

Figure S1. **MERRA2 tropical forcing indexes.** a) The first EOF patterns (EOF1) of the 1991-2022 winter (November to February) related to the Pacific Ocean SST (K) and the Indian Ocean precipitation (mm/day). (b) Standardized Nino indexes and PC time series of Pacific Ocean SSTs EOF1. (c) Standardized precipitation-based index based on Abid et al. (2020) and PC time series of Indian Ocean precipitation EOF1. The results are based on MERRA2 reanalysis.

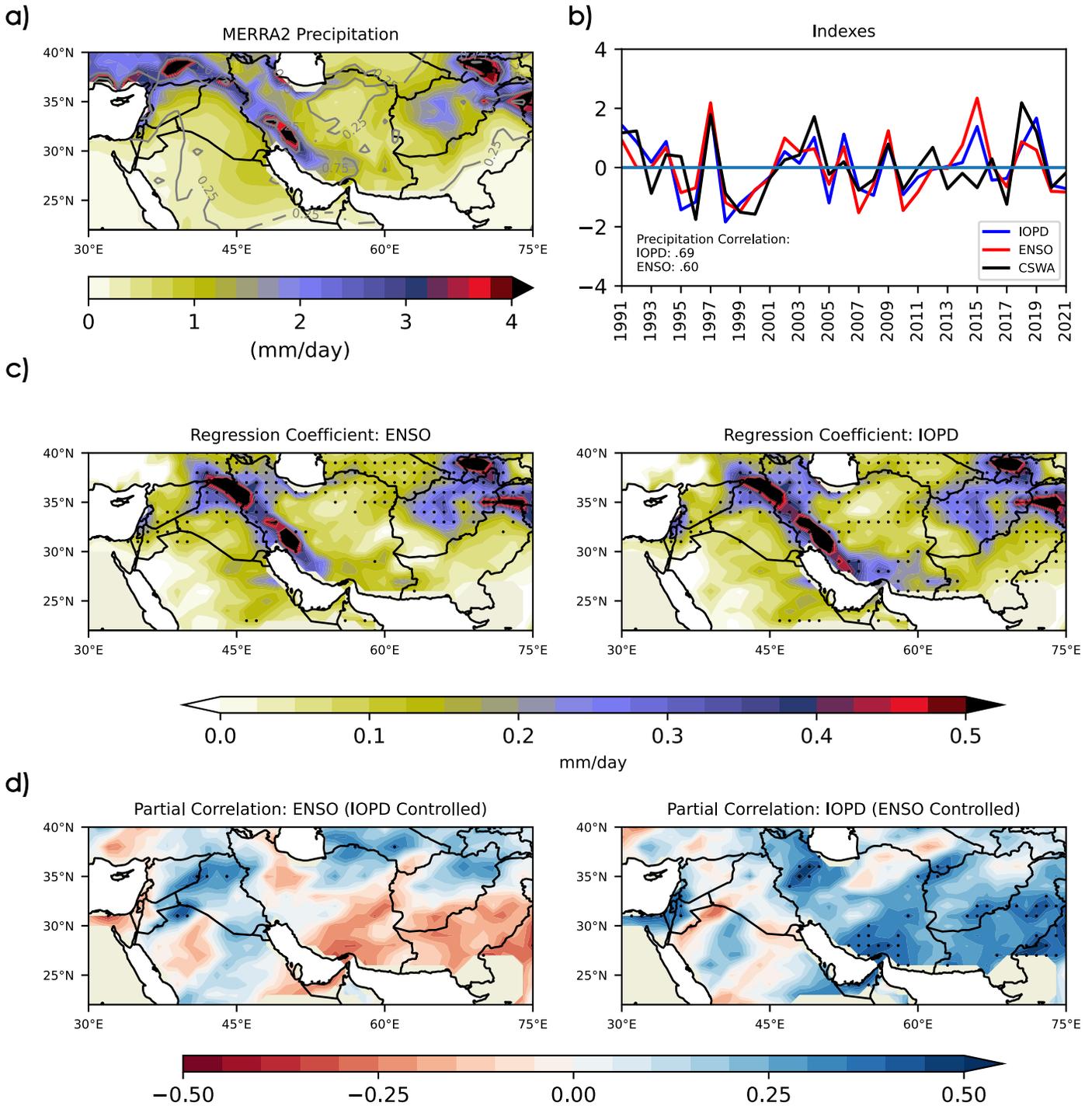


Figure S2. **MERRA 2 CSWA precipitation and tropical teleconnections.** a) Average precipitation (color; mm/day) and standard deviation (contour; mm/day). b) Standardized time series of CSWA precipitation, ENSO, and IOPD. c) Regression of CSWA precipitation (mm/day) onto standardized ENSO and IOPD Indices. d) Partial correlation of ENSO and IOPD with CSWA precipitation. Stippling indicates significance at the 95% confidence level.

