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ABSTRACT

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Significance statement. This is significant becasue I wrote it.

1. Introduction

yada yada SAM yada yada circulation.. yada yada so important. yada yada many impacts.

2. Methods

1) Data

We used monthly geopotential height at 2.5 longitude by 2.5 latitude resolution from ERA5 (Hersbach et al.) for the period 1979 to 2018 (inclusive).

Monthly temperature NOAA Global Surface Temperature (NOAAGlobalTemp) 5.0 degree latitude x 5.0 degree longitude global grid (Vose et al. 2012; Smith et al. 2008). The same analysis was carried out using CRUTEM4 (Osborn and Jones 2014) (not shown).

We used monthly precipitation data from CPC Merged Analysis of Precipitation (Xie and Arkin 1997) 2.5 degree latitude x 2.5 degree longitude.

2) Definition of indices

We defined the Southern Annular Mode (SAM) as the leading EOF of the monthly anomalies of geopotential field at 700 hPa south of 20°S (citation?). The EOF was performed by computing the Singular Value Decomposition of the data matrix consisting in 481 rows and 4176 columns (144 points of longitude and 29 points of latitude). The values where weighted by the square root of the cosine of latitude to account for the non-equal area of each gridpoint (Chung and Nigam 1999). This same method was used at the rest of the levels considered in this paper.

To separate between the zonally symmetric and asymmetric components of the SAM, we computed the zonal mean and anomalies of the full SAM spatial pattern. The results are shown in

Figure 5 for 700hPa. The full spatial signal ($\mathrm{EOF}_1(\lambda,\phi)$) is the sum of the zonally asymmetric ($\mathrm{EOF}_1^*(\lambda,\phi)$) and symmetric ($[\mathrm{EOF}_1](\lambda,\phi)$) components. We then compute the "Full", "Asymmetric" and "Symmetric" indices, by regressing each geopotential field on these patterns (weighting by the cosine of latitude).

The three indices are normalised by dividing them by the standard deviation of the "Full" index at each level. This means that comparing the magnitude between indices is meaningful, but it also means that not every index will have unit standard deviation.

3) Significance

We adjusted p-values for False Detection Rate following Wilks (2016).

3. Results

Figure~6 shows the resulting Asymmetric and Symmetric time series corresponding to 700 and 30hPa. blablababla

- stratosphere clearly nor normally distributed. a lot of values near 0 and some relatively high outliers. Especially true int he case of the asymmetric index. High frequency variablity.
- In both levels, there's correlation between the series (expected),

Correlations between the Asymmetric and Symmetric series are rather constant throught the troposphere, fluctiating between 0.39 and 0.45 (Figure~7). Futhermore, the cross-correlation of each series across levels –shown in Figure~8– are high in the trosposphere (greater than 0.9) for both indices. This suggests that both the Asymmetric and the Symemtric component of the tropospheric SAM are highly vertically coherent, both in their individual evolution and their temporal relationship. This is to be expected since the SAM is mostly equivalent barotropic (citaaaa).

In the stratosphere the situation is different. As can be seen in Figure~7, the relationship between the Asymmetric and Symmetric indices varies with height above 100 hPa. It starts to decreese right over the tropopause, reaches a minium of 0.21 at 20 hPa and then it increases again monotonically with height up to the uppermost level of the reanalysis. The cross-correlation across levels in the stratosphere is generally weaker than in the troposphere (Figure~8). Furthermore, above 100 hPa, the cross-correlation decreases more rapdily with height for the Symmetric SAM than for the Asymmetric SAM as evidenced by the wider dark red areas near the diagonal in Figure~8b) vs. Figure~8c). Moreover, the stratospheric Symmetric SAM seems to be slightly more connected to the trosposphere than the Asymmetric SAM; this can be seen by the lower correlation values in the top right quadrant of Figure~8b) in comparison with Figure~8c).

Figure~8a) show the cross-correlation across levels for the Full SAM index. . . . ..

To undertand the spatial patterns associated with both indeces we regressed monthly geopotential anomalies into both indeces using multiple regression (Figure A6 illustrates the difference between computing two simple regressions and one multiple regression).

Figure~9 shows the spatial year-long regression for selected levels. In the troposphere the Full annular mode is clearly “contaminated” with well known zonal asymemtries (panels g and j) which are succesfully sepparated by our methodology (panels h, i, k and l). In the stratosphere, the spatial pattern associated with the Full SAM is much more clearly dominated by a zonally symmetric, monopolar structure (panels a and d) that is, however, not perfectly centered in the south pole. The monopoloe obtained by multiple regression with the Asymmetric and Symmetric SAM (panels c and f in Figure~9) is much more symmetric and the shift from total symmetry is captured by the regression pattern of the Asymmetric SAM as a wave-1 pattern (panels b and e).

