

Supplement of

Explaining the Modulation of Forced Precipitation Changes with Internal Variability Storylines: The case of decadal Sahel Precipitation Changes

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1 Supplemental Figures

1.1 Causal Network Analysis

To assess the consistency of the relationships between the large-scale drivers, NARI, and Sahel precipitation across forcing states and over time, we estimate path coefficients within a causal network, also called directed acyclic graph (DAG; Kretschmer et al. (2021)). In the DAG in which AMV and PDV affect both the mediator NARI and the target variable precipitation, while NARI directly affects precipitation only (Fig. SS). For the piControl simulation, the model is fitted across the non-overlapping decadal samples. For SSP3–7.0, it is fitted independently at each decadal time step across the ensemble members. We estimate the following multiple linear regression models:

$$\hat{NARI} = d\hat{PDV} + e\hat{AMV} + \epsilon_{NARI} \quad \text{and} \quad \hat{PR} = a\hat{PDV} + b\hat{AMV} + c\hat{NARI} + \epsilon_{PR}. \quad (1)$$

10 where hats denote standardized variables and PR is the JAS Sahel precipitation anomaly. The coefficient c represents the NARI–precipitation relationship conditional on AMV and PDV, while the total effects of AMV and PDV on precipitation (direct + indirect) are $T_{AMV} = b + ec$ and $T_{PDV} = a + dc$.

References

- Kretschmer, M., Adams, S. V., Arribas, A., Prudden, R., Robinson, N., Saggioro, E., and Shepherd, T. G.: Quantifying Causal Pathways of
15 Teleconnections, 102, E2247–E2263, <https://doi.org/10.1175/BAMS-D-20-0117.1>, 2021.

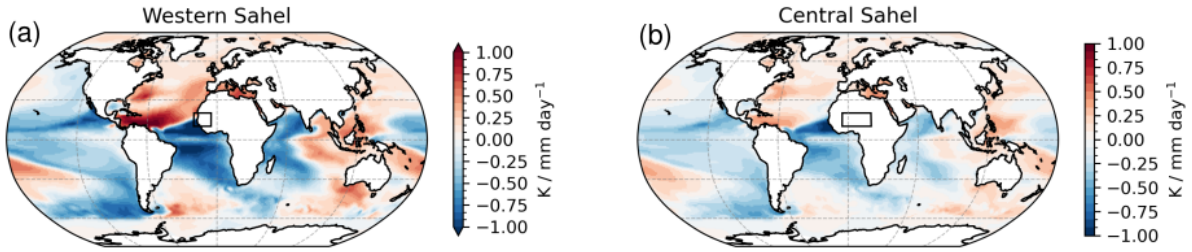


Figure 1. Remote Oceanic Drivers of Sahel Summertime Precipitation. As Figure 1a) for a) Western Sahel and b) Central Sahel.