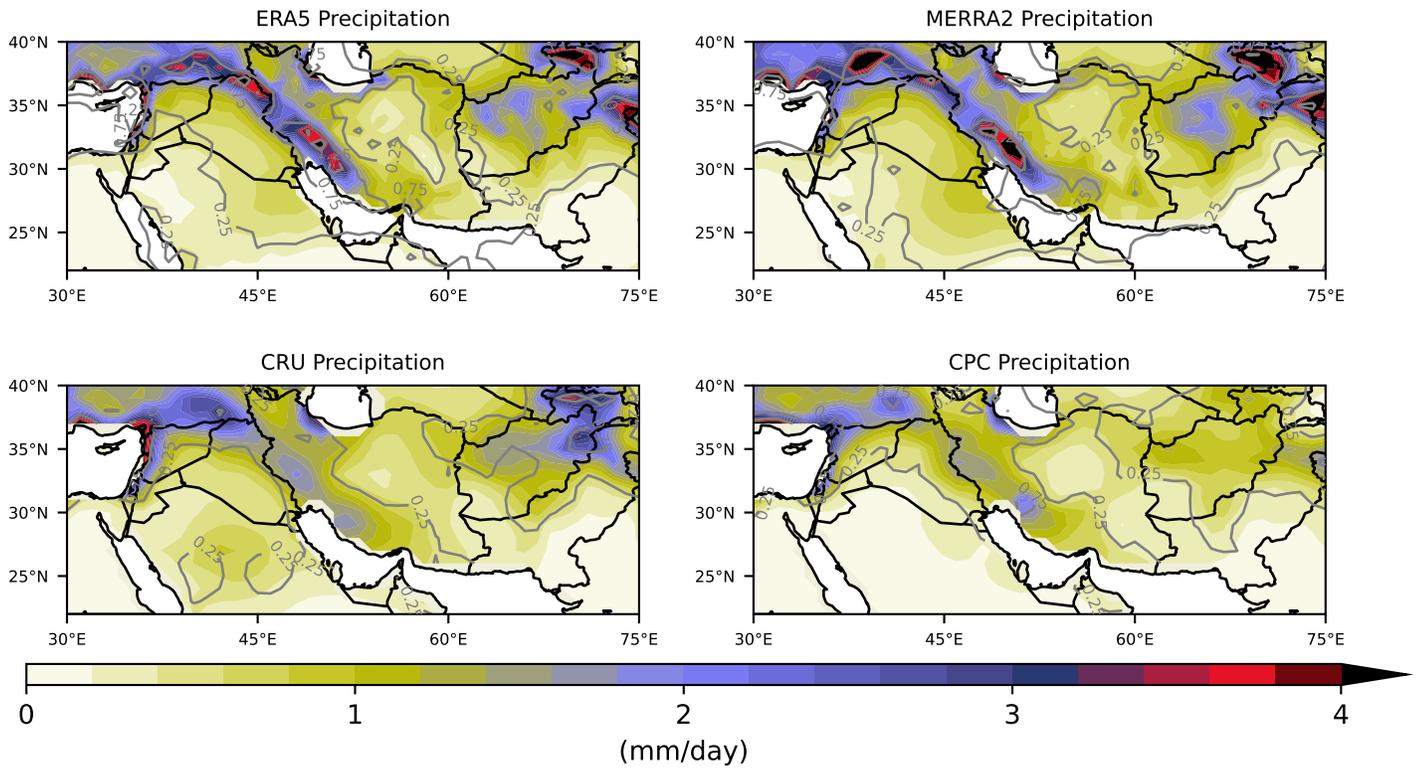


Figure S3. **CSWA precipitation.** Average precipitation (color; mm/day) and standard deviation (contour; mm/day) in reanalyses (ERA5, MERRA2) and observations (CRU, CPC).

