Geophysical Research Letters

Supporting Information for

Seasonal variability and predictability of monsoon precipitation in Southern Africa

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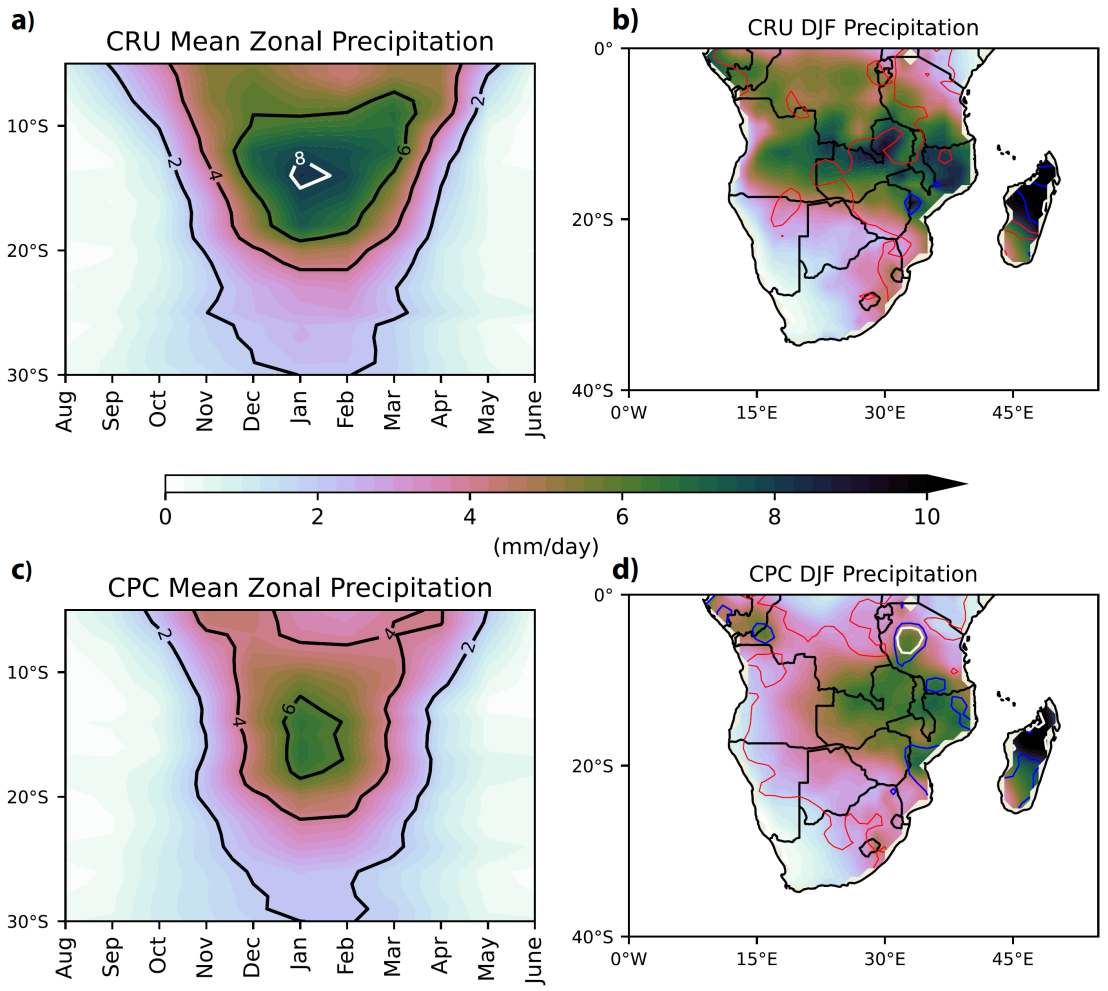

Figure S1. a) The monthly zonal average (5°E to 52°E, land points) of precipitation in CRU from 1991-2022. b) Color contours: DJF precipitation (land), line contours: DJF precipitation standard deviation (red, blue, white: 1, 2, 3 mm/day for CRU. (c-d) same as a-b but for CPC.

