Resolving Sahelian Thunderstorms Improves Mid-Latitude Weather Forecasts

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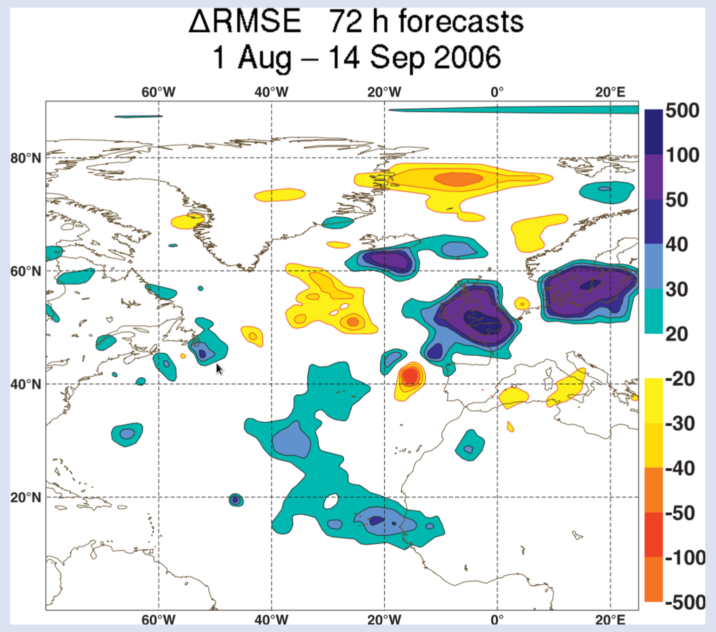
INTRODUCTION

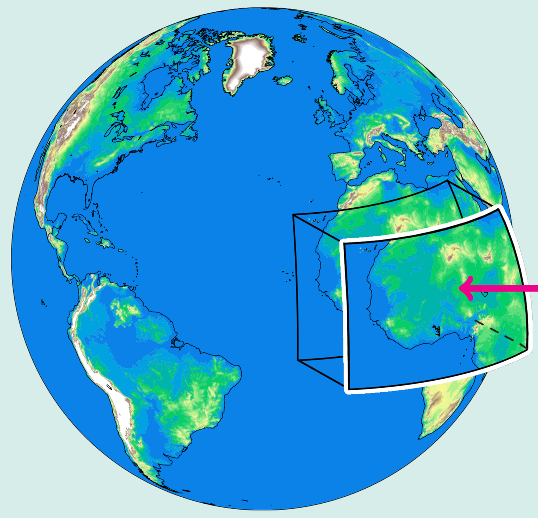
- About **90%** of total annual rainfall in Sahel region from **organised convective systems**.
- Convection parameterisations struggle to realistically represent West African convection.
- **Additional soundings** over West Africa during AMMA field campaign → improved analysis → **positive influence on forecasts** over Europe (*Faccani et al. 2009*). →



- **Questions:**
  - Does explicit convection lead to improved forecasts in the Sahel region?
  - Does explicit convection in the Sahel influence forecasts over the North Atlantic-European sector?
  - Does this influence lead to an improvement of the forecasts?
- Answers based on **Pante & Knippertz (2019)** ***Nat. Commun.***