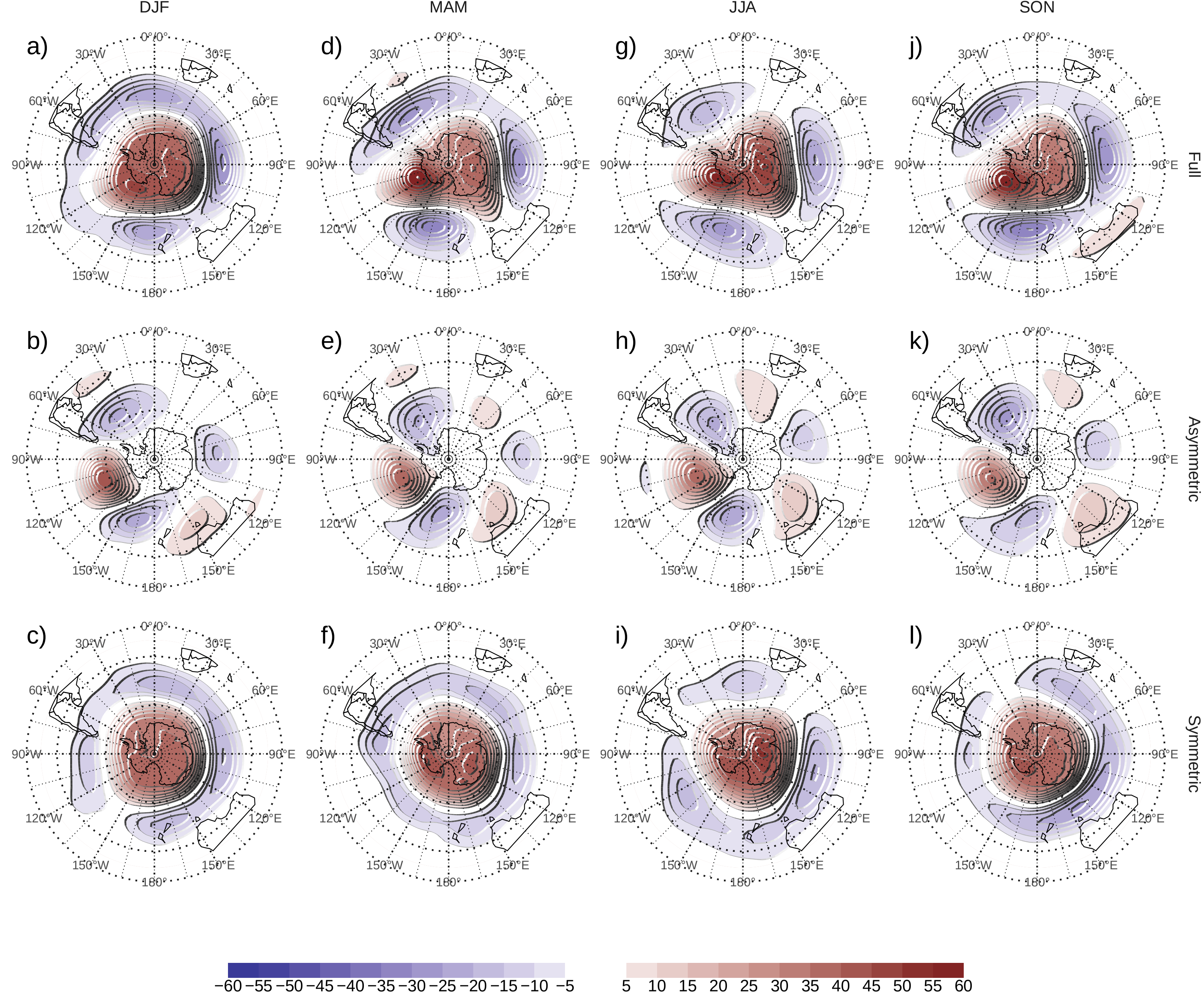

FIG. 1. Seasonal regression patterns of geopotential height at 700 hPa with the Full, Asymmetric and Symmetric SAM. The regression patterns for Asymmetric and Symmetric SAM are the result of one multiple regression using both indices, not of two simple regressions involving each index by itsef.