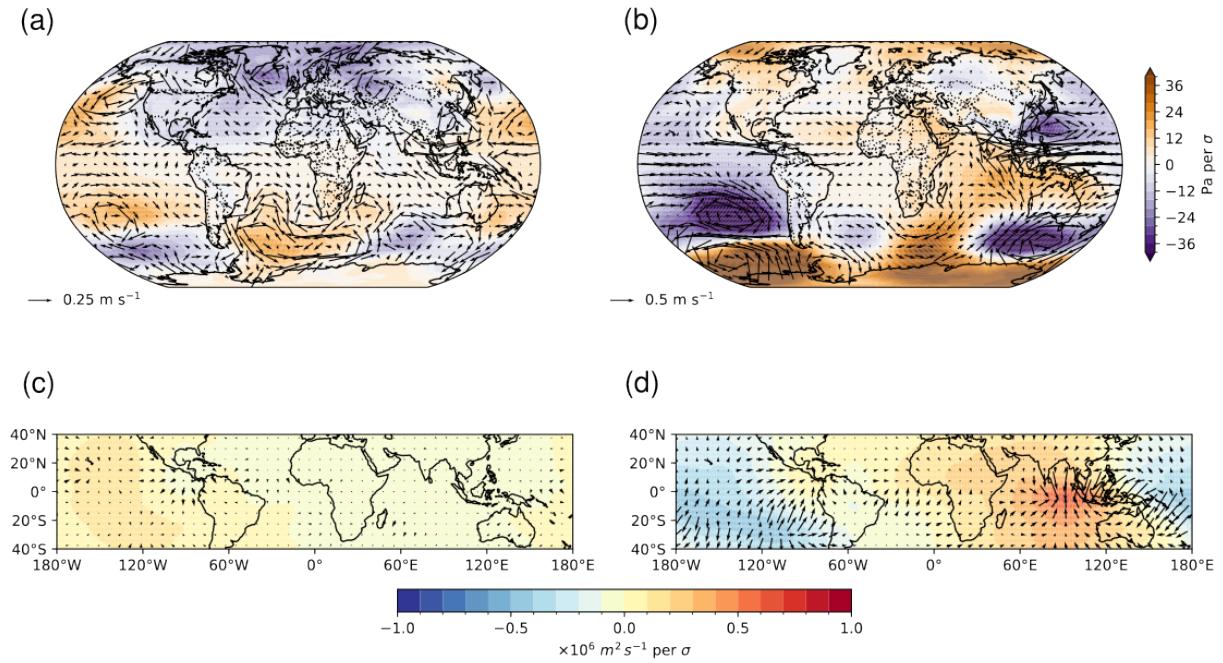


Figure 2. Mechanisms of Sahel Rainfall Modulation a) Regression of decadal means of PSL anomalies (shading) and low-level (850hPa) winds onto AMV and b) PDV. c, d) As in a,b) for velocity potential anomalies and winds at 250 hPa.

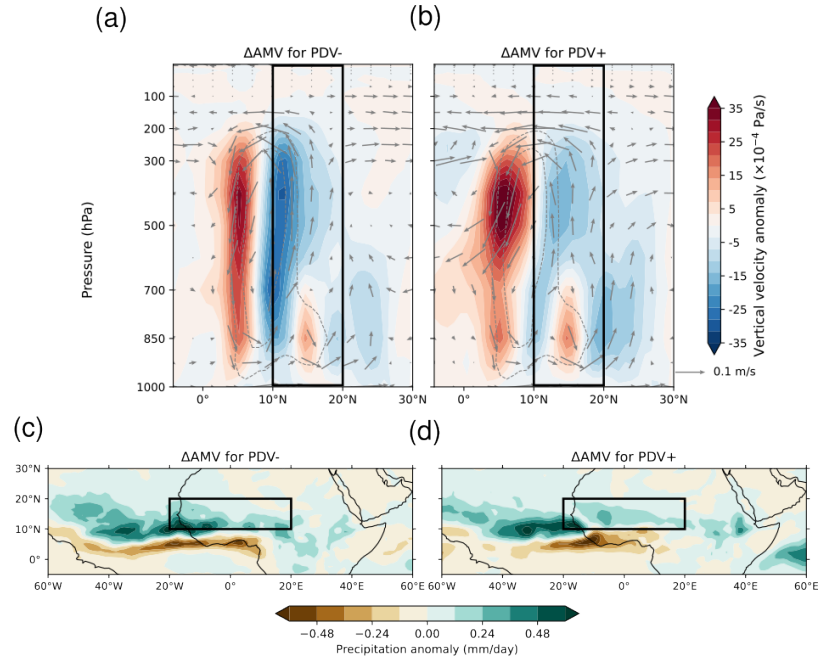


Figure 3. Changes of AMV in different PDV States. Differences of Zonal Crosssections of Circulations as In Figure 4 for **a)** AMV+/PDV- minus AMV-/PDV- and **b)** AMV+/PDV+ minus AMV-/PDV+. **c)** As in a) for precipitation, **d)** as in b) for precipitation.

