

## 1. Motivation

- Precipitation over the Arabian Peninsula (AP) is primarily convective [1] and influenced by spatiotemporally variable drivers.
- Climate change is shifting large-scale circulation patterns over the AP [2,3].
- Explainable machine learning (ML) can help evaluate drivers of convection in climate models for the current climate and track changes in future projections..
- SHAP (SHapley Additive exPlanations) [4] is a game theoretic approach to explain the drivers of any ML model output.

## 2. Methodology

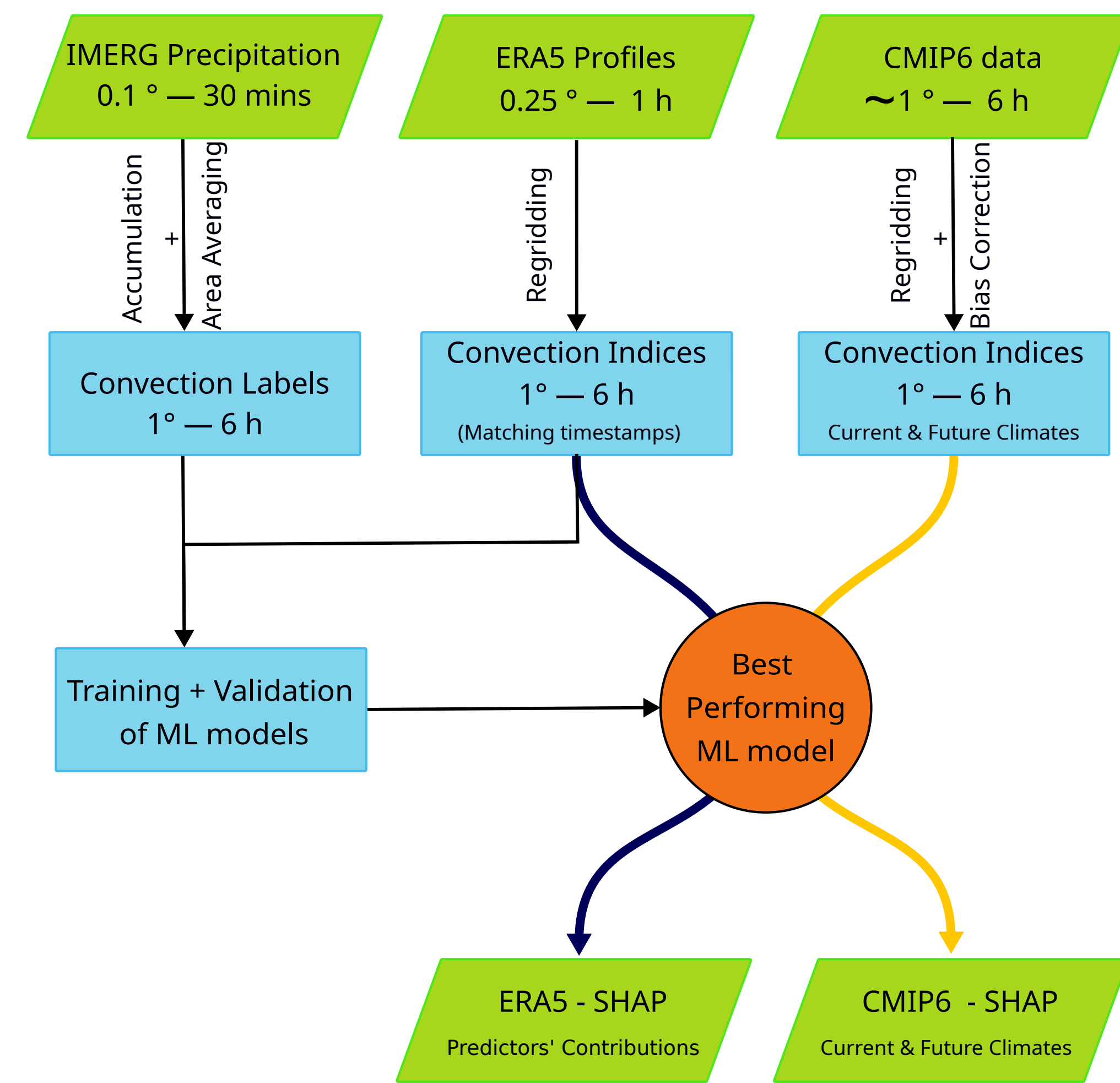


Fig 1: Schematic of the convection drivers analysis framework.