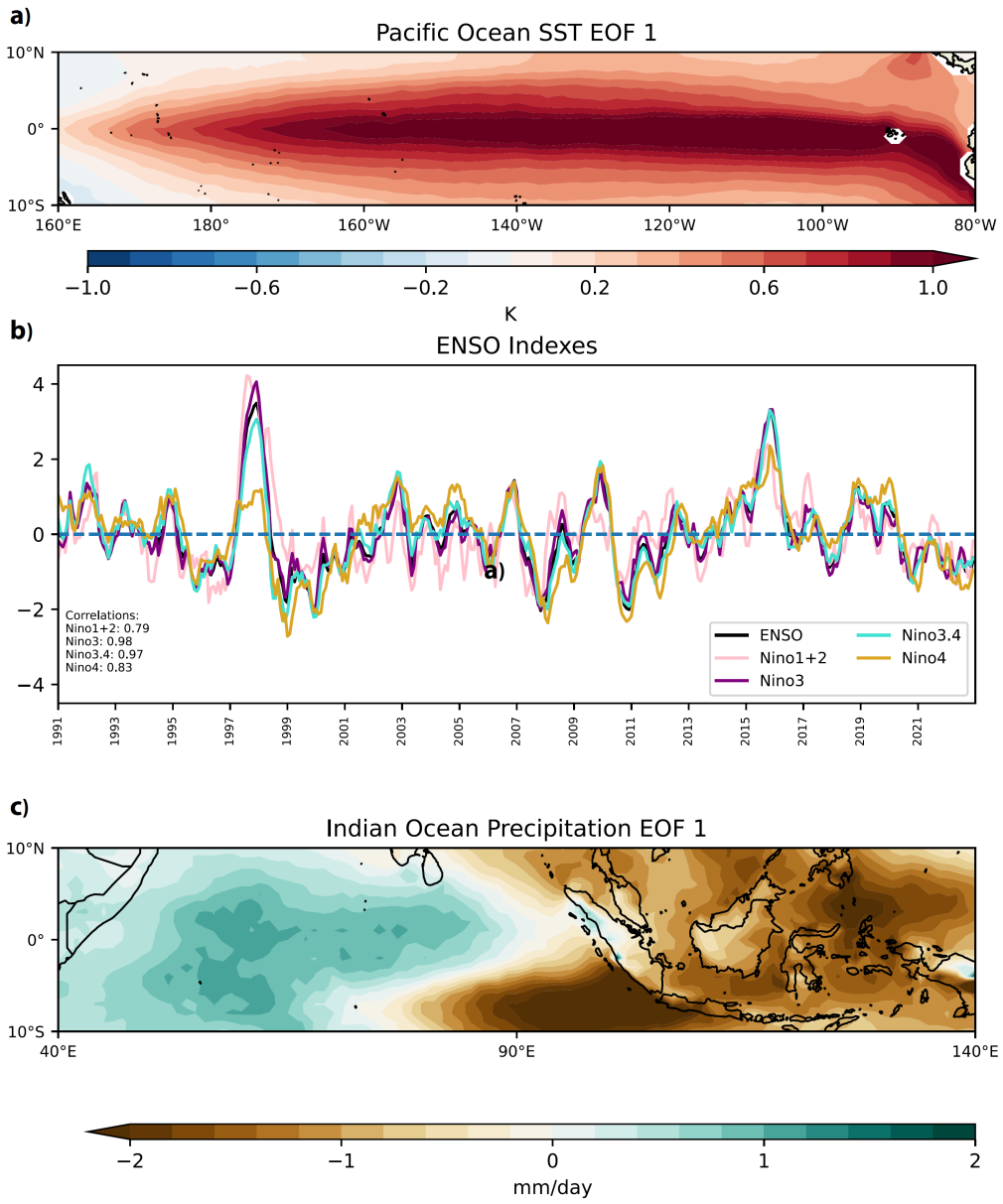

Figure S2. a) The loading pattern of sea surface temperatures used to define ENSO. b) Line plots of EOF-based ENSO index (black) used in this study and Niño indexes (other colors), correlations with each are labeled on the left. c) Loading pattern of Indian Ocean precipitation used to define IOPD.