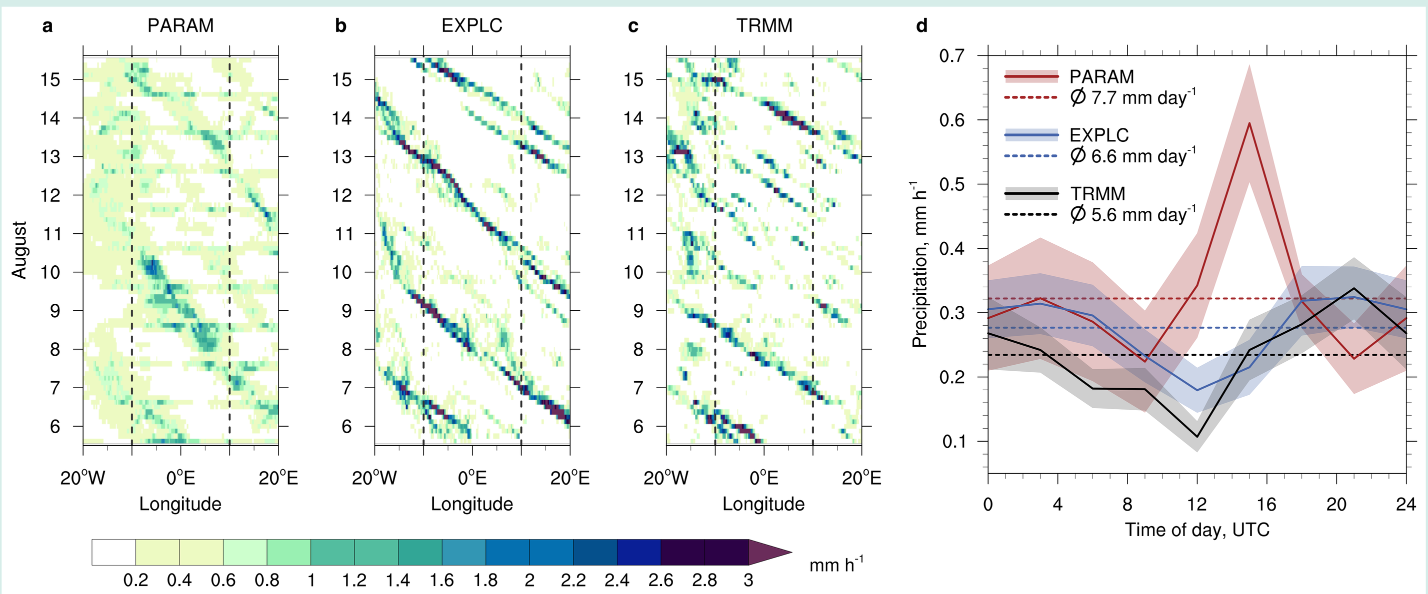
ICON MODEL SETUP

- **ICON** (ICOsahedral Non-hydrostatic) developed at DWD & MPI-M (*Zängl et al. 2015*).



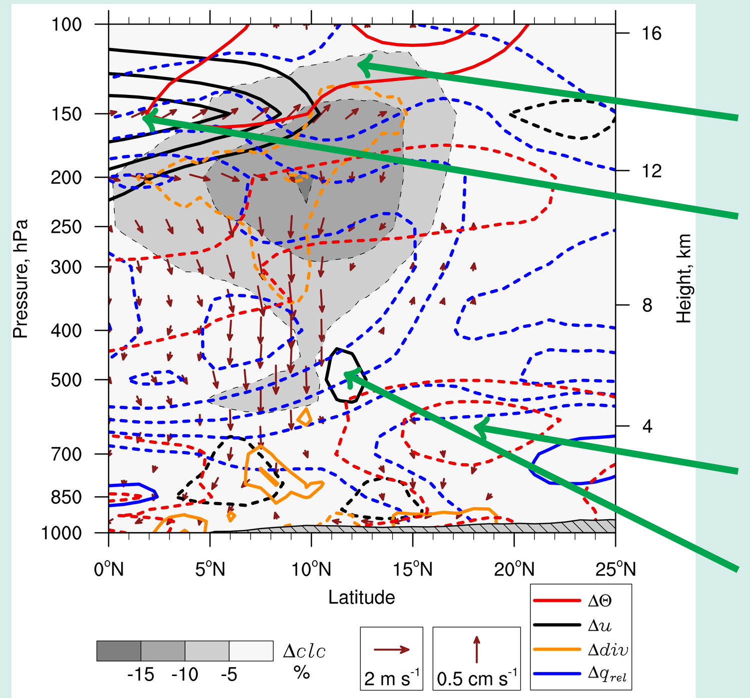
- Initialisation: daily at 12 UTC in July and August 2016 and 2017 → **10-day forecasts**
- **PARAM**: global simulation, grid spacing ≈ 13 km
- **EXPLC**: local grid refinement (≈ 6.5 km) in region of West African monsoon (WAM), explicit convection in nest, relaxation of prognostic variables, i.e., **2-way nesting** → feedback on global simulation