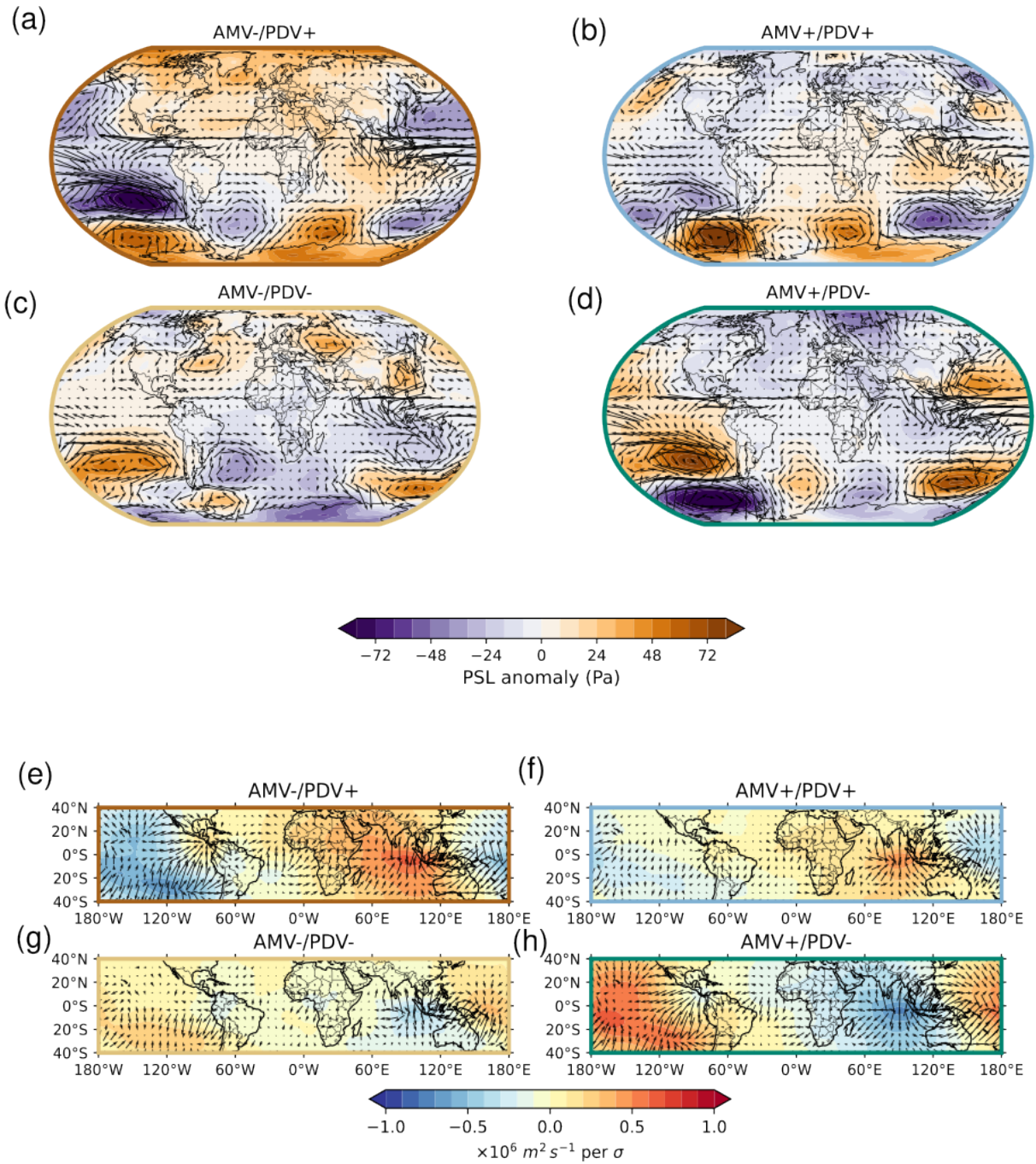


Figure 4. Storylines of Physical Coherent Changes a-d) Anomalies of sea level pressure (shading) and winds at 850hPa for each Storyline. e-h) As in a-d) for velocity potential anomalies and divergent winds at 250hPa.