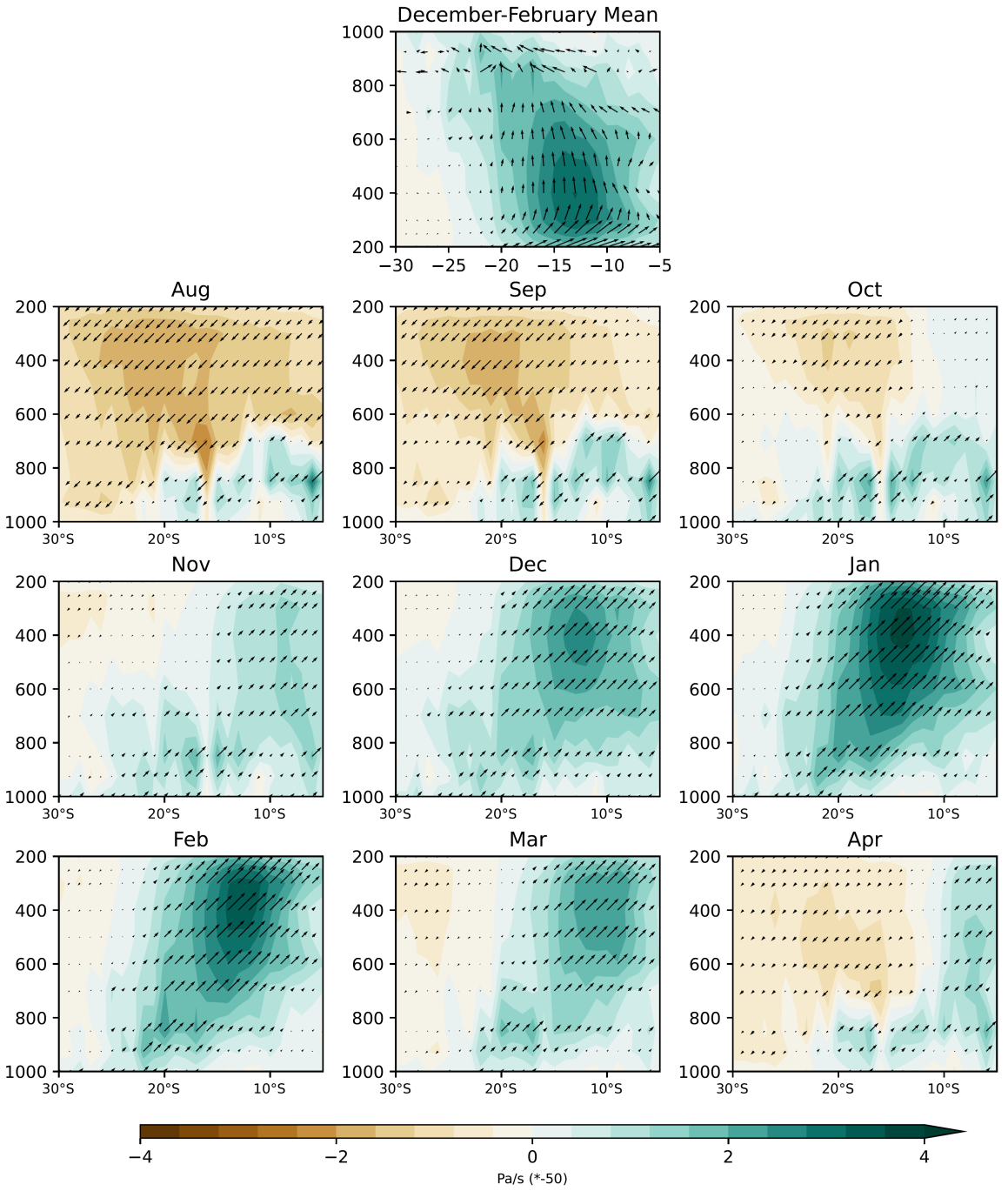

Figure S3. (top) Zonally averaged mean vertical cross-section of DJF divergence (multiplied by 10E6) and vertical pressure velocity (multiplied by -50), shown as vectors. Vertical pressure velocity is also shown in color vectors. (bottom three rows) Same as in the top panel but for monthly data.

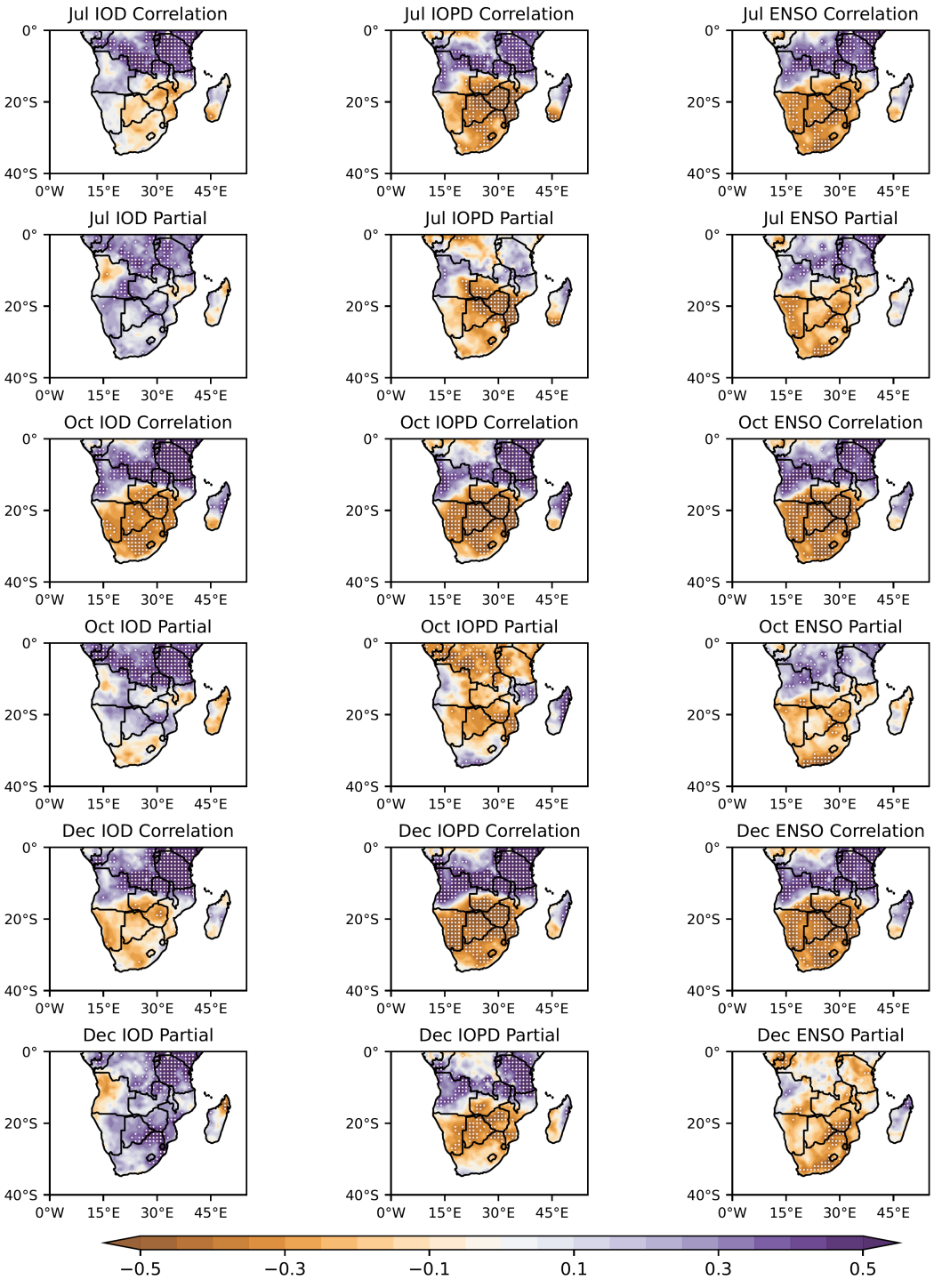

Figure S4. The Pearson and partial correlations of IOD, IOPD, and ENSO with DJF precipitation over Southern Africa using July, October, and December preconditioning.