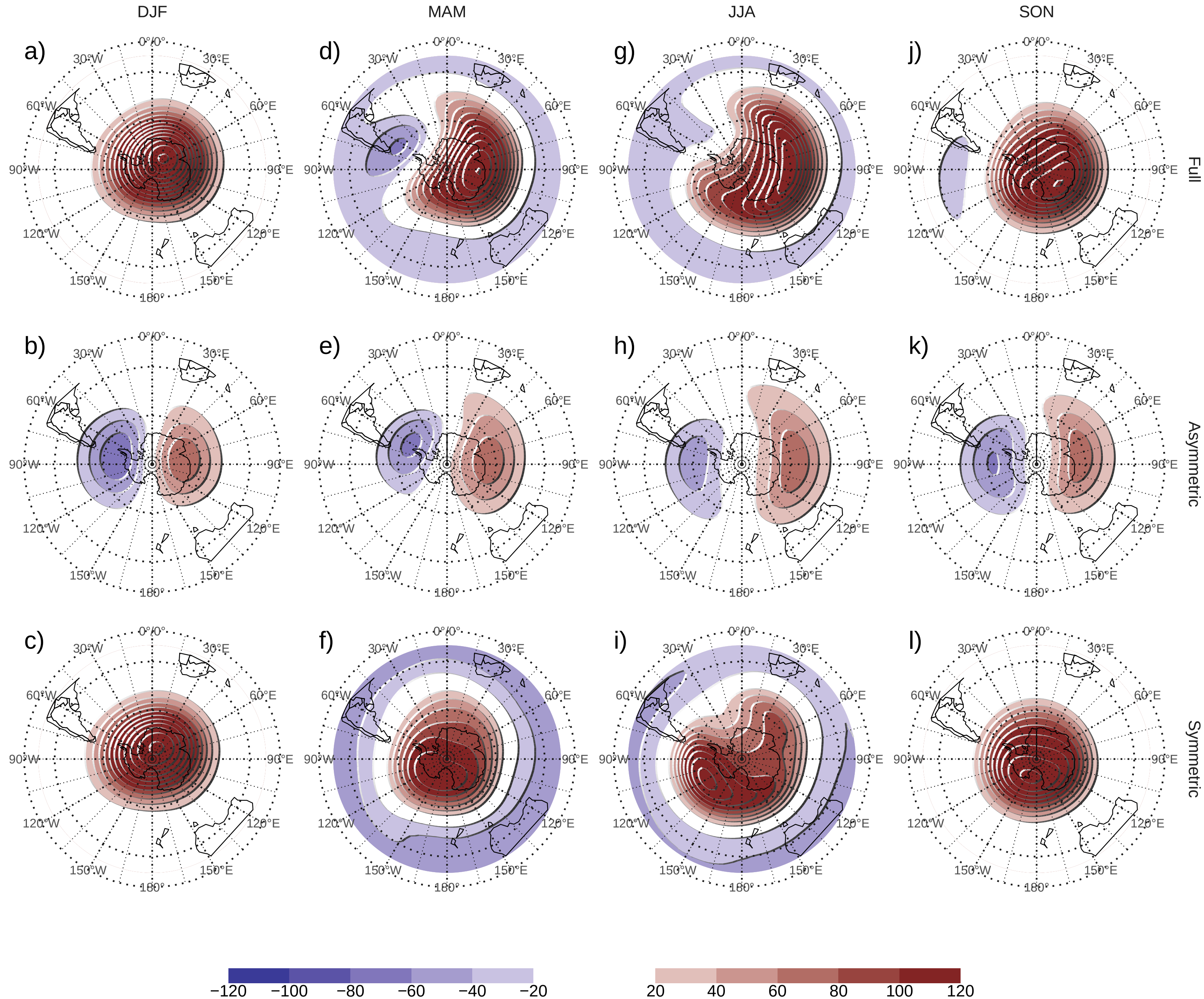

FIG. 2. Seasonal regression patterns of geopotential height at 30 hPa with the Full, Asymmetric and Symmetric SAM. The regression patterns for Asymmetric and Symmetric SAM are the result of one multiple regression using both indices, not of two simple regressions involving each index by itself.