## 3. Results

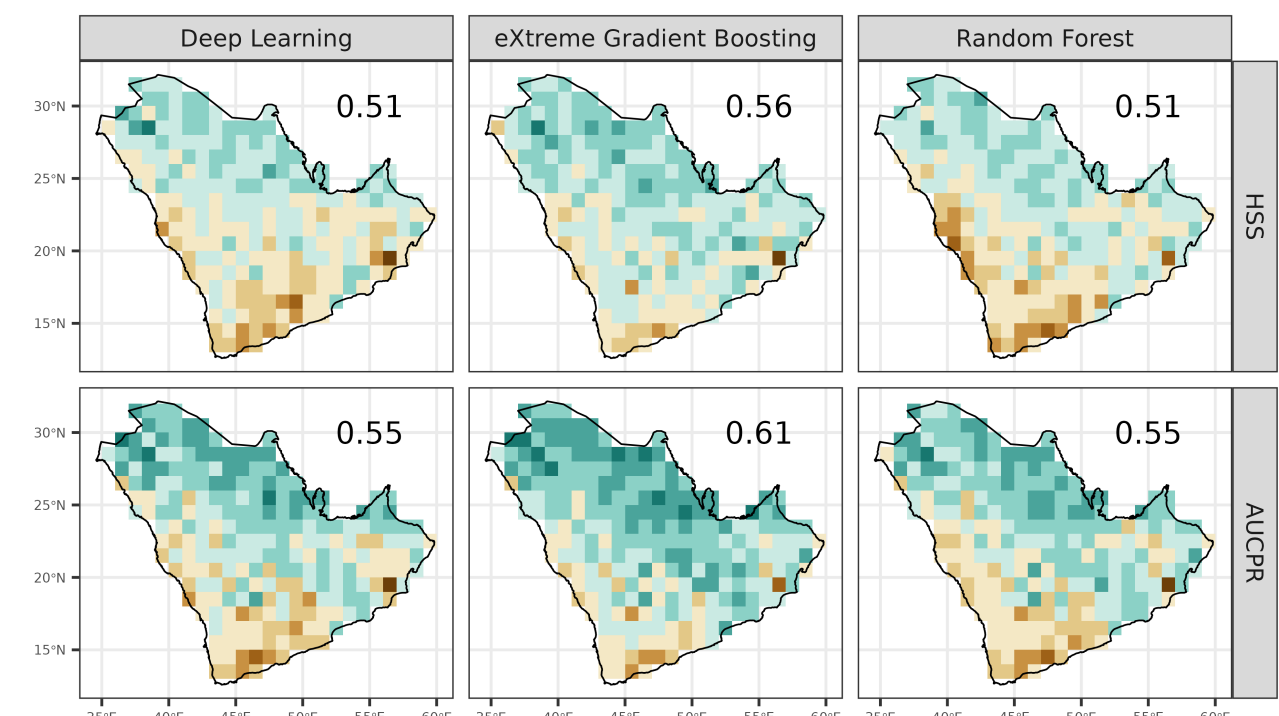


Fig 2: Spatial Hedike Skill score (top) and Area under the Precision-Recall Curve (bottom) for deep learning (left), XGBoost (middle), and random forest (right). The text in the top-right corner shows the spatial mean.