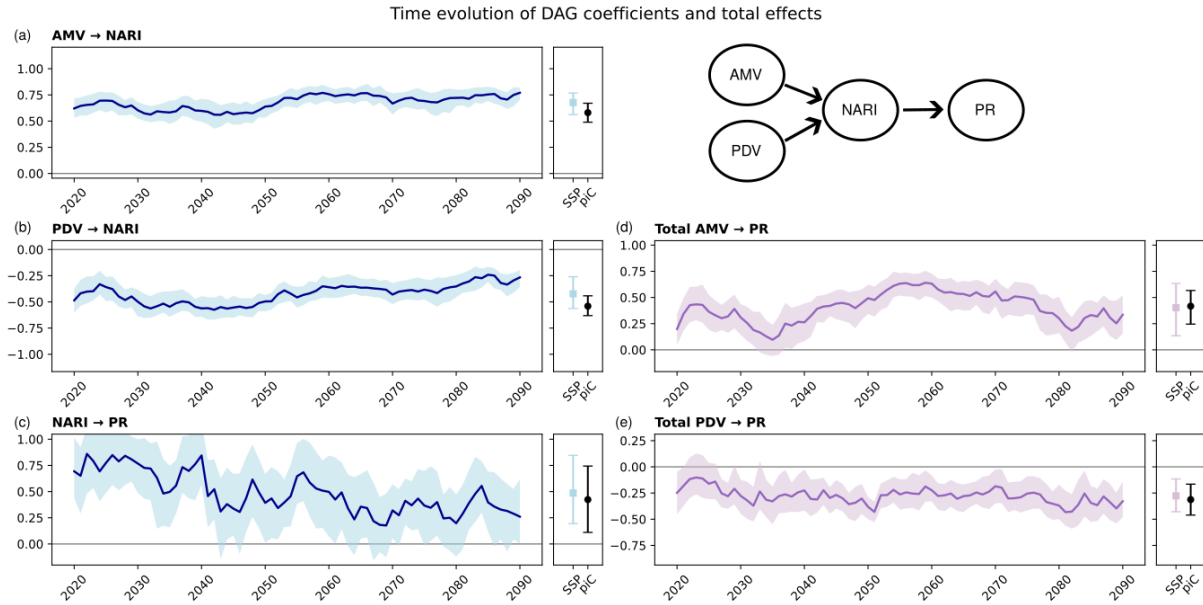


Figure 5. Causal Network in piControl and SSP3.70. Regression coefficients of the directed acyclical graph (top right) over time (black line) and its bootstrapped 95% confidence interval, as well as the temporal mean (and 95% confidence interval) for SSP3-7.0 (color) and the piControl mean, with the 95% bootstrapped confidence interval (black) displayed. Direct effects from **a)** AMV on NARI, **b)** PDV on NARI and **c)** NARI on total Sahel precipitation, as well as the total (including the direct effects from drivers on precipitation) from **d)** AMV and **e)** PDV on total Sahel precipitation.