PRECIPITATION IN WAM REGION



- Hovmoeller diagrams ø 8–18°N: **PARAM (a)** vs. **EXPLC (b)** vs. TRMM observations **(c)**
  - ➡ Mesoscale convective systems (**MCS**) are **reproduced** in **EXPLC** not in **PARAM**.
- Diurnal cycle ø 8–18°N, 10°W–10°E **(d)**
  - ➡ Precipitation in **PARAM** **too early**, **too intense**.
  - ➡ Diurnal cycle clearly improved in **EXPLC**, remarkably close to TRMM observations.

IMPACT OF EXPLICIT CONVECTION ON FORECASTS



- Vertical cross section ø 10°W–10°E, difference **EXPLC–PARAM**
  - CLC: Less clouds, less OLR → **warmer upper troposphere/lower stratosphere**
  - TEJ: Weaker divergence, weaker updrafts, weaker outflow → **weaker TEJ** (Lemburg et al. 2019)
  - RH: Less intense southerly inflow, detrainment → **drier mid troposphere**
  - SHL: Ventilation by coldpool outflow, stronger radiative cooling → **colder SHL**
  - AEJ: Less intense SHL → **weaker AEJ**

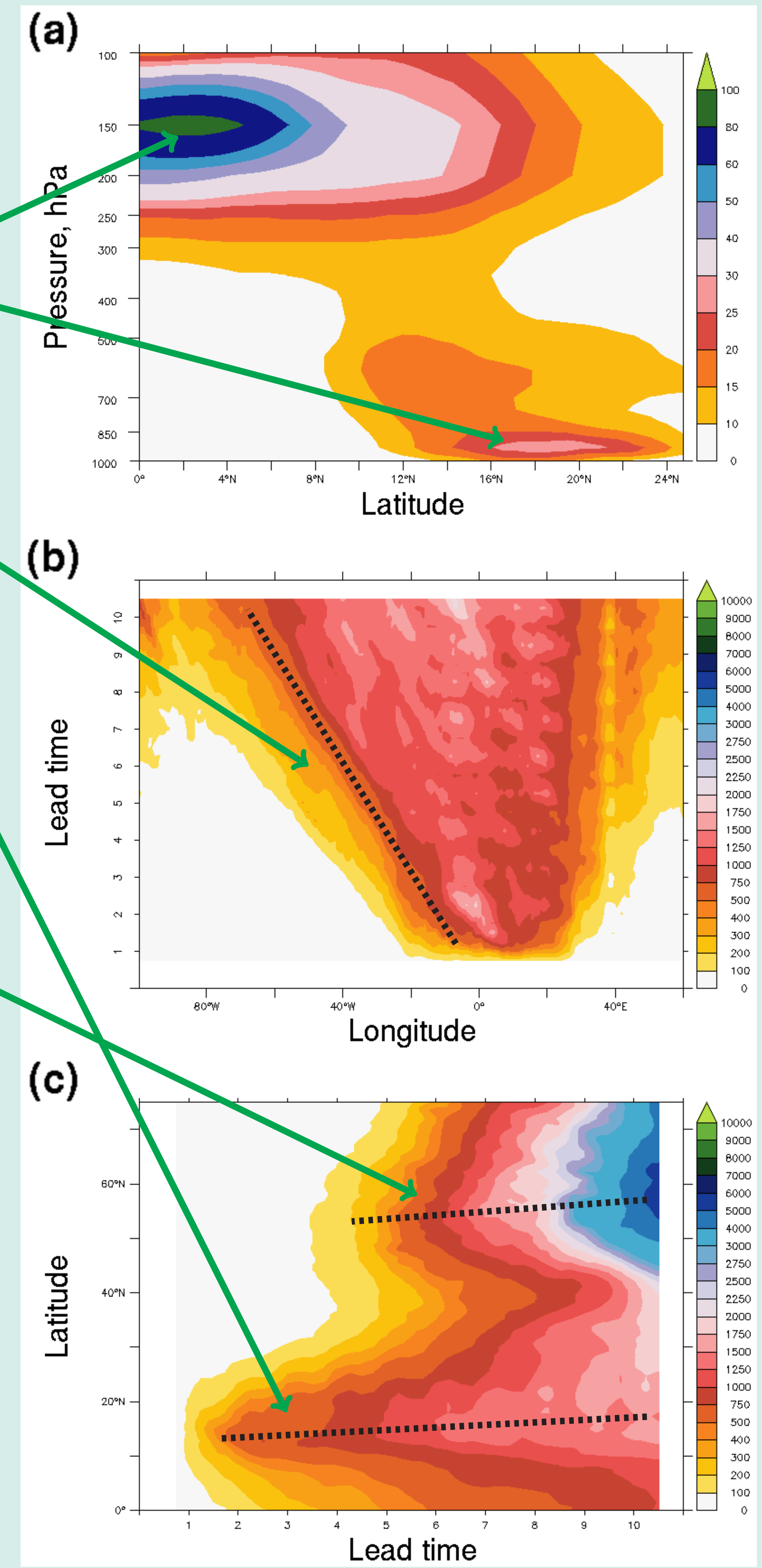
CLC: Total cloud cover, TEJ: Tropical easterly jet, RH: Relative humidity, SHL: Saharan heat low, AEJ: African easterly jet