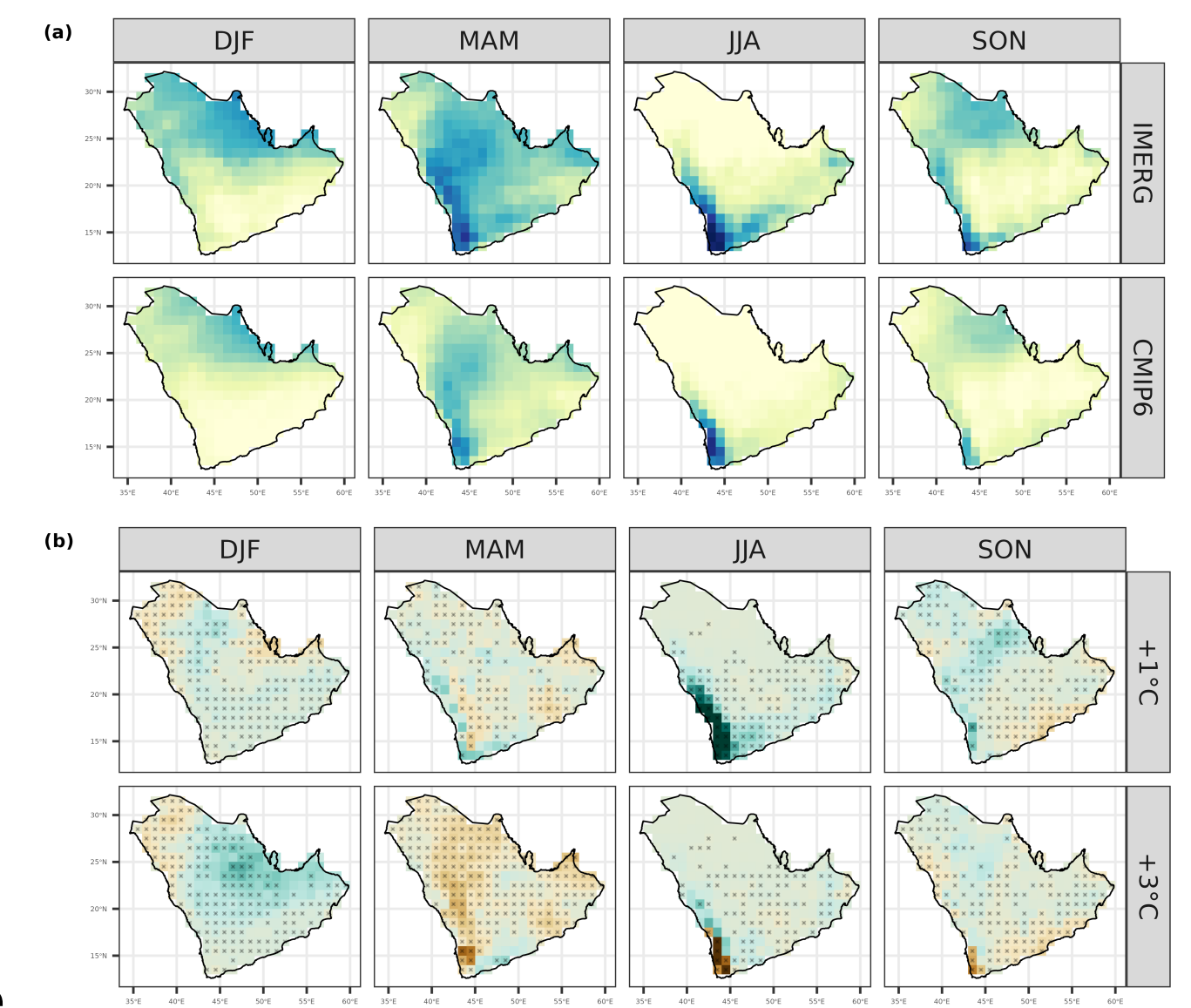


Fig 3: (a) Seasonal frequency of convective environments (season<sup>-1</sup>) from IMERG and the CMIP6 ensemble mean at the current (+1.22°C) regional warming levels, and (b) changes at +2.22°C, and (+4.22°C) warming levels. The stippling indicates at least 70% model agreement.

Skill & Frequency

## 4. Take Home Messages

- ☀ Extreme gradient boosting [5] performs best in identifying convective environments over the AP.
- ☀ CMIP6 ensemble underestimates the frequency of convective environments at current regional warming levels (+1.22°C) relative to the preindustrial (1850 - 1900).
- ☁ At an additional +1°C (+3°C) above the current regional warming level, convective environments are projected to increase (decrease) except in boreal spring (winter).

$$\text{SHAP Score} = \underbrace{\text{Frequency}}_{\text{positive SHAP in convective cases}} \times \underbrace{\text{Magnitude}}_{\text{mean positive SHAP for convective cases}}$$

High SHAP Score indicates a frequent and strong positive contribution to convection prediction.