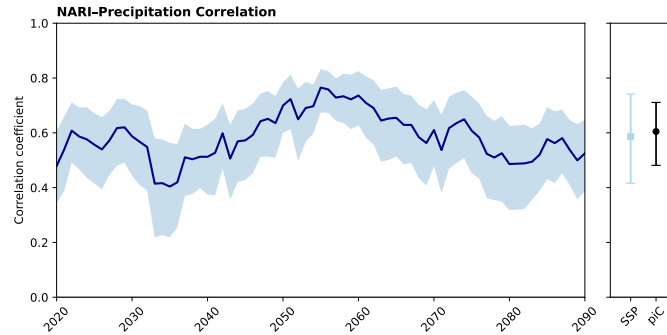


Figure 6. Temporal Evolution of the NARI to Total Sahel Relation. Pearson correlation coefficient (PCC) of decadal NARI and total Sahel precipitation, regressed over the 100 members of the SSP3.70 scenario. The solid line shows the correlation coefficient and the blue shading the 95% bootstrapped confidence interval. At the right, the mean of the PCC are shown for SSP3-7.0 (blue) and piControl (black), the errorbars denote the 95% bootstrapped confidence interval for piControl and the 95% confidence interval for temporal variation for SSP3-7.0.

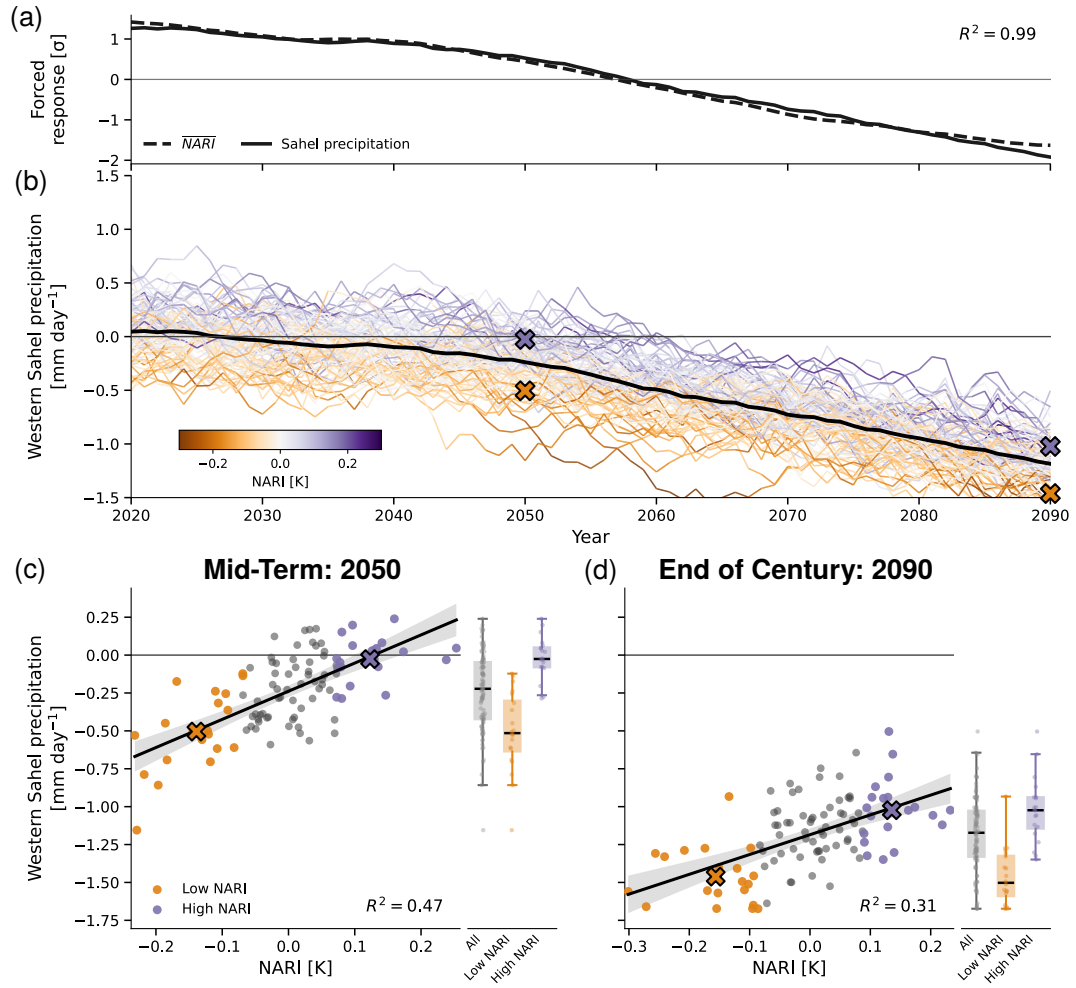


Figure 7. Modulation of the Forced Response for Western Sahel As for Figure 5 in main text, but for Western Sahel