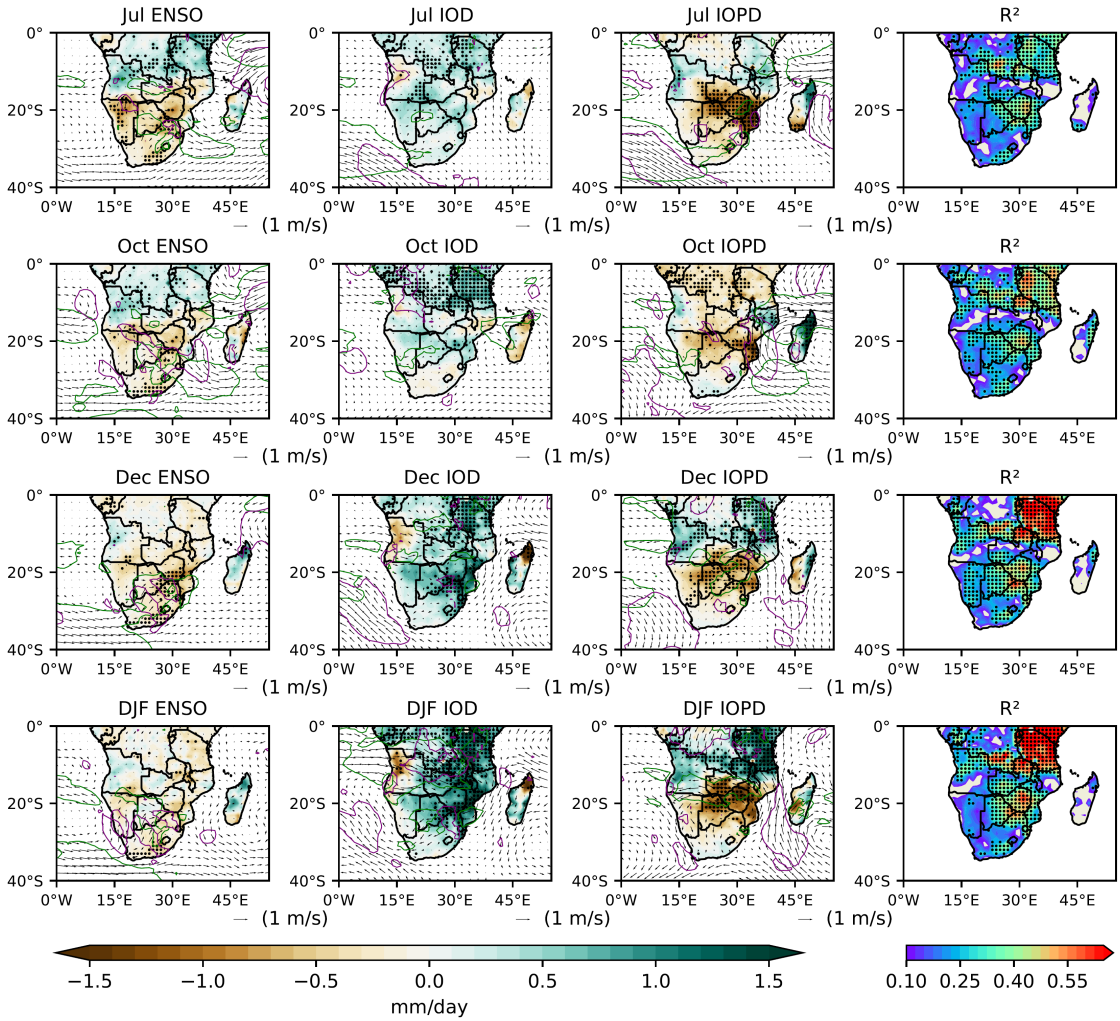

Figure S5. Partial regression coefficients from multi-linear regression model describe the lead and contemporaneous influences of IOD (left column), IOPD (second column from left), and ENSO (third column from left) on DJF precipitation (colors) and 850 hPa winds (vectors) over Southern Africa using their July (first row), October (second row), December (third row) and DJF (fourth row) forcings. Stippling (dots) and green (purple) contours represent the statistical significance of precipitation and zonal (meridional) winds regression coefficient at the 95% confidence level. The right column shows the corresponding coefficients of determination with the F-test stippled ($p<.05$).