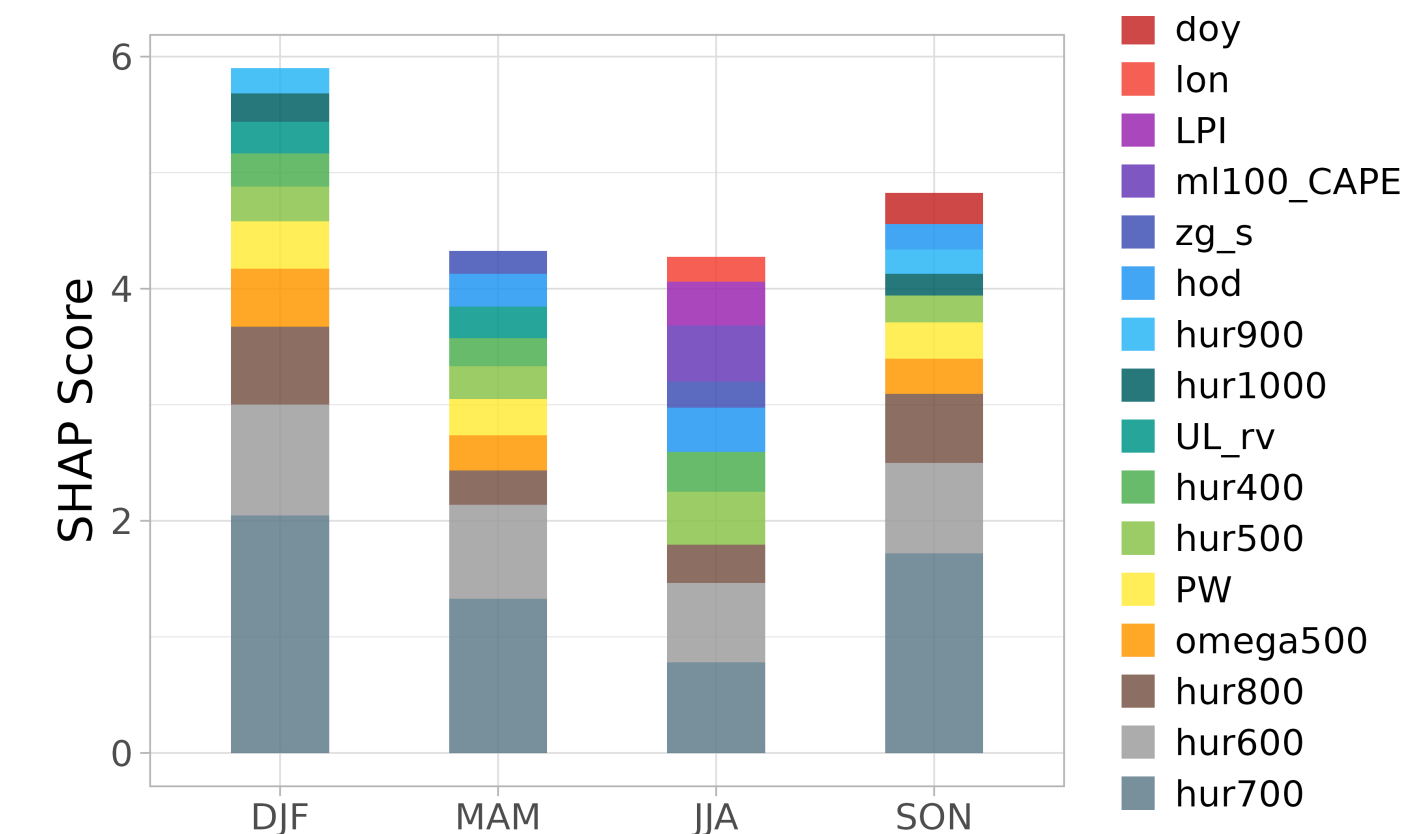


Fig 4: Seasonal top 10 convection drivers from ERA5 according to eXtreme Gradient Boosting.