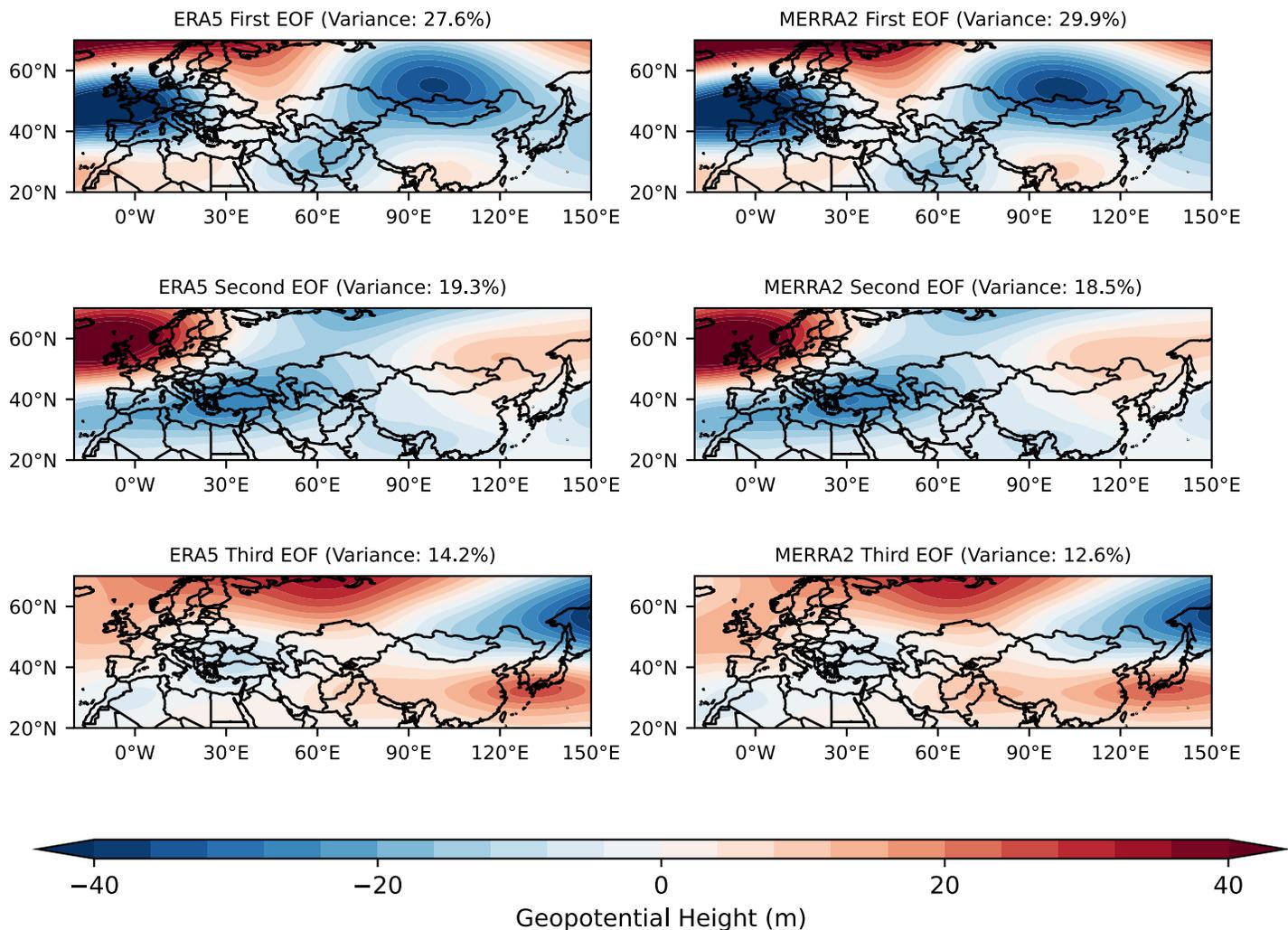


Figure S4. **EOF Loading Patterns.** Maps of first three EOFs of 200 hPa geopotential height in reanalysis after removing tropical forcing. Numbers in parentheses indicate the explained variance of each EOF.

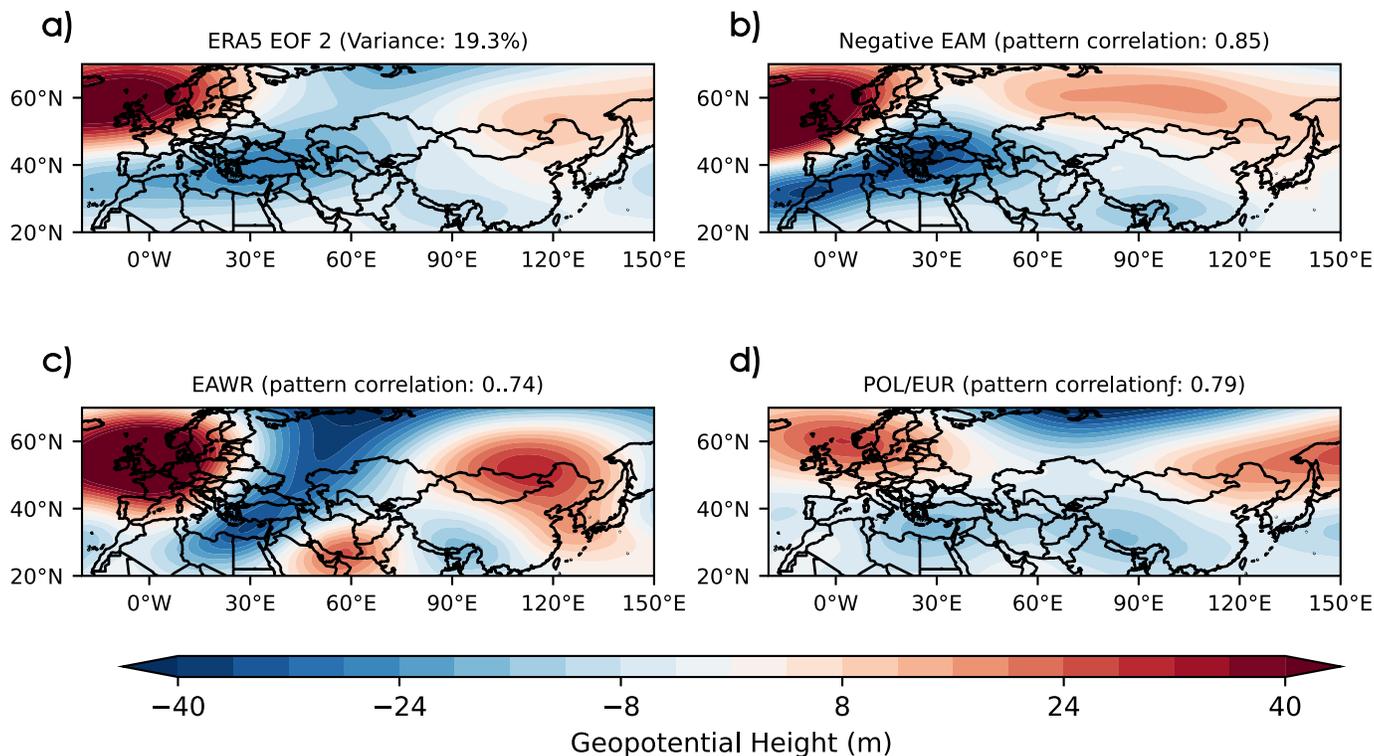


Figure S5. **CSWA-relevant extratropical forcing.** a) The second EOF of 200 hPa geopotential height after linearly removing ENSO and IOPD influences. b) The regression of 200 hPa geopotential height onto the negative East Atlantic Mode after removing ENSO and IOPD. c) as b) but onto the East Atlantic/Western Russia Pattern. d) as c) but onto the Polar/Eurasian pattern