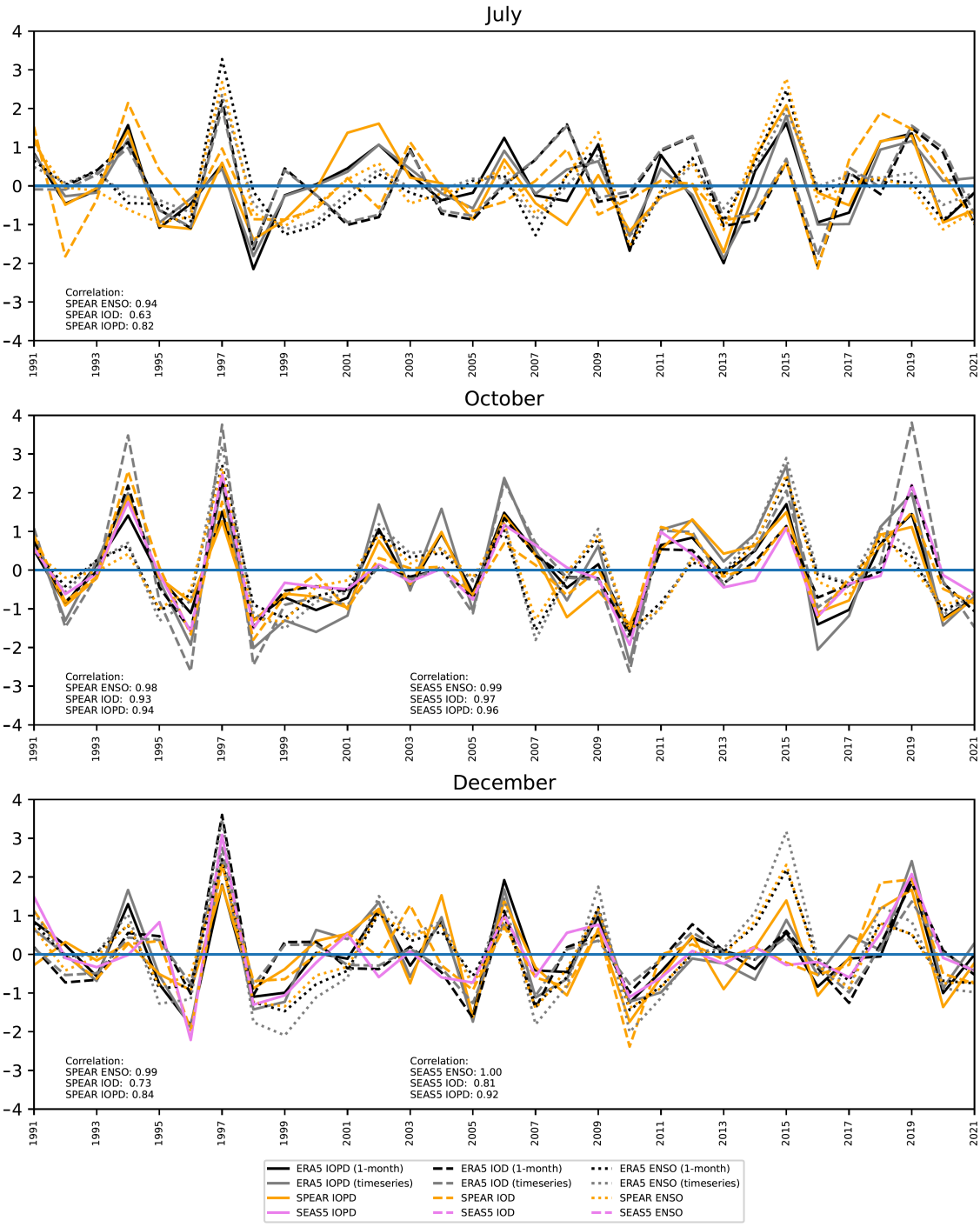

Figure S6. ENSO, IOD, and IOPD indexes in July, October, and December in ERA5, SPEAR, and SEAS5. ERA5 (timeseries, gray) indicates index calculated using all months during the full (1991-2022) time-period. Model indexes are calculated and standardized at lead-0 (initialization month). To demonstrate these values on the same scale, ERA5 (1-month, black) values are standardized using only the month plotted (July, October, December).