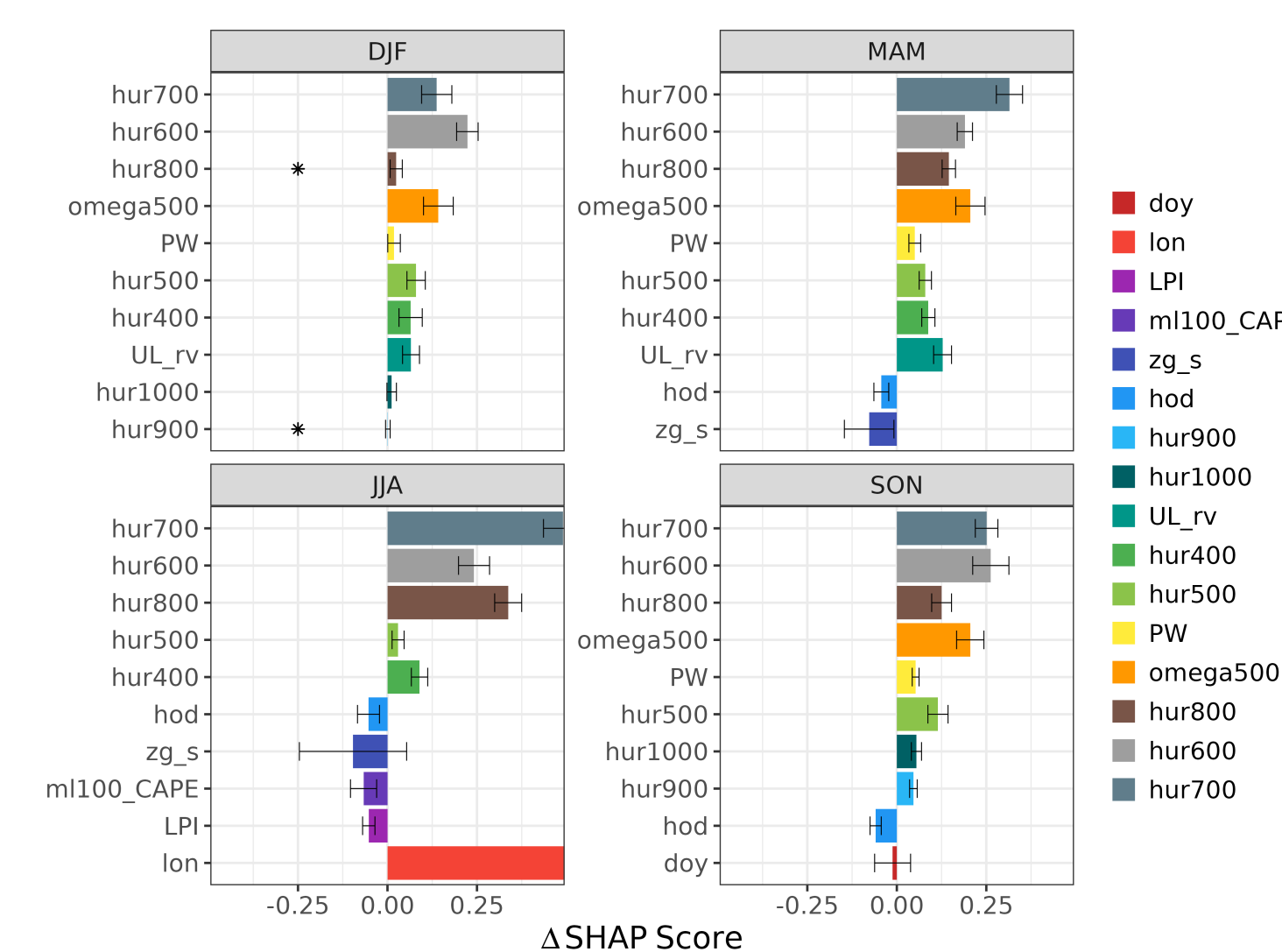


Fig 5: CMIP6 ensemble SHAP Score change relative to ERA5. Error bars show ensemble spread (2σ).

Current Climate

- ☁ Midtropospheric humidity dominates the drivers of convection, with thermodynamic instability (summer) and dynamic forcing (cold months) as secondary drivers.
- ☁ In CMIP6, moisture- and dynamics-related drivers are more relevant than in ERA5, while instability-based drivers are less relevant.
- ☁ With further warming, moisture-related drivers become more relevant, while dynamic [6] and instability become less relevant.

