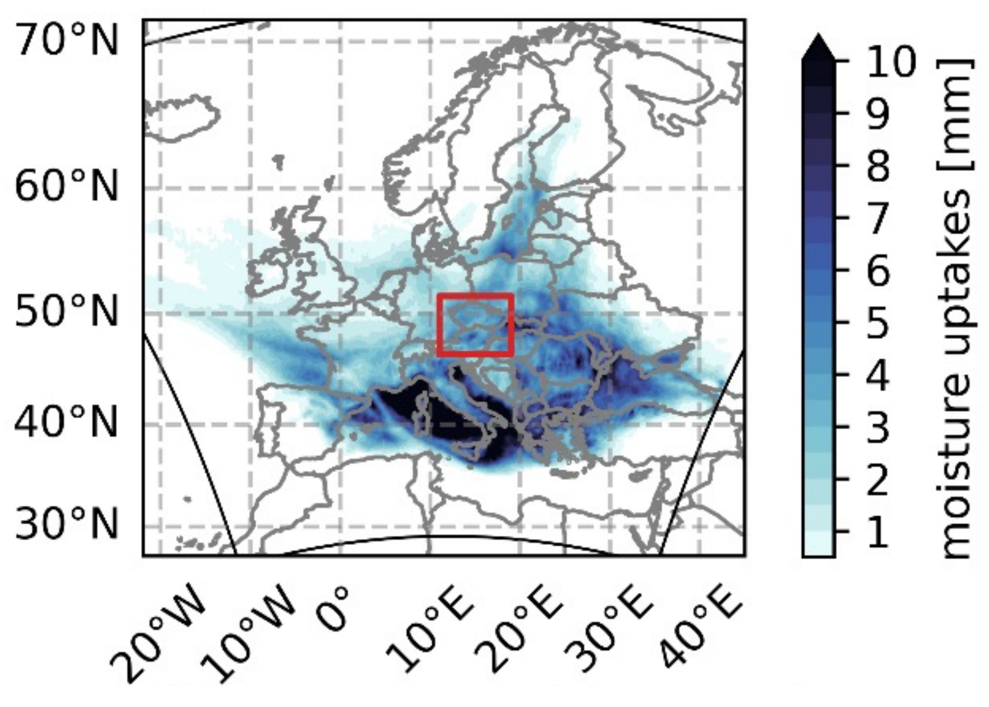


Figure 2: Precipitation sum of storm Boris over land in D02 in mm with the outlines of the precipitation target region (red box) as simulated in the CTRL run. Local maxima are visible in Austria near Vienna and at the border of Czechia and Poland, both located in the precipitation target region.

Figure 3: Moisture uptake sum in mm. The values correspond to the total amount of precipitation (in liters) that fell in the target region, normalized by the grid cell area at the uptake locations. The red box refers to the target precipitation domain, the black lines show the D01 WRF domain. The dominant moisture sources are the northernmost regions of the Mediterranean.