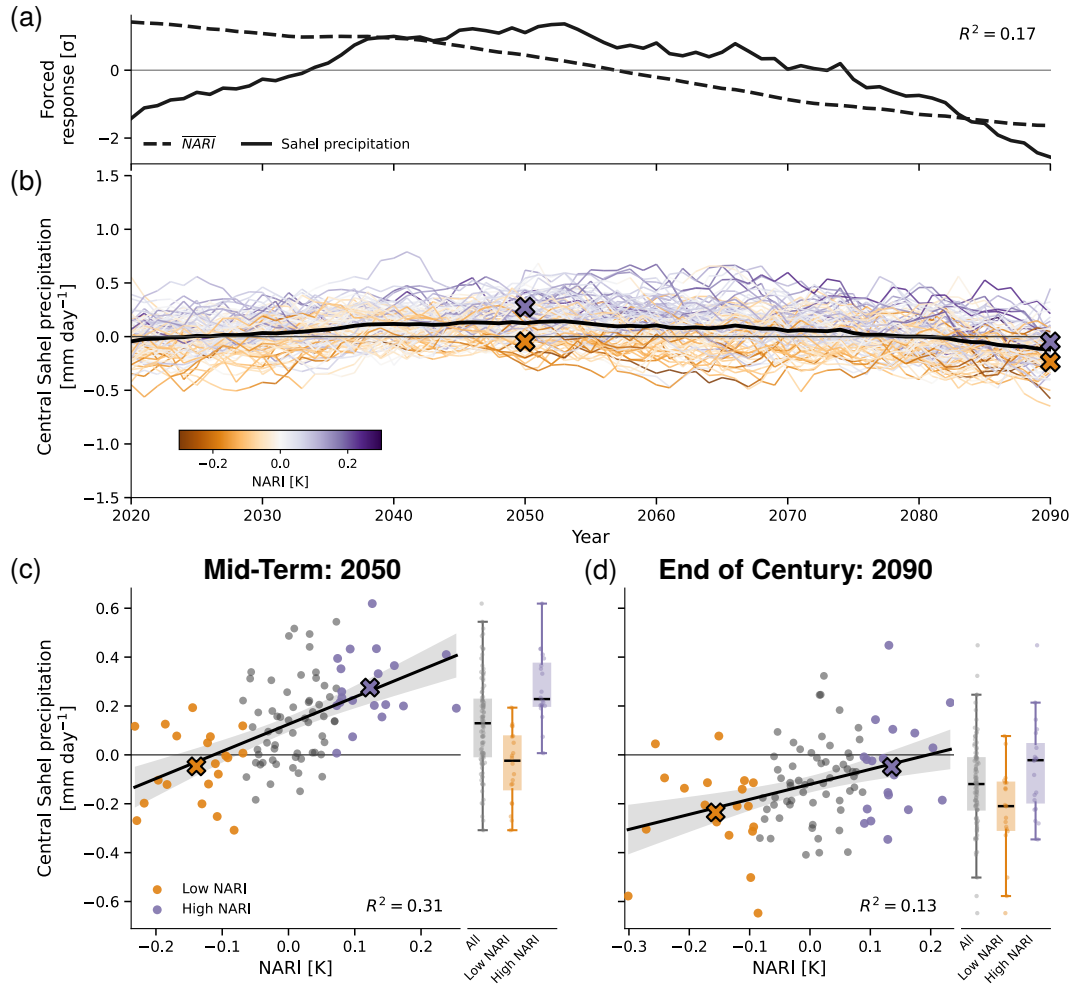


Figure 8. Modulation of the Forced Response for Central Sahel As for Figure 5 in main text, but for Central Sahel