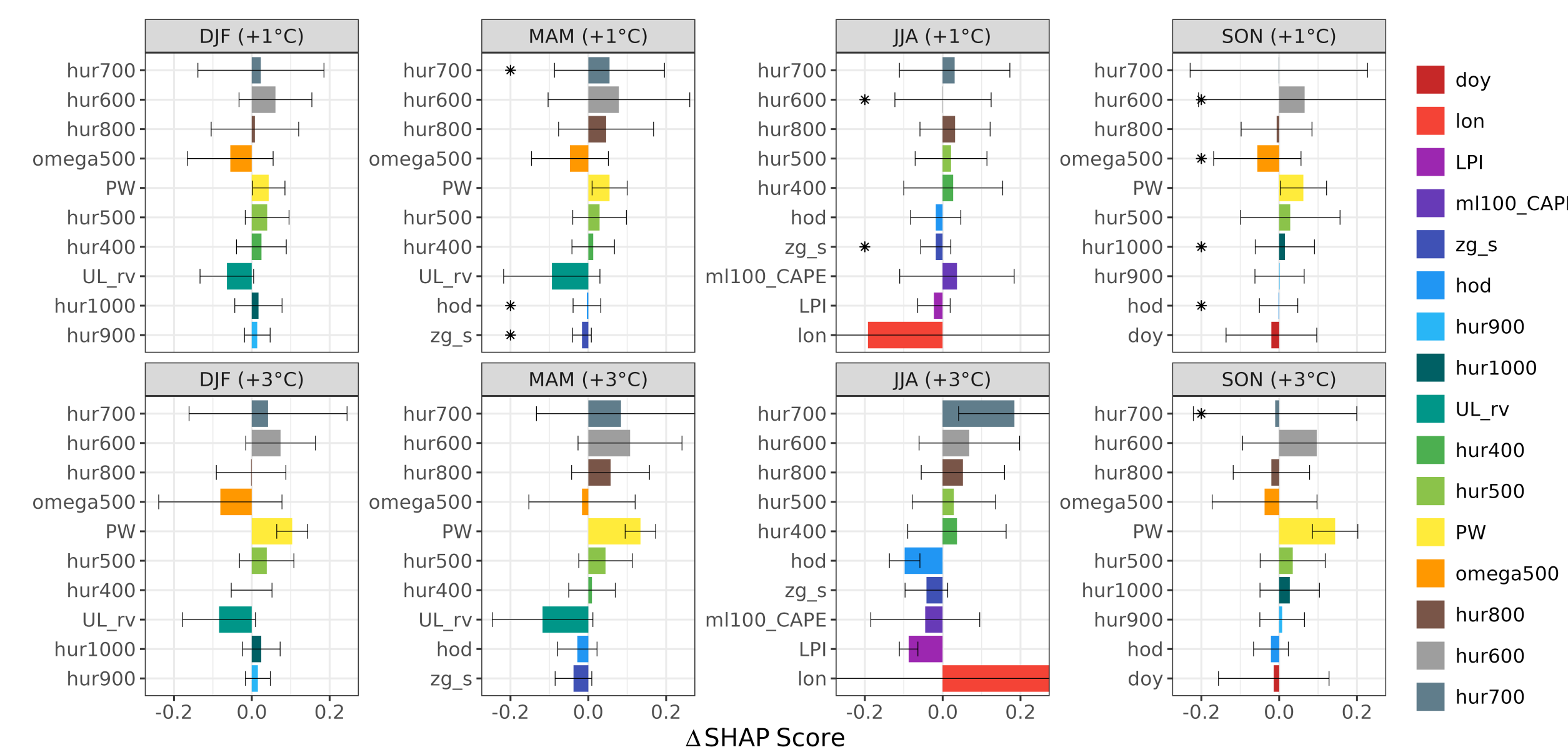


Fig 6: SHAP Score change per +1°C and +3°C additional warming above the current regional level from the CMIP6 ensemble. Error bars show ensemble spread (2σ). The asterisk indicates < 70% of models show a significant distributional difference (p.value < 0.01).