EOF 2 and Indices

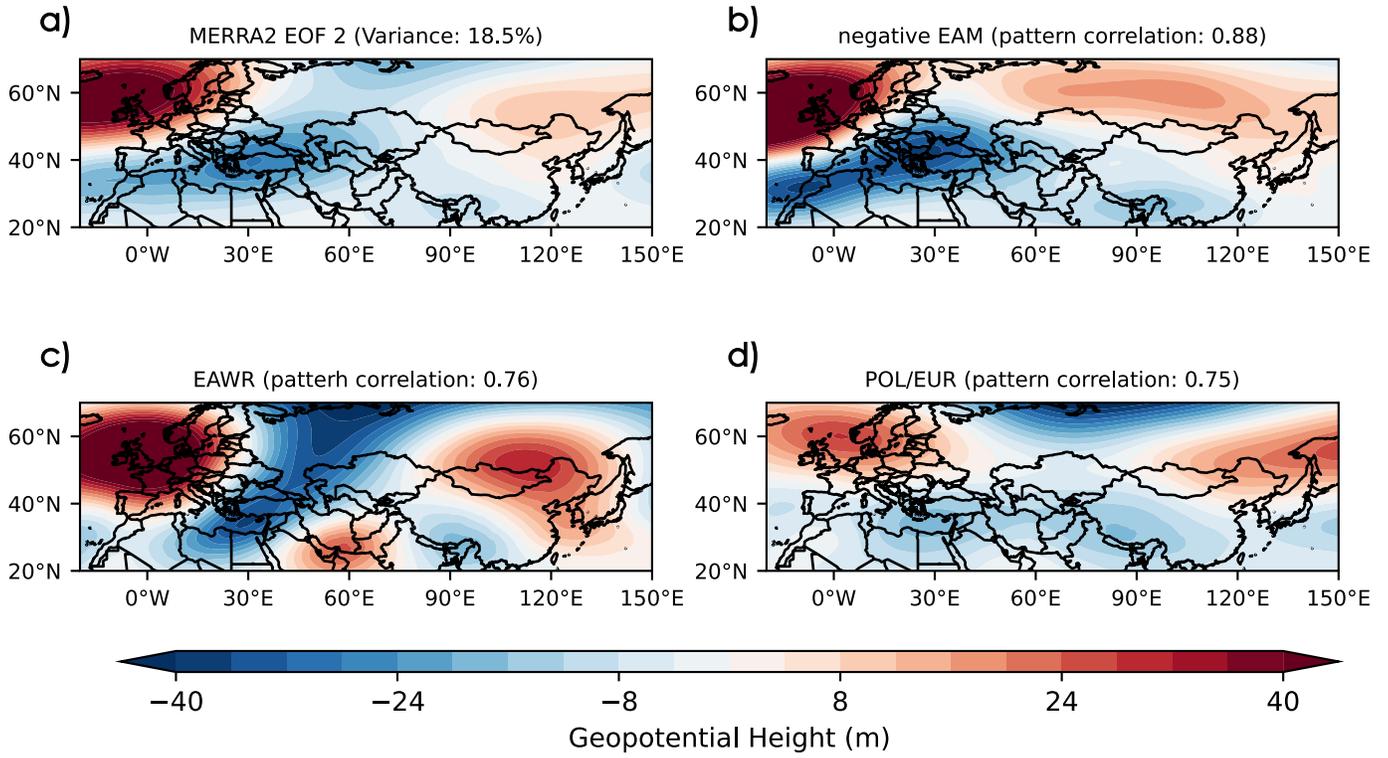


Figure S6. **MERRA2 CSWA-relevant extratropical forcing.** Same as Figure S5 but with MERRA2 data.