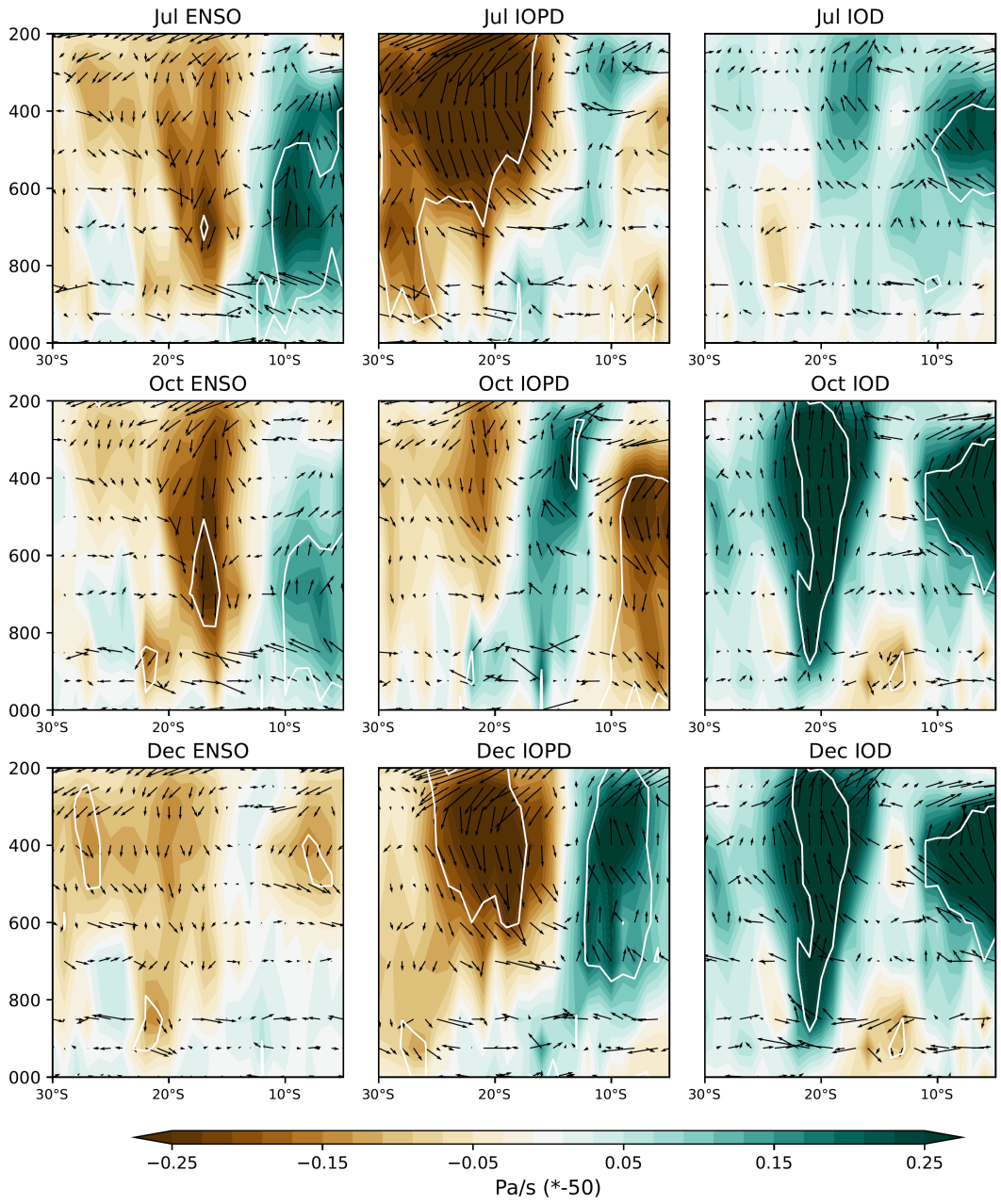

Figure S7. Partial regression coefficients from the multi-linear regression model describe the lead influences of ENSO (left column), IOPD (middle column), and ENSO (right column) on the zonally averaged vertical cross-section of DJF divergence (multiplied by 10E6) and vertical pressure velocity (multiplied by -50) using their July (first row), October (second row), and December (third row) forcings. The regression coefficients related to vertical pressure velocity are also shown in color. White contours represent the statistical significance of colored contours ($p<.05$)

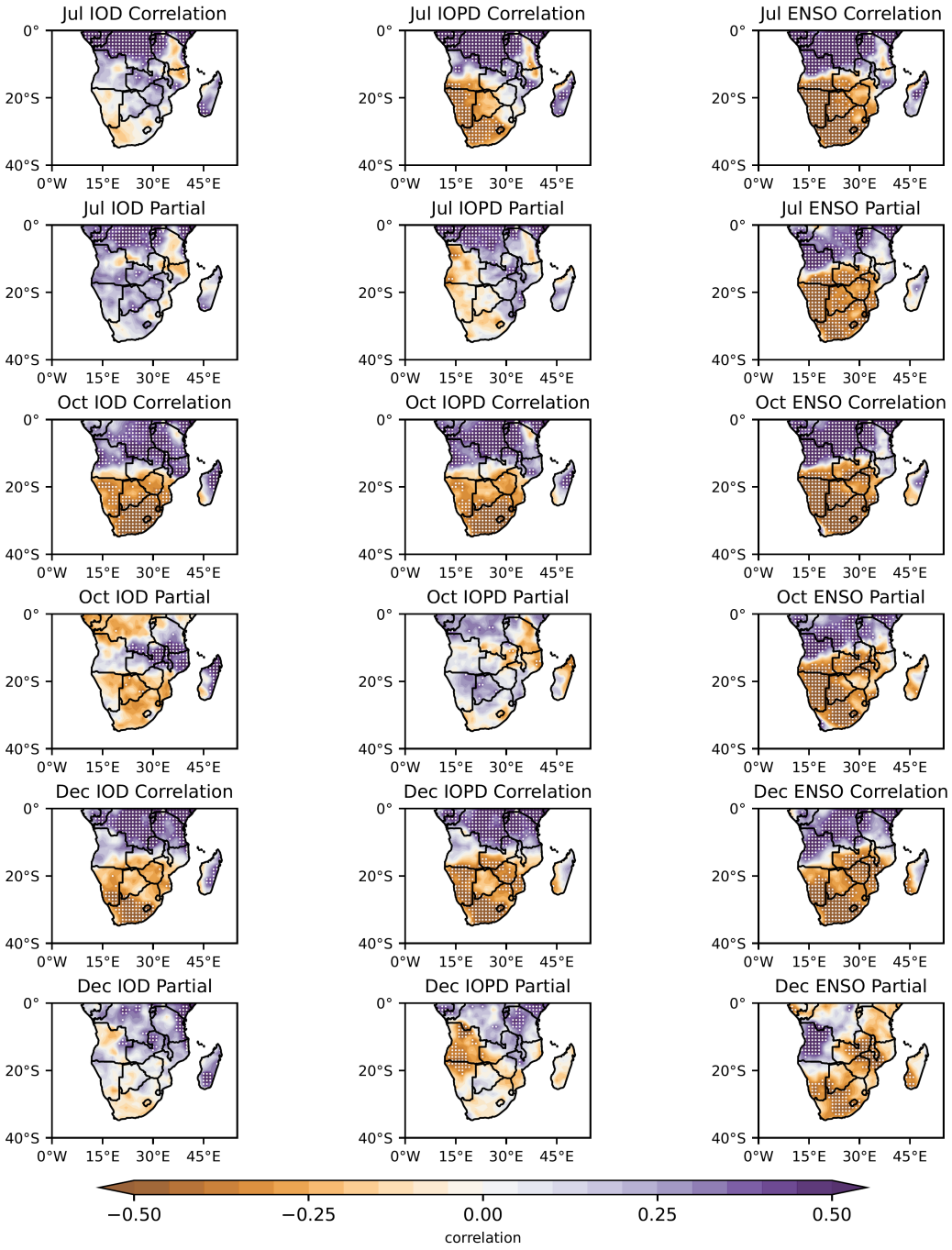

Figure S8. Same as S4 but for SPEAR data.