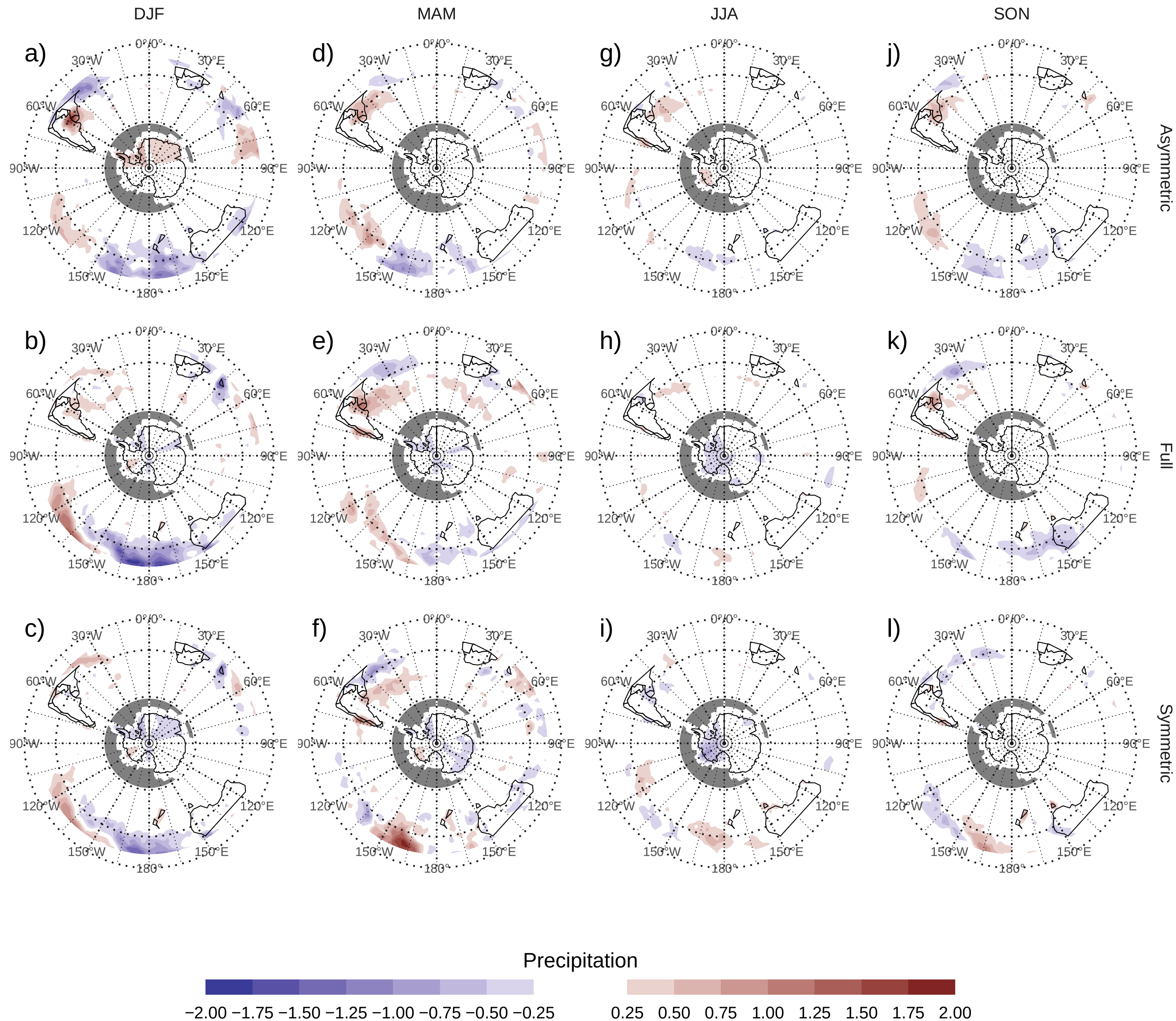

FIG. 3. Regression pattern of precipiation with Asymmetric and Symmetric SAM. P-values smaller than 0.05 (controlling for Flase Detection Rate) as hatched areas.

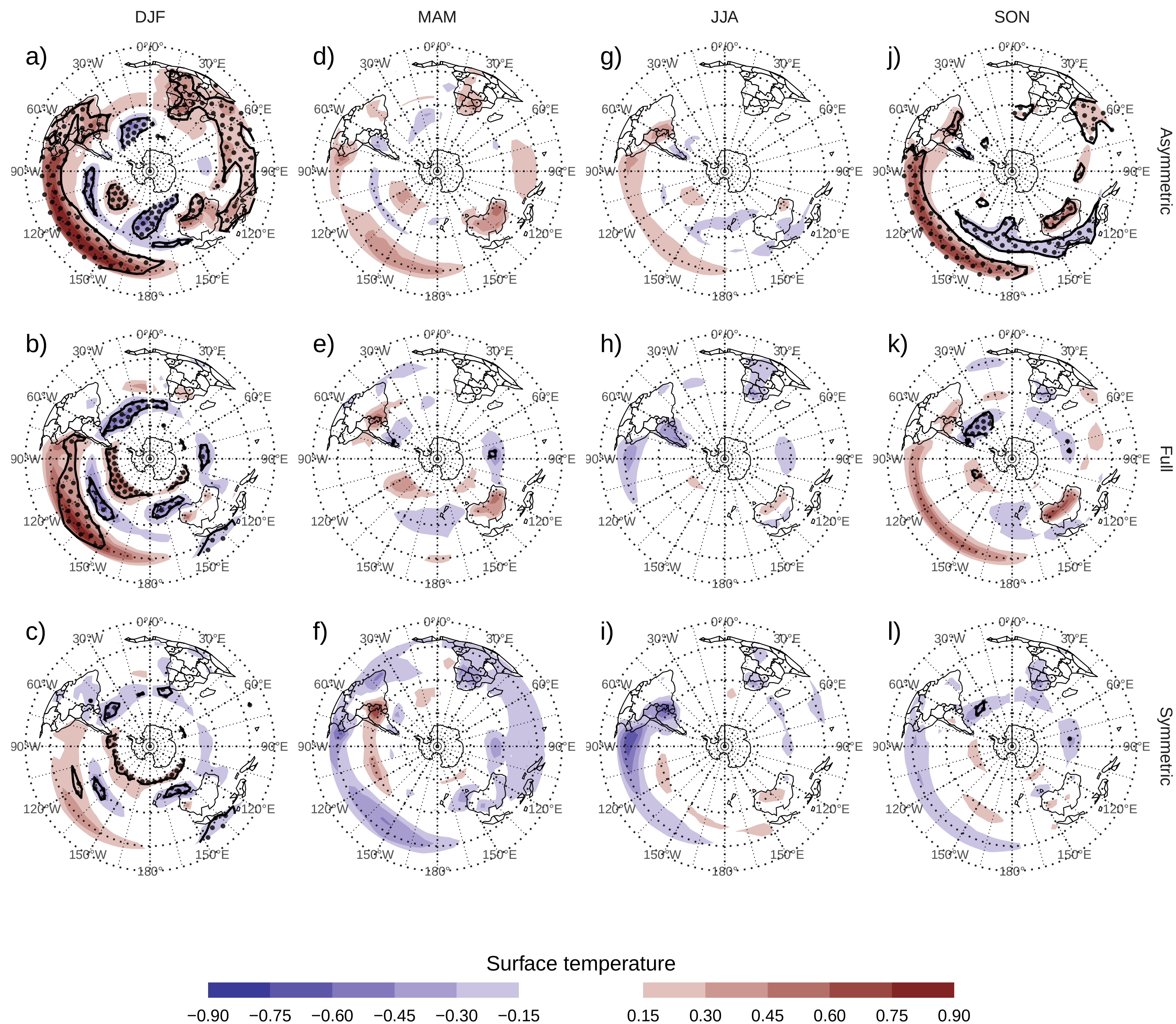

FIG. 4. Regression pattern of surface temperature with Asymmetric and Symmetric SAM. P-values smaller than 0.05 (controlling for Flase Detection Rate) as hatched areas.