MERRA 2 Multilinear Regression model ($r^2 = .72$) Start 1991

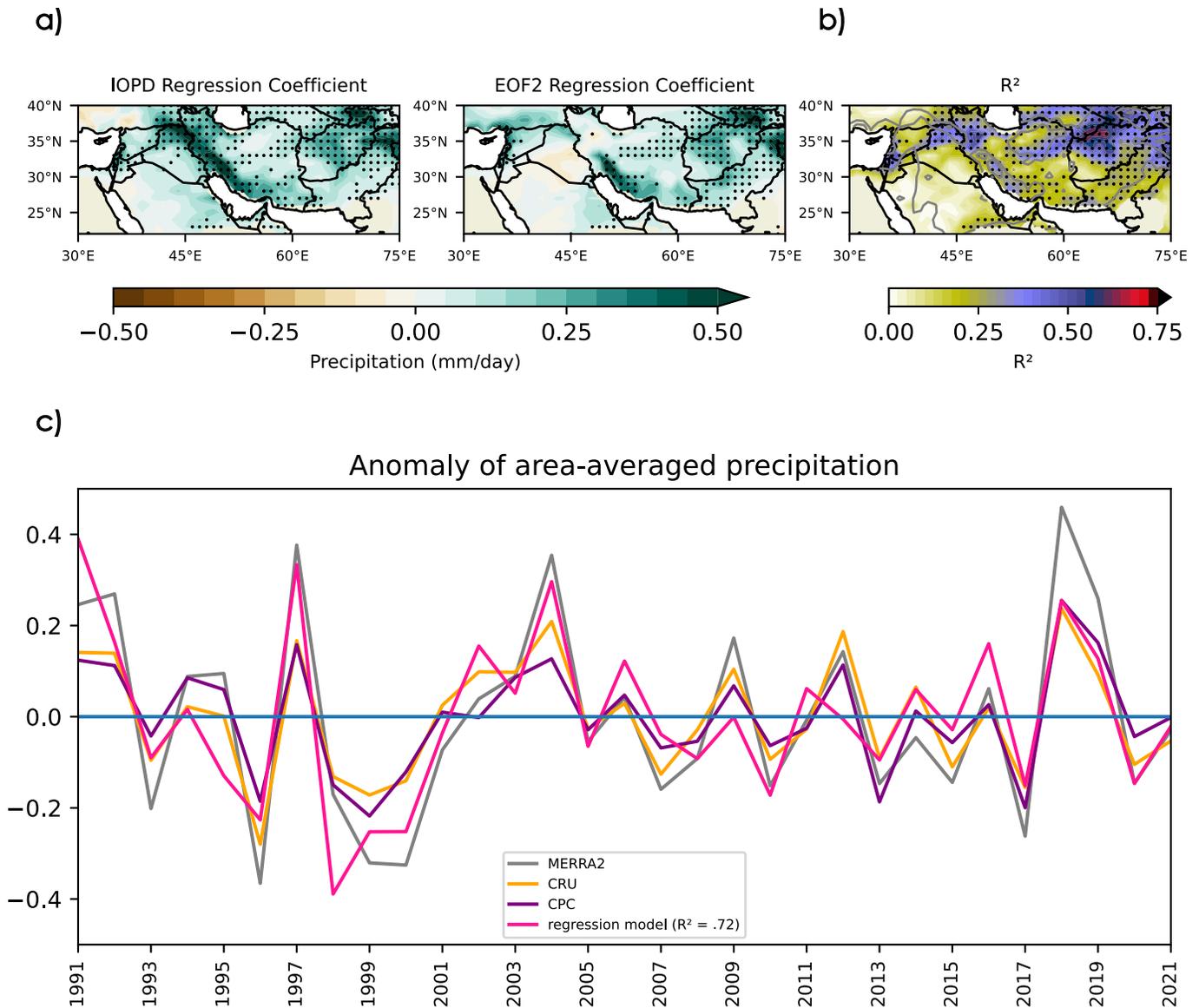


Figure S7. **Multiple linear regression analyses with MERRA2.** a) Partial regression coefficients of IOPD and PC2. Stippling indicates significance at the 95% confidence level. b) The coefficient of determination (r-squared) based on the multiple linear regression model. Stippling indicates the statistical significance of the F-test ($p < 0.05$). c) Area-averaged precipitation time series in MERRA2, CRU, CPC, and regression model. The results are based on MERRA2 reanalysis.

Anomaly of CSWA area-averaged precipitation (mm/day)

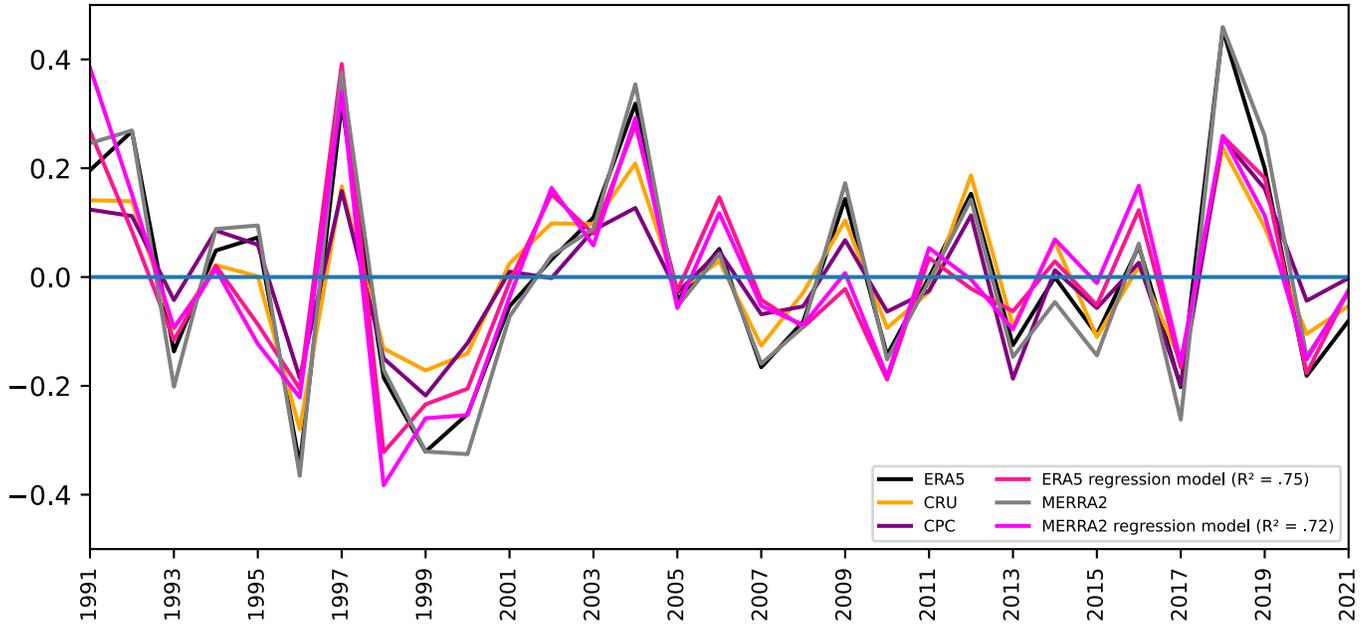


Figure S8. **Multiple linear regression analyses with ENSO.** Area-averaged precipitation time series in ERA5, CRU, CPC, MERRA2, and regression model using IOPD, PC2 and ENSO as a predictor. R squared for the regression models are based on the relevant reanalysis to which they are based.