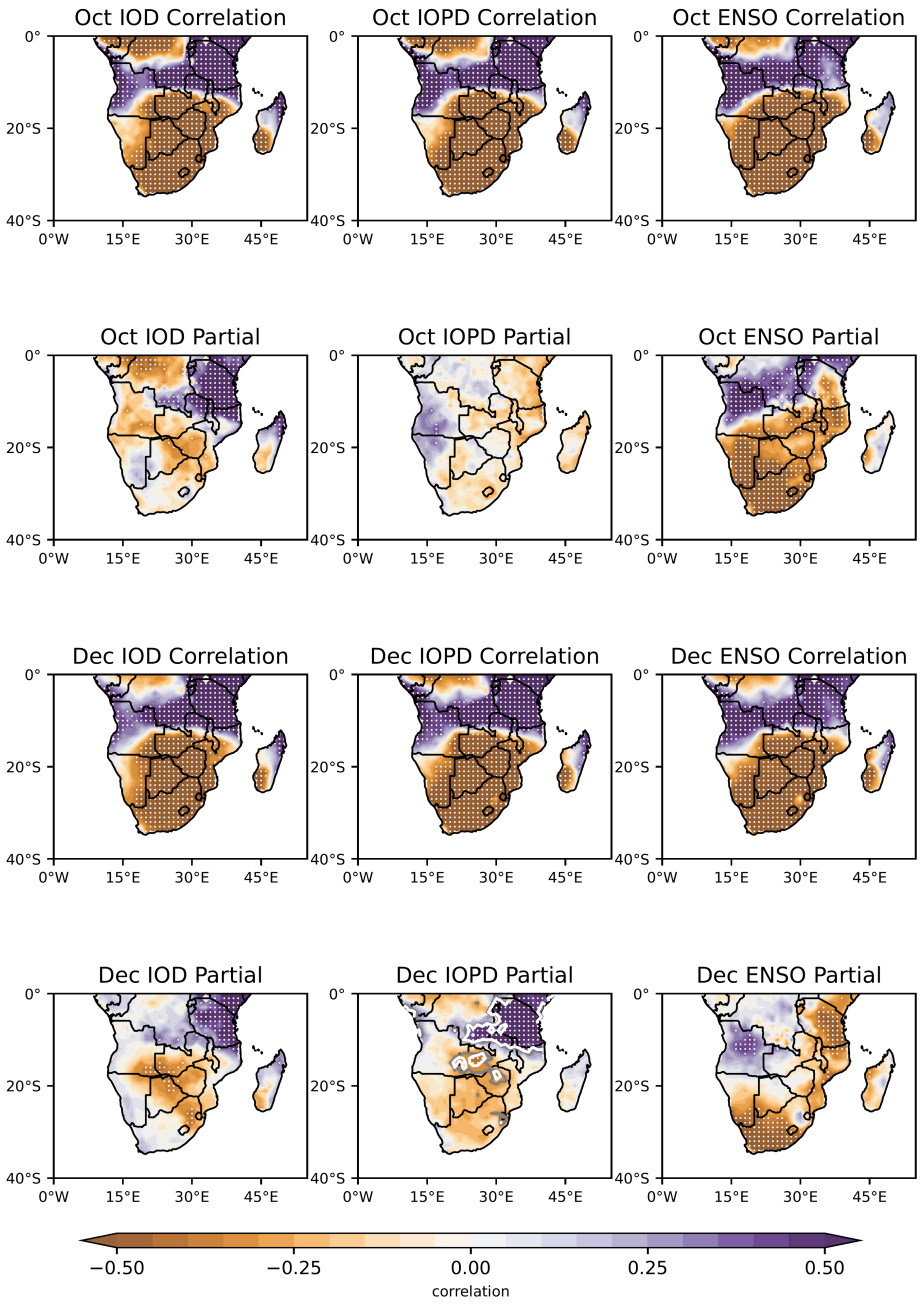

Figure S9. Same as S4 but for SEAS5 data. Note that SEAS5 initiated in July does not include data for February, so it was not included.