- Difference Total Energy $DTE = \frac{1}{2}\left(\Delta u^2 + \Delta v^2 + \kappa \Delta T^2\right)$, $\kappa = \frac{c_p}{287\mathrm{K}}$
- Difference **EXPLC-PARAM**

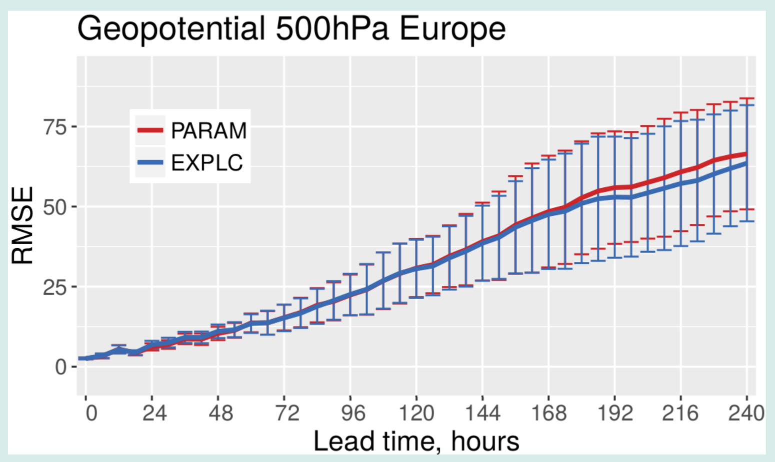
(a) *DTE* ø 10°W–10°E → **Largest differences** in regions of **TEJ and SHL**.

(b) Hovmoeller diagram (ø 10–15°N) of vertically integrated *DTE* $\int_{950\,\mathrm{hPa}}^{250\,\mathrm{hPa}}$ → **Differences spread** from the nesting region westward **to the Atlantic Ocean**.

(c) As (b) but ø 40–0°W → Differences intensify with lead time in the region of the **SHL and Azores High**. Differences in the region of the **mid-latitude stormtrack** north of 40°N appear **from forecast day 4 on** and intensify with lead time.