ENSO time series

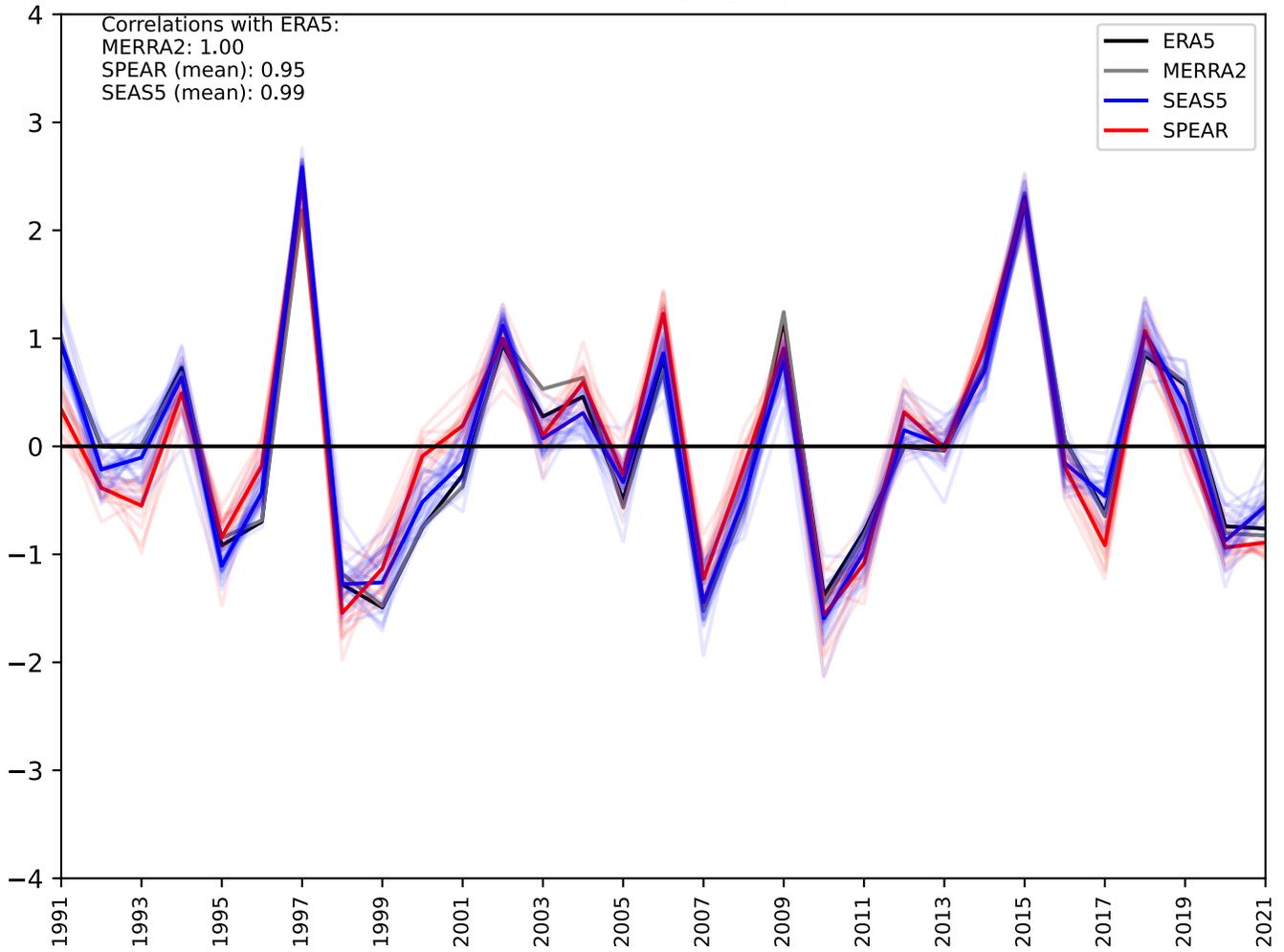


Figure S9. **ENSO index.** Standardized ENSO index in SEAS5 (blue) and SPEAR (red), ERA5 (black), and MERRA2 (grey). Light color lines represent individual ensemble members in SEAS5 and SPEAR. The correlation numbers are based on ERA5

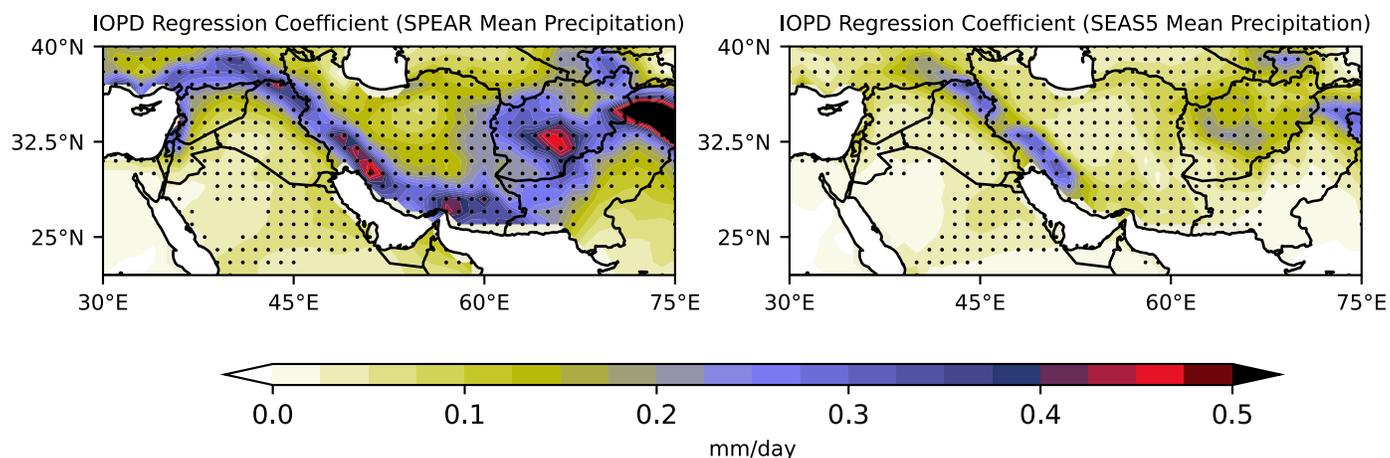


Figure S10. **Tropical forcing teleconnections with CSWA in SEAS5 and SPEAR ensemble mean.** Regression of CSWA precipitation (mm/day) onto the standardized IOPD index using the ensemble mean in SEAS5 and SPEAR. Stippling indicates statistical significance at the 95% confidence level.