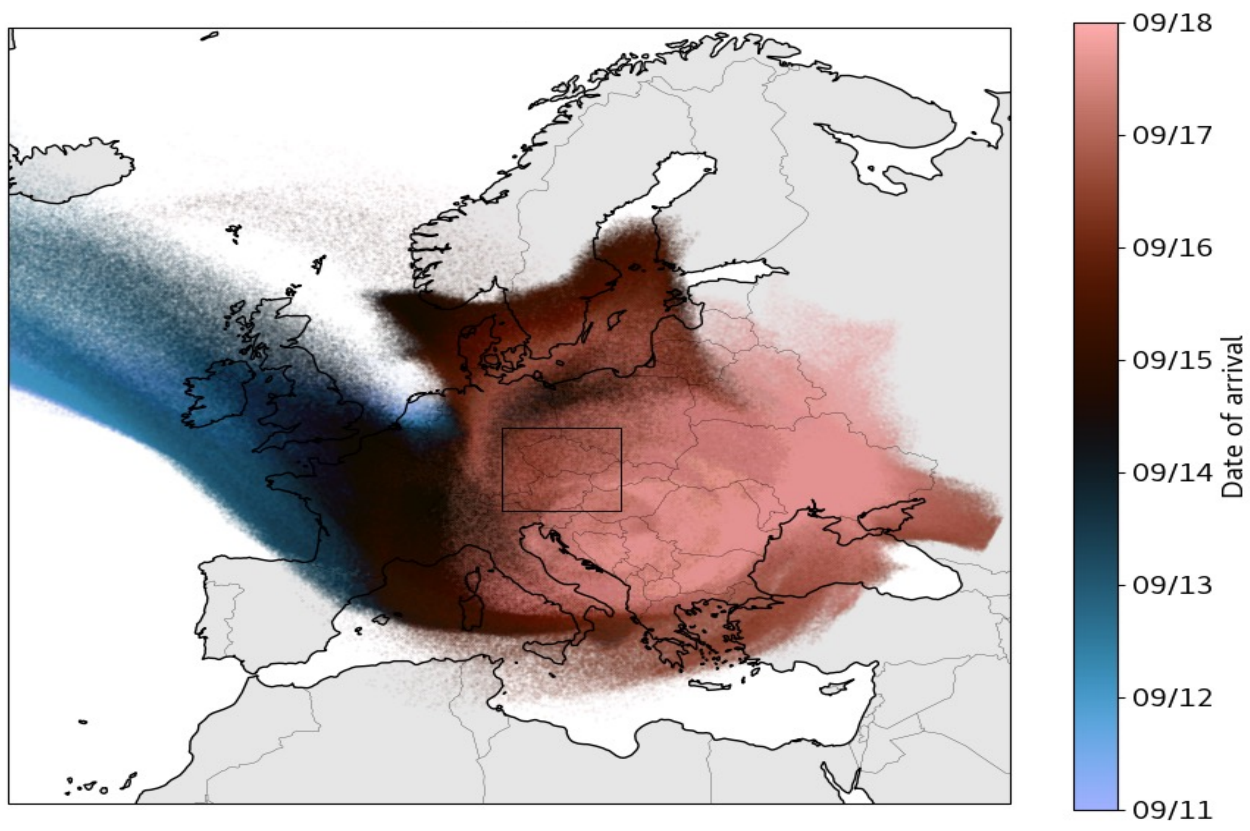


Figure 4: Locations of moisture-carrying air parcels 9 hours prior to their arrival in the precipitation region (black box) with color-coded arrival times. Landmasses tend to contribute later, after initial precipitation from ocean sources has fallen and moisturized land areas.

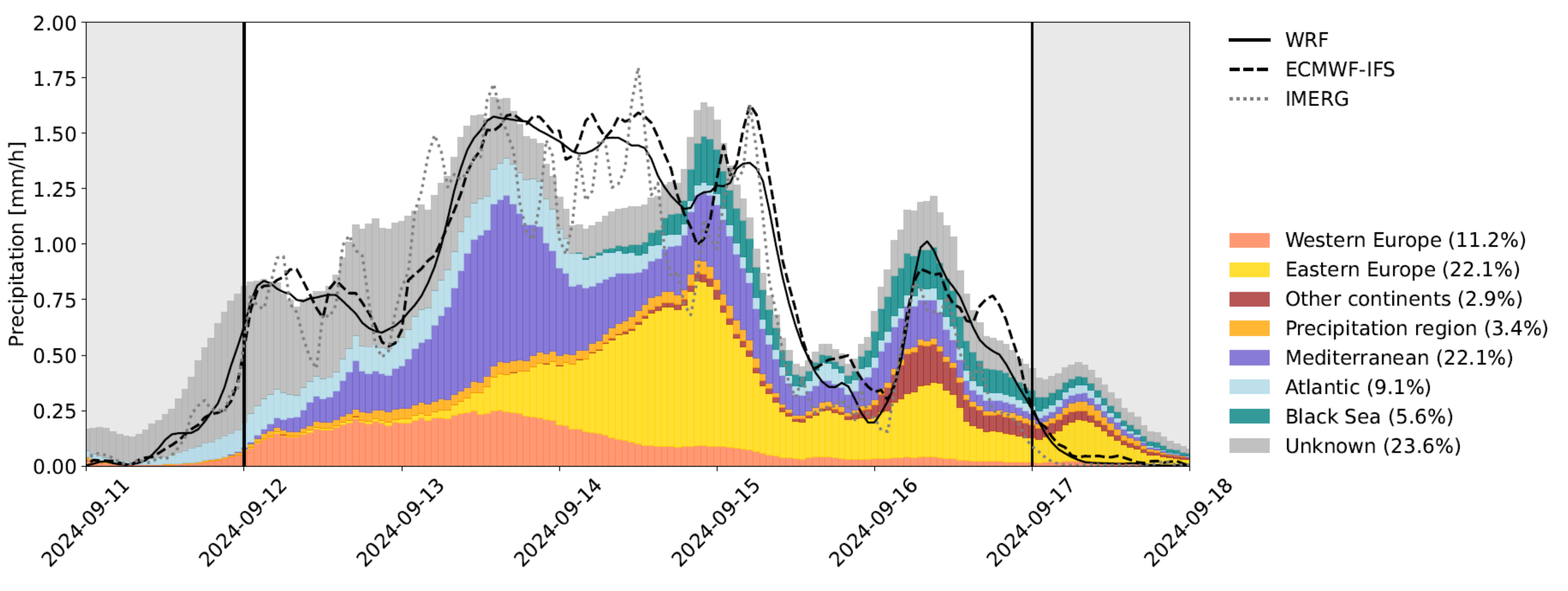


Figure 5: Precipitation time series in the precipitation region of Boris in mm/h with attribution to different geographical regions (colored) compared to the nudged WRF CTRL run (solid), the input data ECMWF-IFS (dashed) and the satellite product IMERG (dotted).