End of Century: 2090

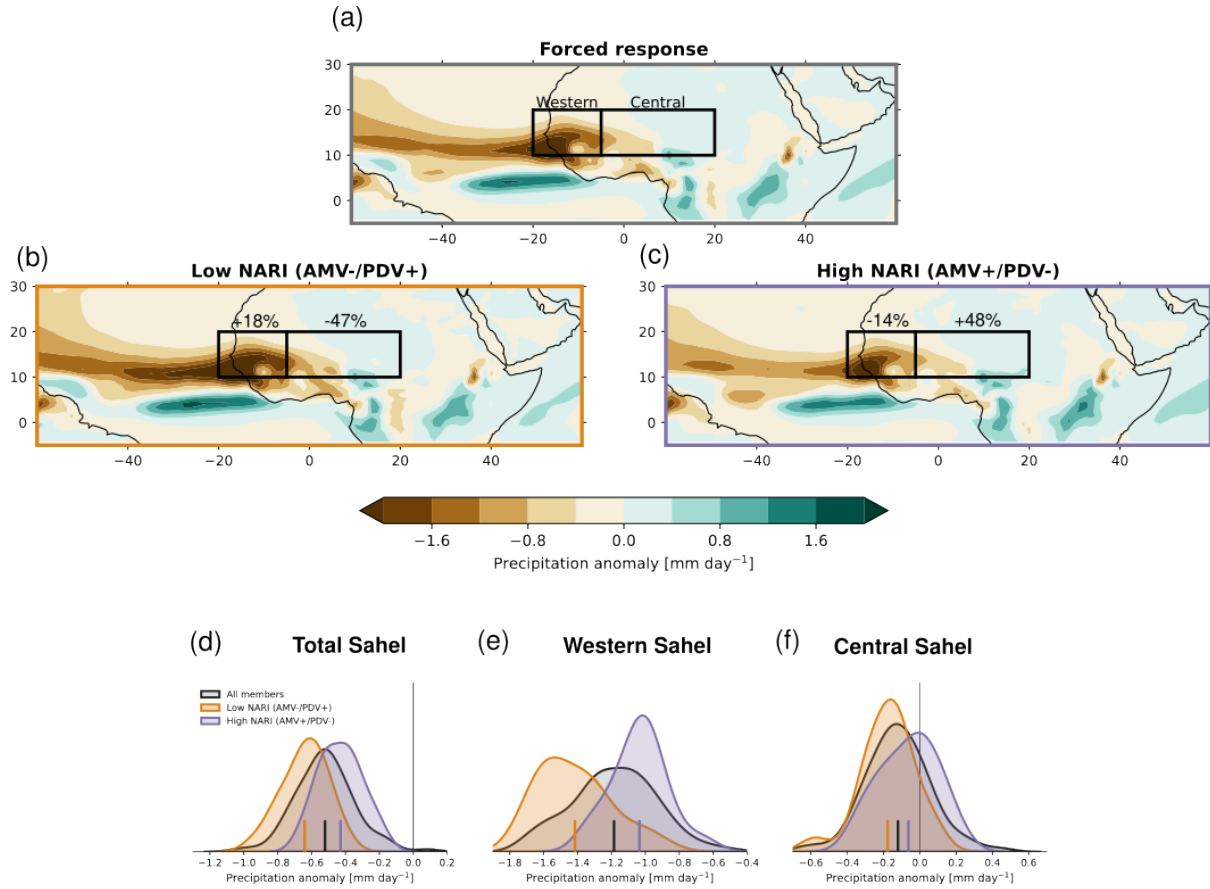


Figure 9. Modulation of end of century (2090) Sahel precipitation change by AMV–PDV storylines. As Figure 9 for decadal precipitation changes for 2090 relative to a 2015–2035 climatology.