Acknowledgments. CMAP Precipitation data provided by the NOAA/OAR/ESRL PSL, Boulder, Colorado, USA, from their Web site at https://psl.noaa.gov/

NOAA Global Surface Temperature (NOAAGlobalTemp) data provided by the NOAA/OAR/ESRL PSL, Boulder, Colorado, USA, from their Web site at https://psl.noaa.gov/

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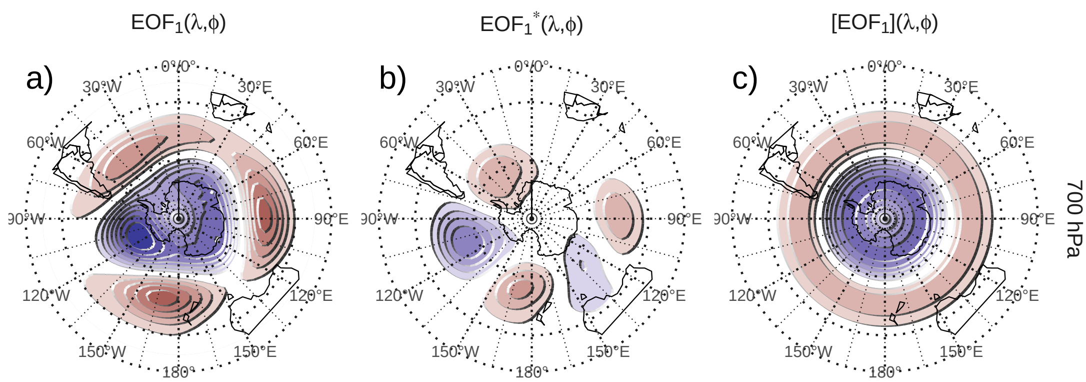
Xie, P., and P. A. Arkin, 1997: Global Precipitation: A 17-Year Monthly Analysis Based on Gauge Observations, Satellite Estimates, and Numerical Model Outputs. *Bull. Amer. Meteor. Soc.*, **78 (11)**, 2539–2558, doi:10.1175/1520-0477(1997)078<2539:GPAYMA>2.0.CO;2.

APPENDIX

Extra figures

LIST OF FIGURES



138 FIG. 5. Spatial patterns of the first EOF of 700 hPa geopotential height. Full field (left), zonally asymmetric
139 component (middle) and zonally symmetric component (right). Arbitrary units.

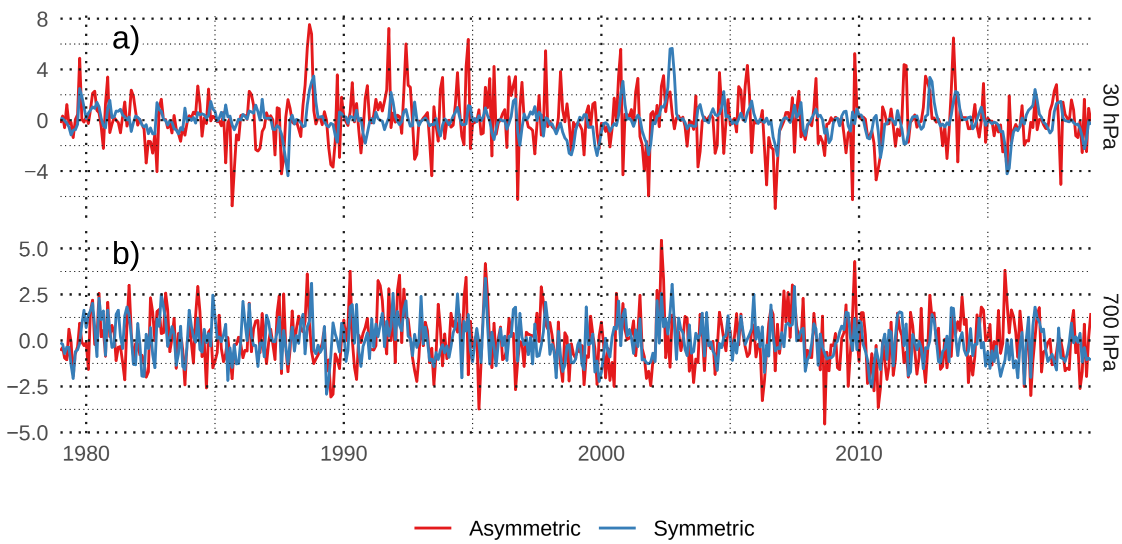


FIG. 6. Time series for the asymmetric SAM and symmetric SAM.