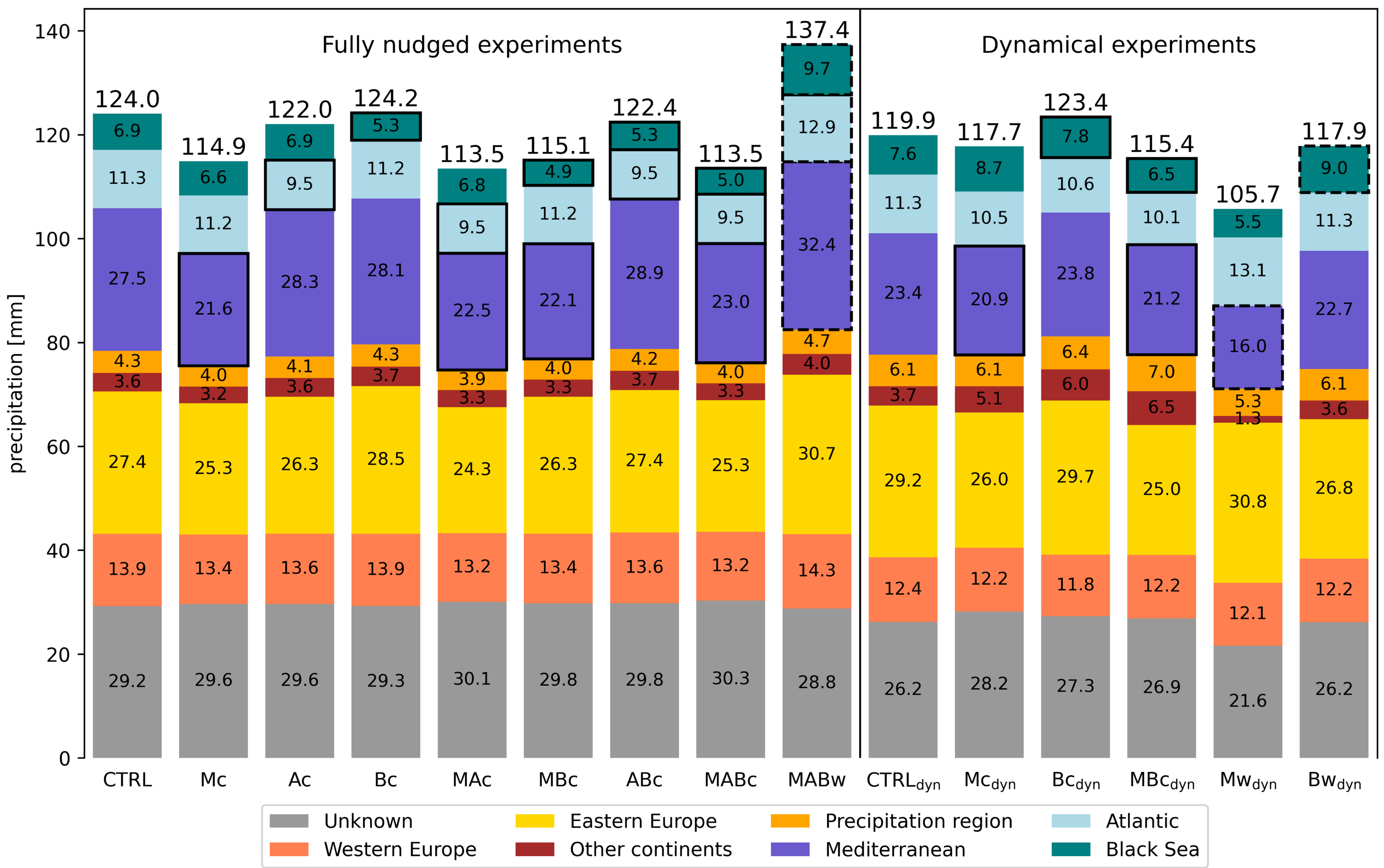


Figure 6: Precipitation origin of Boris, attribution to different geographical regions with contributions of each region in mm. Boxes are framed with solid (dashed) lines, if the SST of the specific basin was decreased (increased) during the experiment.

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References:

Brioude, J., Arnold, D., Stohl, A., Cassiani, M., Morton, D., Seibert, P., Angevine, W., Evan, S., Dingwell, A., Fast, J. D., Easter, R. C., Pisso, I., Burkhart, J., & Wotawa, G. (2013). The Lagrangian particle dispersion model FLEXPART-WRF version 3.1. Geoscientific Model Development, 6(6), 1889–1904. https://doi.org/10.5194/gmd-6-1889-2013

Skamarock, W. C., Klemp, J. B., Dudhia, J., Gill, D. O., Liu, Z., Berner, J., Wang, W., Powers, J. G., Duda, M. G., Barker, D. M., & Huang, X.-Y. (2019). A Description of the Advanced Research WRF Model Version 4. UCAR/NCAR. https://doi.org/10.5065/1DFH-6P97

Sodemann, H., Schwierz, C., & Wernli, H. (2008). Interannual variability of Greenland winter precipitation sources: Lagrangian moisture diagnostic and North Atlantic Oscillation influence. Journal of Geophysical Research: Atmospheres, 113(D3), 2007JD008503. https://doi.org/10.1029/2007JD008503