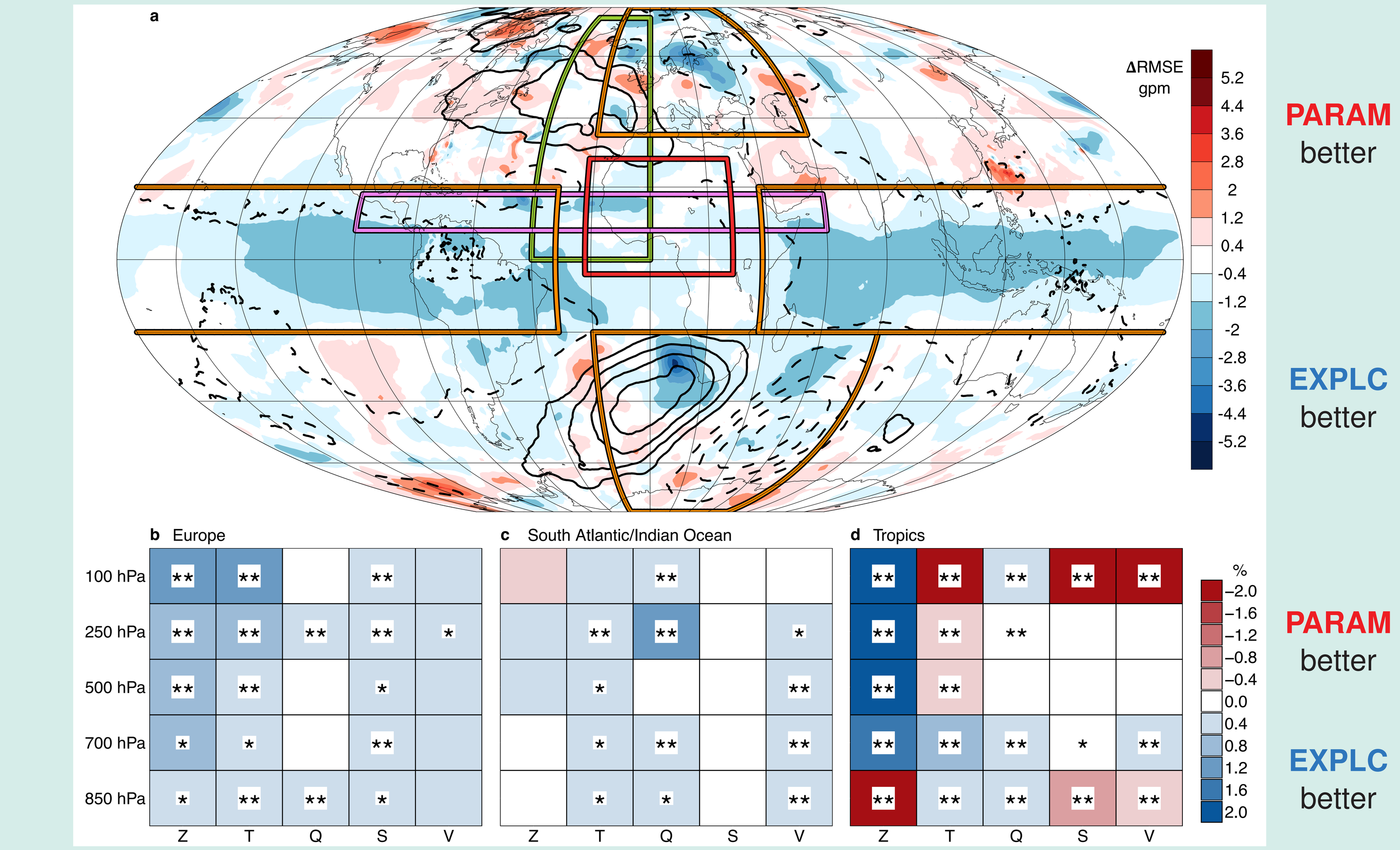


- Mean RMSE over all 31 simulations in July 2016 shows **improvement of Z500 over Europe after about 5 days.**