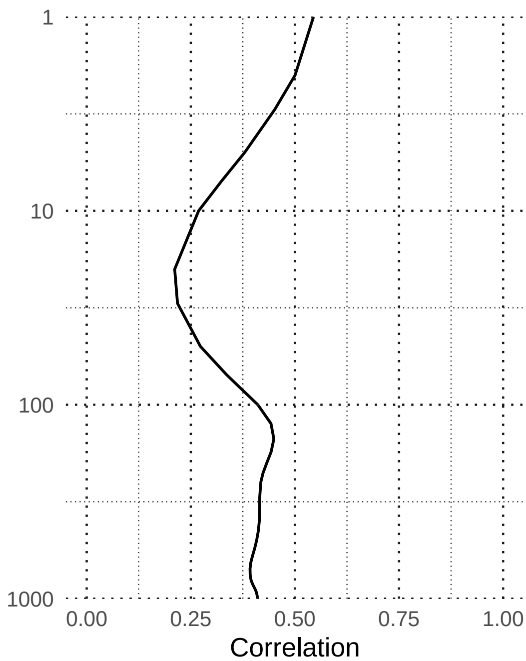


FIG. 7. Correlation between the Symmetric and Asymmetric SAM at each level.

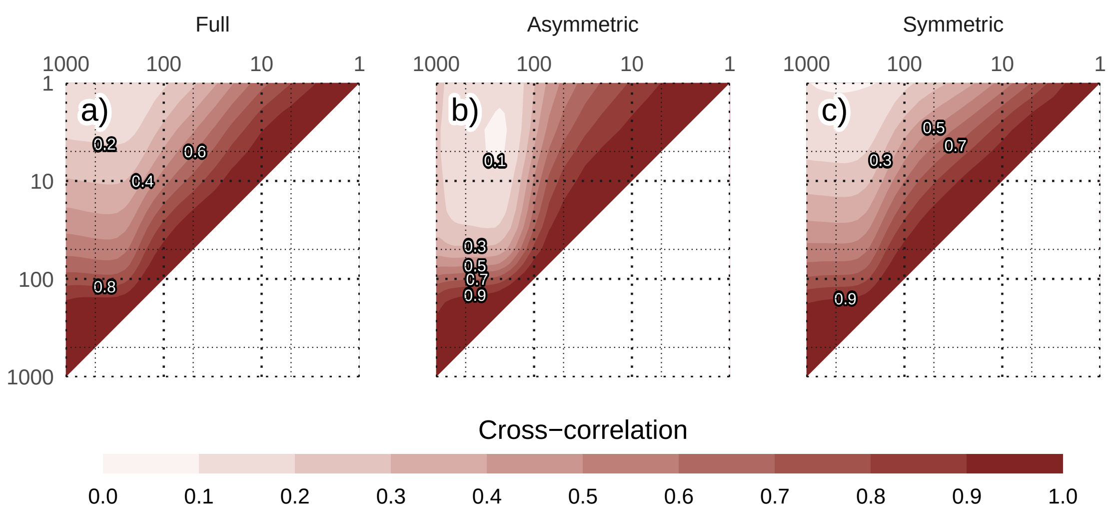
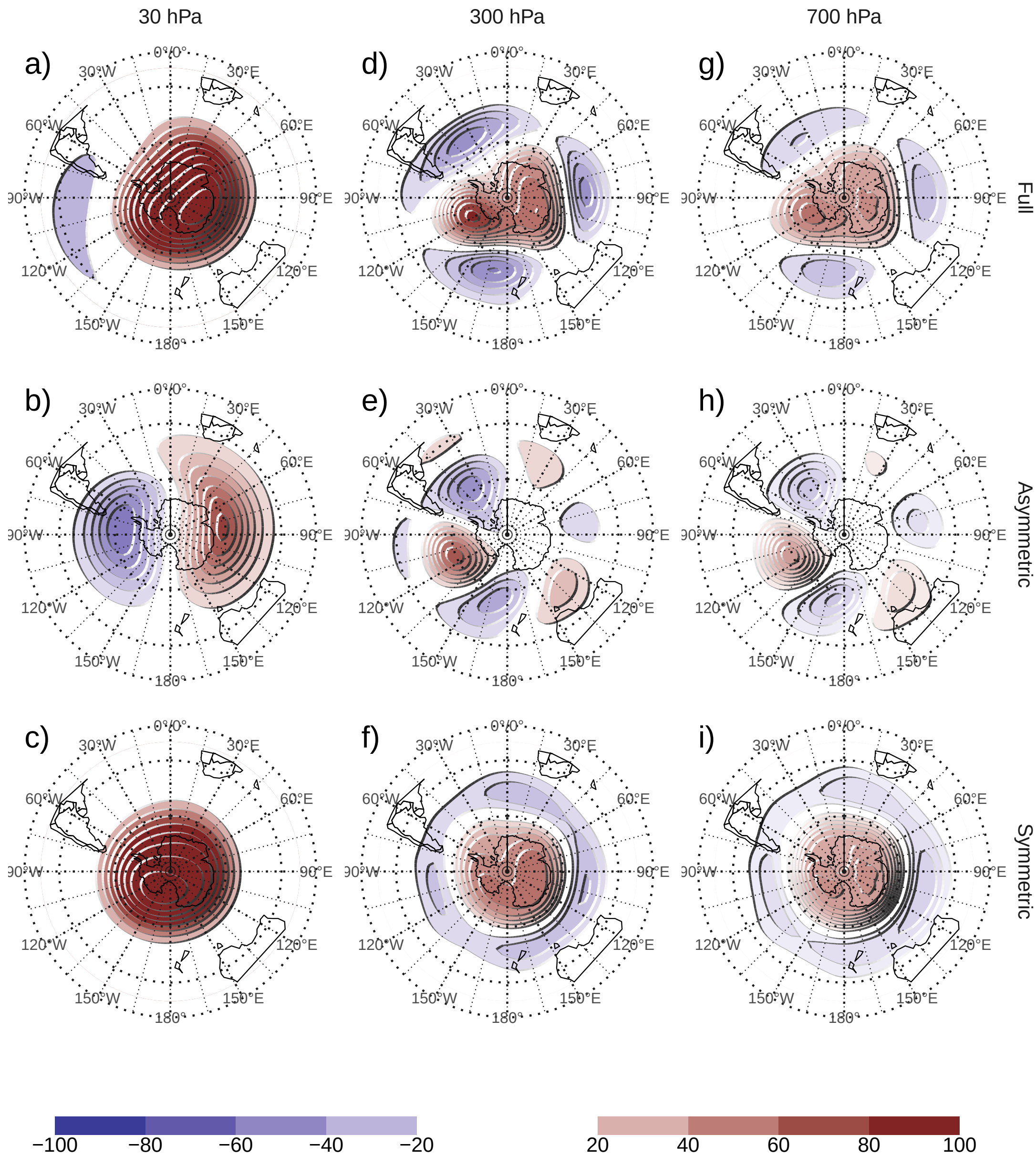
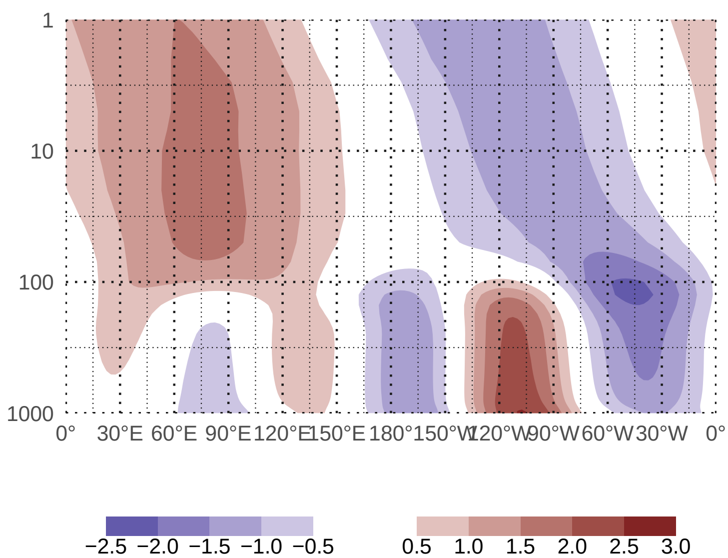