Future Climates

## 5. References

[1] Luong, T. M., Dasari, H. P., Doan, Q.-V., Alduwais, A. K., & Hoteit, I. (2024). Organized precipitation and associated large-scale circulation patterns over the Kingdom of Saudi Arabia. *International Journal of Climatology*, 44(10), 3295–3314. <https://doi.org/10.1002/joc.8524>

[2] Pathak, R., Dasari, H. P., Ashok, K., & Hoteit, I. (2025). Dynamics of intensification of extreme precipitation events over the Arabian Peninsula derived from CMIP6 simulations. *Npj Climate and Atmospheric Science*, 8(1), 126. <https://doi.org/10.1038/s41612-025-01016-w>

[3] Sandeep, S. & Ajayamohan, R. S. (2015). Poleward shift in Indian summer monsoon low level jetstream under global warming. *Climate Dynamics*, 45(1), 337–351. <https://doi.org/10.1007/s00382-014-2261-y>

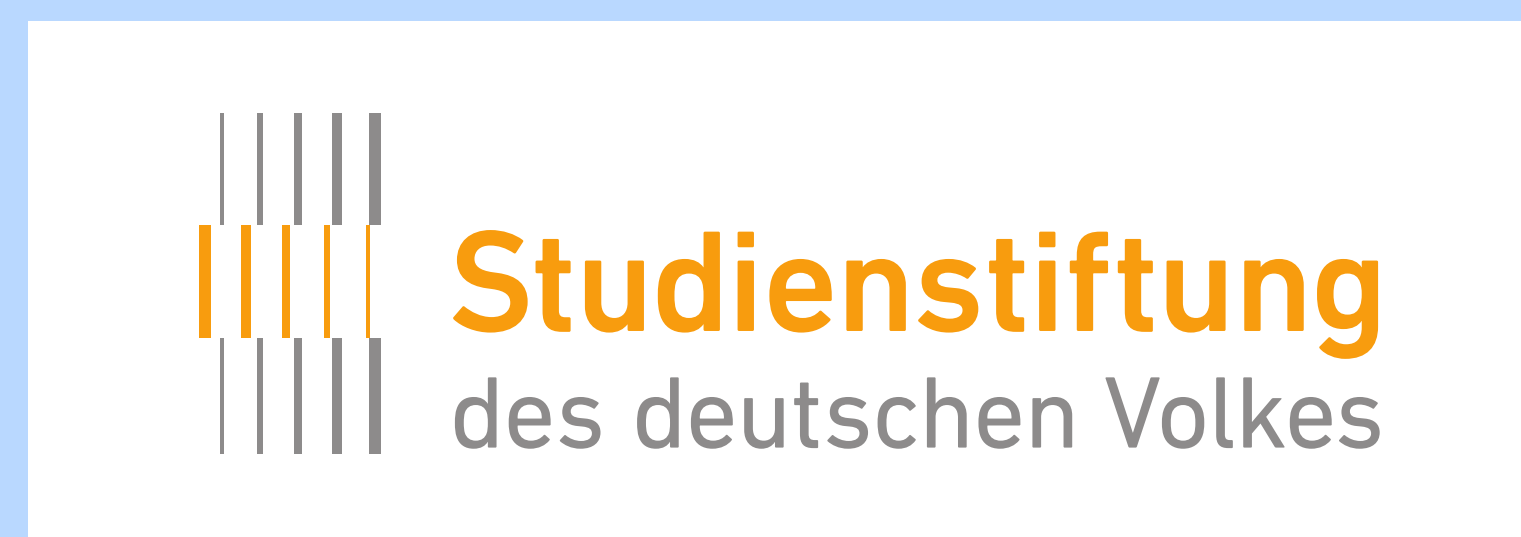
[4] Lundberg, S. & Lee, S.-I. (2017). A Unified Approach to Interpreting Model Predictions (arXiv: 1705.07874). arXiv. <https://doi.org/10.48550/arXiv.1705.07874>

[5] Chen, T. & Guestrin, C. (2016, March 9). XGBoost: A Scalable Tree Boosting System. arXiv.Org. <https://doi.org/10.1145/2939672.2939785>

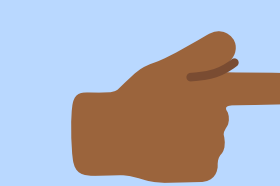
[6] Pfahl, S., O’Gorman, P. A., & Fischer, E. M. (2017). Understanding the regional pattern of projected future changes in extreme precipitation. *Nature Climate Change*, 7(6), 423–427. <https://doi.org/10.1038/nclimate3287>

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Poster's Abstract



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