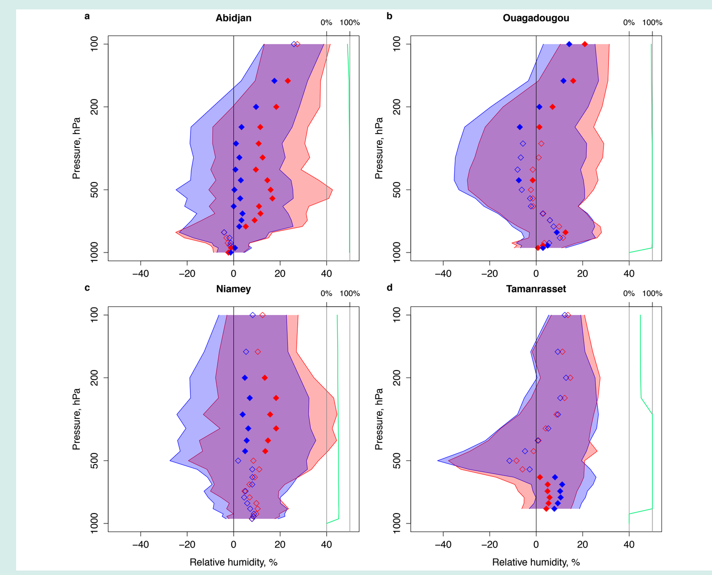


IMPROVEMENT OF FORECASTS

- **(a)** Difference **EXPLC-PARAM** of RMSE (colors) and absolute values (contours) of 500 hPa geopotential averaged over forecast days 5–8.
- **(b–d)** Change of RMSE for geopotential (Z), temperature (T), specific humidity (Q), wind speed (S) and wind vector (V) throughout the troposphere.



- Bias of relative humidity of **EXPLC** and **PARAM** compared to available radiosonde data during forecast days 2–5.
- Moist bias at Abidjan (a) and Niamey (c) significantly reduced in **EXPLC** compared to **PARAM**.
- Vertical profile of Tamanrasset (d) may indicate problems in the model to transport low-level moisture out of the deep Saharan boundary layer into the free troposphere above.



CONCLUSIONS

- **Explicitly resolving convection in Sahel** region **improves** forecasts of **single MCS and diurnal cycle of precipitation**.
- **PARAM** generates Sahelian rainfall too early, too short and too intense **without organised MCS** → Warmer SHL, stronger upper-level divergence, updrafts and moistening of free troposphere.
- Differences between **EXPLC** and **PARAM** **influence remote regions** over the Atlantic Ocean, Europe, and the tropics **after some days**.
- **Positive influence** of **EXPLC** on **RMSE of Z, T, Q and wind over Europe throughout the troposphere**.
- There is the potential to **improve operational medium-range weather forecasts over Europe** during summer **by explicitly resolving MCS in the Sahel** at a relatively moderate additional computational cost.

REFERENCES

- Pante, G. & Knippertz, P., 2019: Resolving Sahelian thunderstorms improves mid-latitude weather forecasts, *Nat. Commun.*, 10, 3487
- Faccani, C., F. Rabier and N. Fourrié, 2009: The Impacts of AMMA Radiosonde Data on the French Global Assimilation and Forecast System, *Weather Forecast.*, 24(5), 1268–1286
- Zängl, G., D. Reinert, P. Rípodas and M. Baldauf, 2015: The ICON (ICOsahedral Non-hydrostatic) modelling framework of DWD and MPI-M: Description of the non-hydrostatic dynamical core, *Q. J. Roy. Meteorol. Soc.*, 141(687), 563–579.
- Lemburg, A., Bader, J. & Claussen, M., 2019: Sahel RainfallTropical Easterly Jet Relationship on Synoptic to Intraseasonal Time Scales, *Mon. Weather Rev.*, 147(5), 1733–1752.

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