FIG. 8. Cross correlation between levels of the Full, Asymmetric and Symmetric SAM.



140 FIG. 9. Regression patterns of geopotential height at 30, 300 and 700 hPa with the Full, Asymmetric and Symmetric SAM. The regression patterns for Asymmetric and Symmetric SAM are the result of one multiple regression using both indices, not of two simple regressions involving each index by itsef.



143 FIG. 10. Asymmetric coefficient of the multiple regression of mean monthly geopotential height anomalies between 65 and 40 South. Values are standarised by the standard deviation at each level. (this caption needs some love)

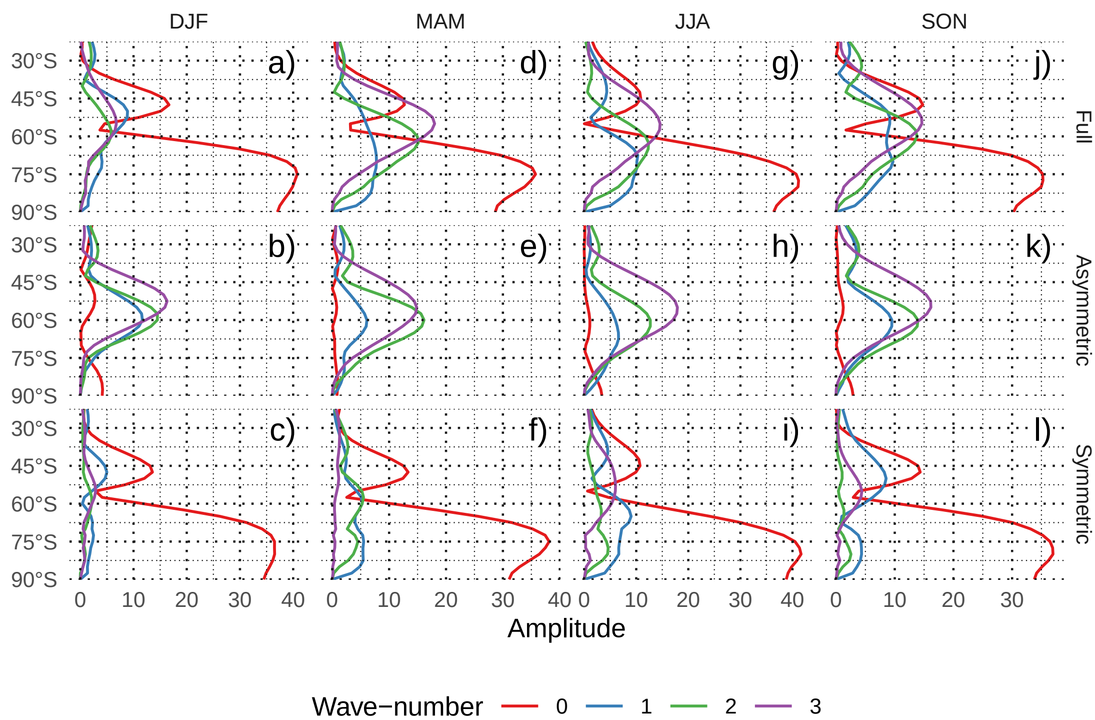


FIG. 11. Planteray wave amplitude for the regression patterns at 700 hPa.