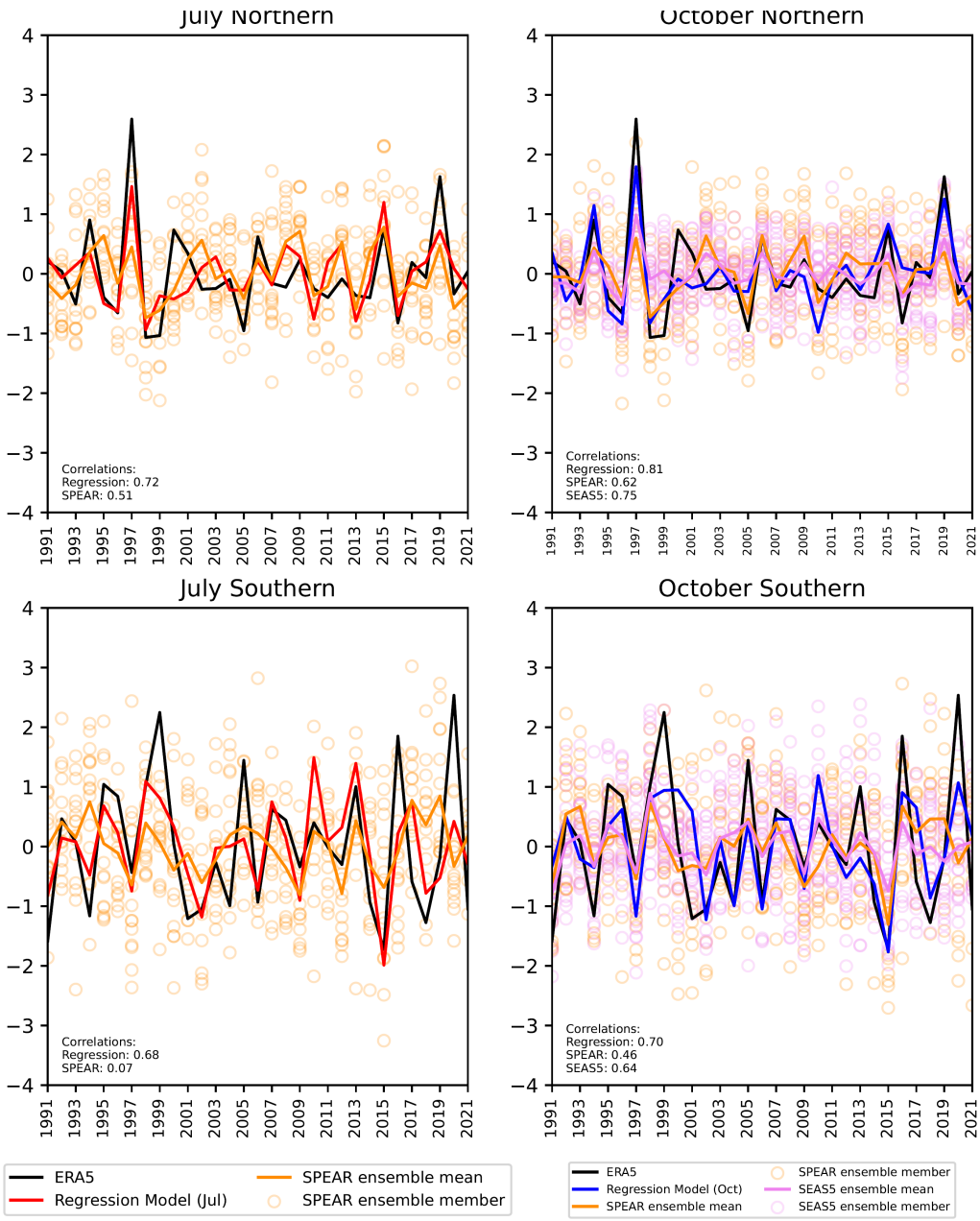

Figure S10. The mean area-averaged precipitation over northern (above) and southern (below) parts of Southern Africa in ERA5 (black), regression model (red/blue), SPEAR (orange) ensemble mean, and SEAS5 (violet) ensemble mean initialized in (left) July and (right) October. Light circles indicate ensemble members. The northern and southern regions used in these analyses are shown in Figure 3h. The text in each panel describes the correlations with ERA5.

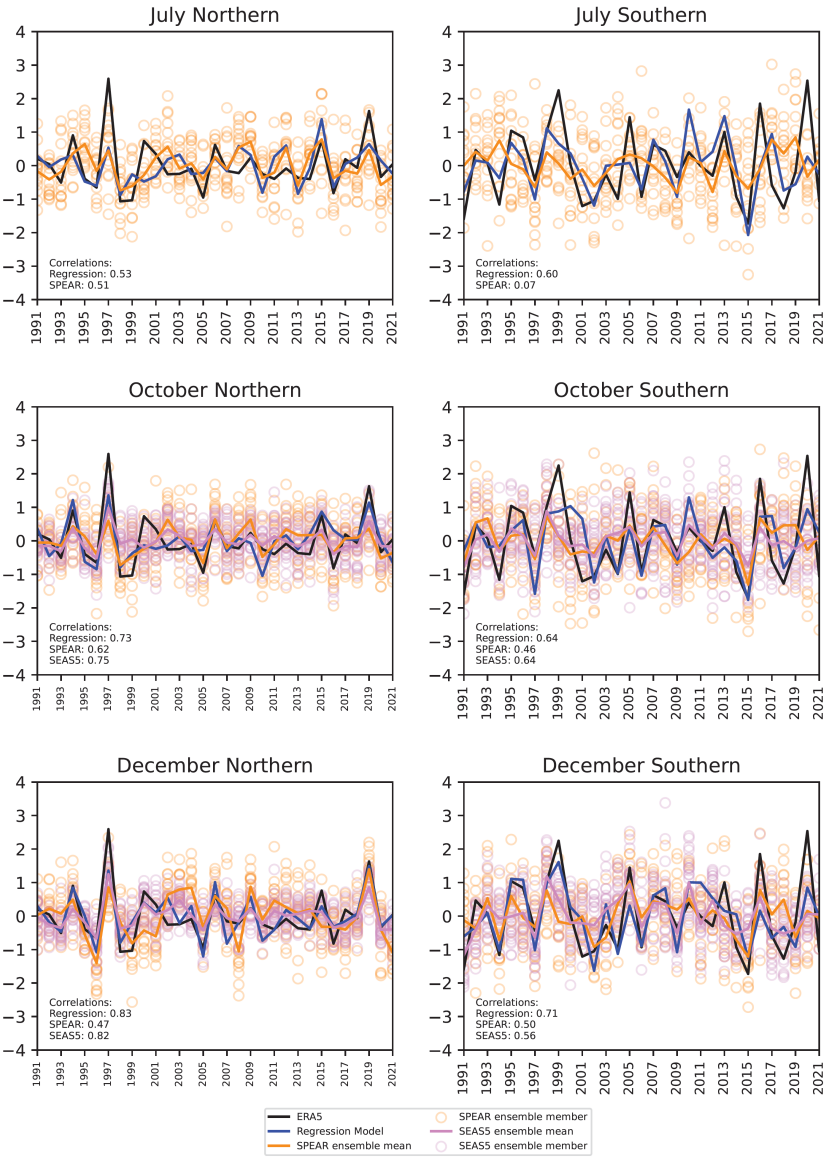

Figure S11. The predicted mean area-averaged precipitation over northern (left) and southern (right) parts of Southern Africa in ERA5 (black), regression model (green), SPEAR (orange) ensemble mean, and SEAS5 (violet) ensemble mean. For calculating the predicted time series, we remove each year from the time series at each grid point, calculate the regression equation, and subsequently use that equation to predict the removed year. The process is repeated for each year until we have a time series that is completely predicted based on the regression model. The text in each panel describes the correlations with ERA5.