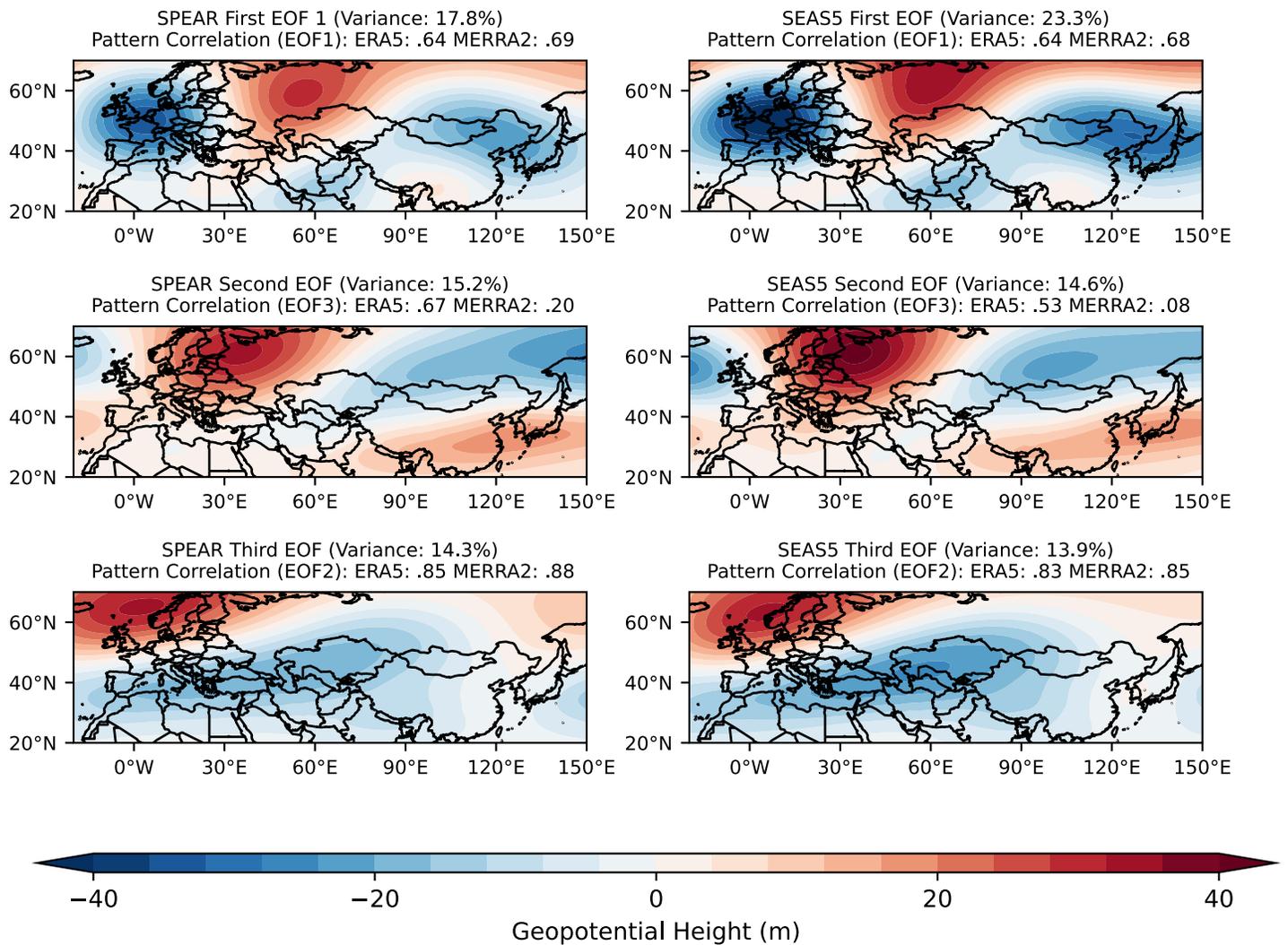


Figure S11: **Extratropical forcing in SPEAR and SEAS5.** Loading patterns (m) of 200 hPa geopotential height after linearly removing ENSO and IOPD influences. The analysis is based on concatenated SPEAR and SEAS5 data. Pattern correlations with the most relevant EOF in reanalysis are noted.

Monthly IOPD

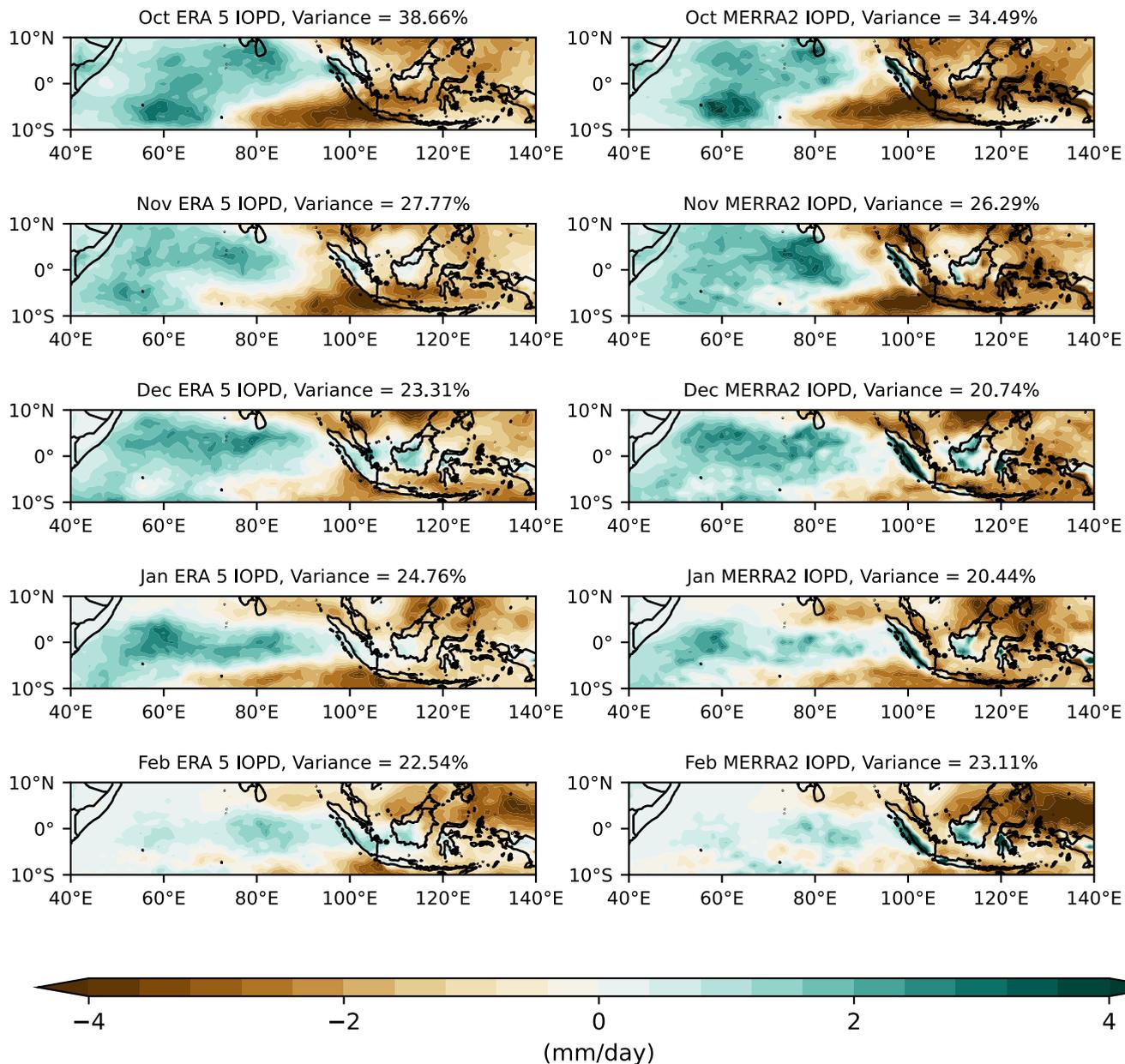


Figure S13: **Monthly IOPD**. Monthly loading pattern of first EOF of Indian Ocean precipitation in (left) ERA5 and (right) MERRA2.

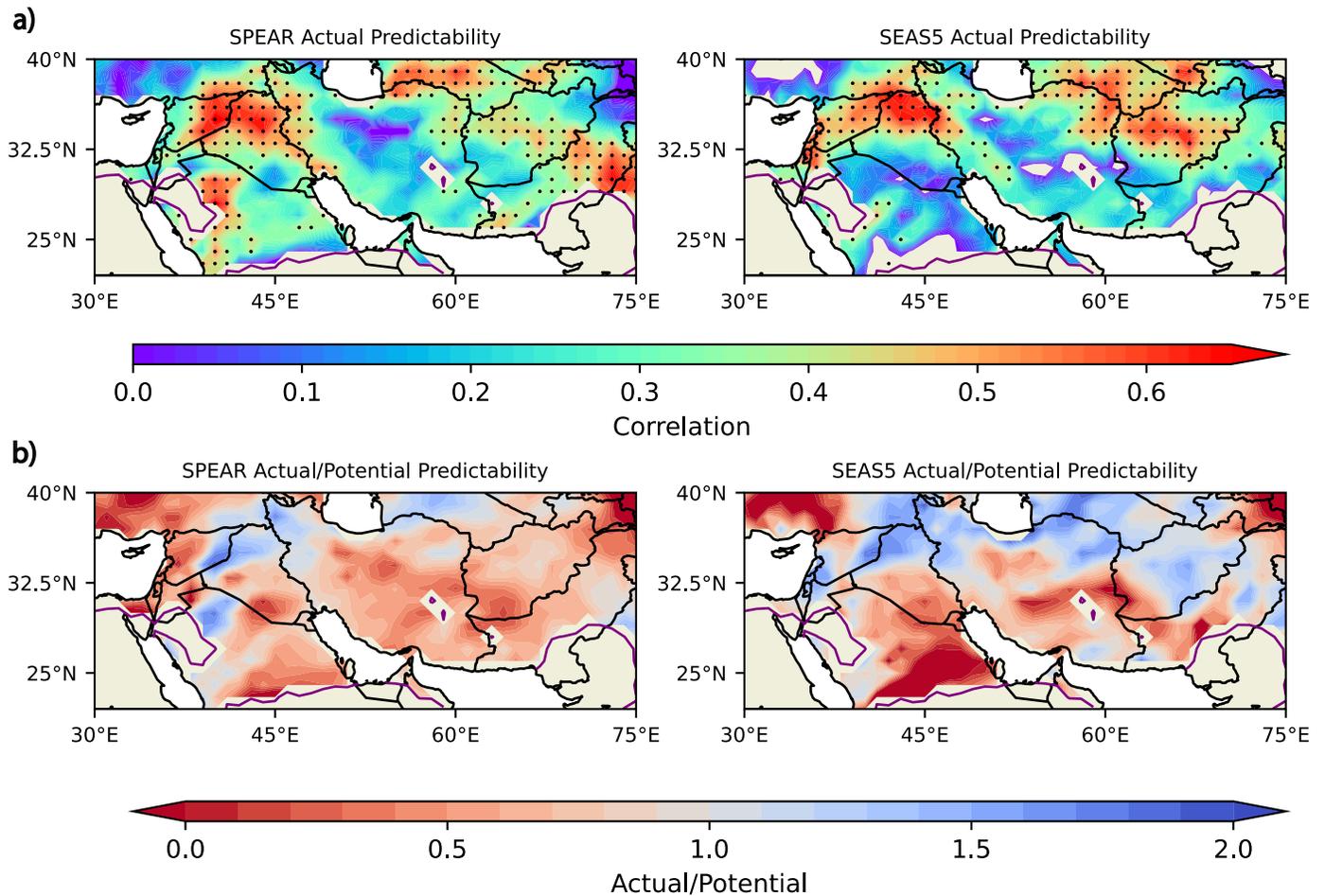


Figure S13. **Predictability measures in SEAS5 and SPEAR with reference to MERRA2.** a) Actual predictability skill calculated as anomaly correlation between the SEAS5 and SPEAR ensemble mean and MERRA2. Stippling indicates statistical significance at the 95% confidence level. b) The ratio of a) to potential predictability (Figure 5a). In all panels, areas where the ERA5 mean precipitation is less than 0.2 mm/day are masked.