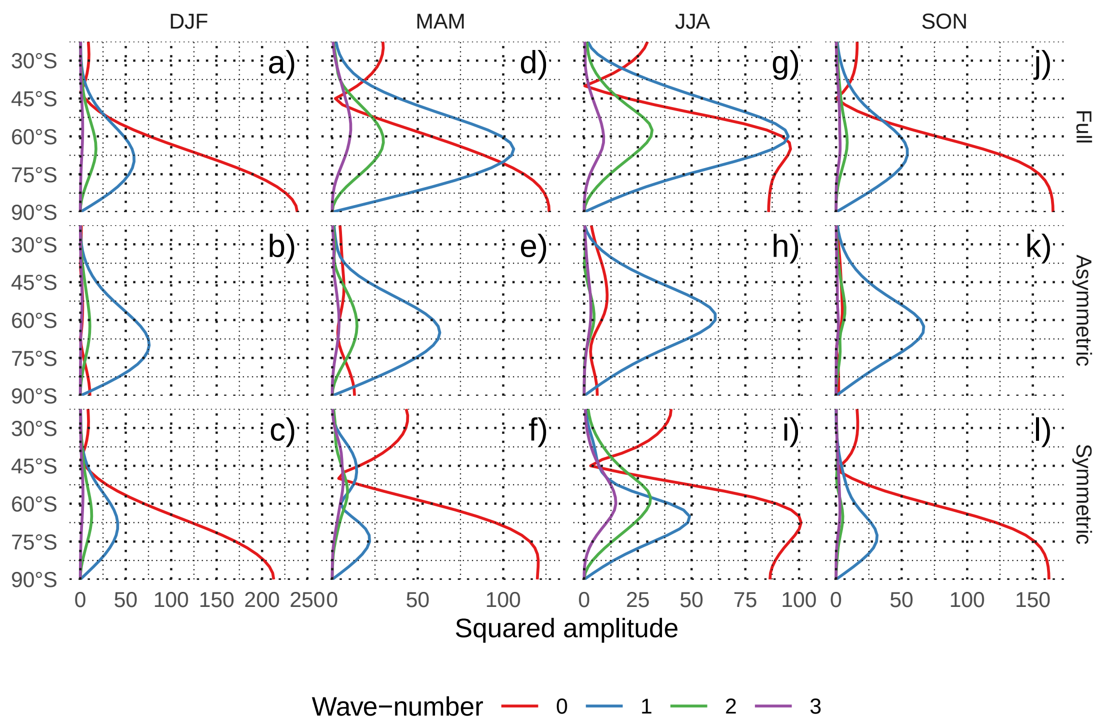


FIG. 12. Planteray wave amplitude for the regression patterns at 30 hPa.

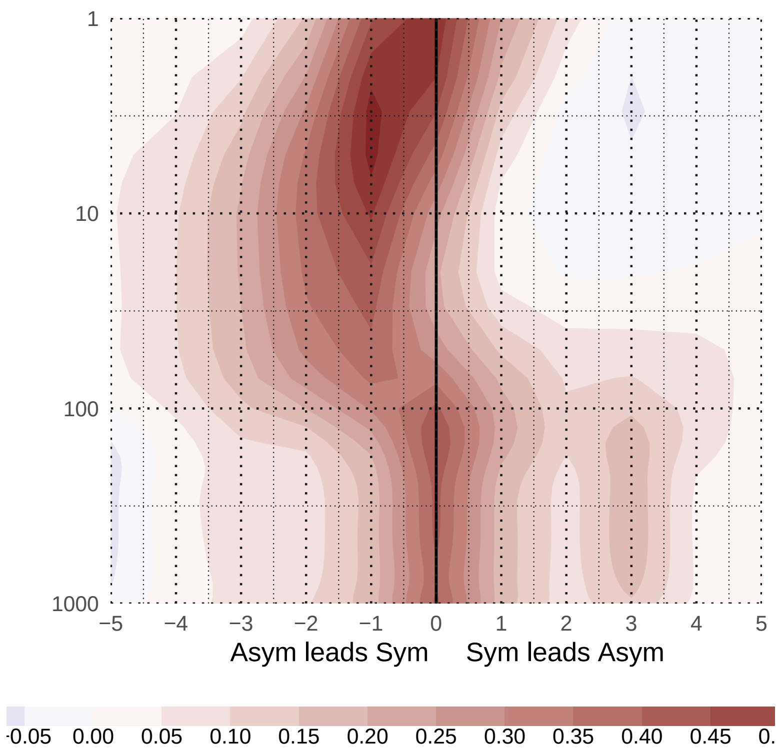


Fig. A1. Lag-correlation between Symmetric and Asymmetric SAM at each level.

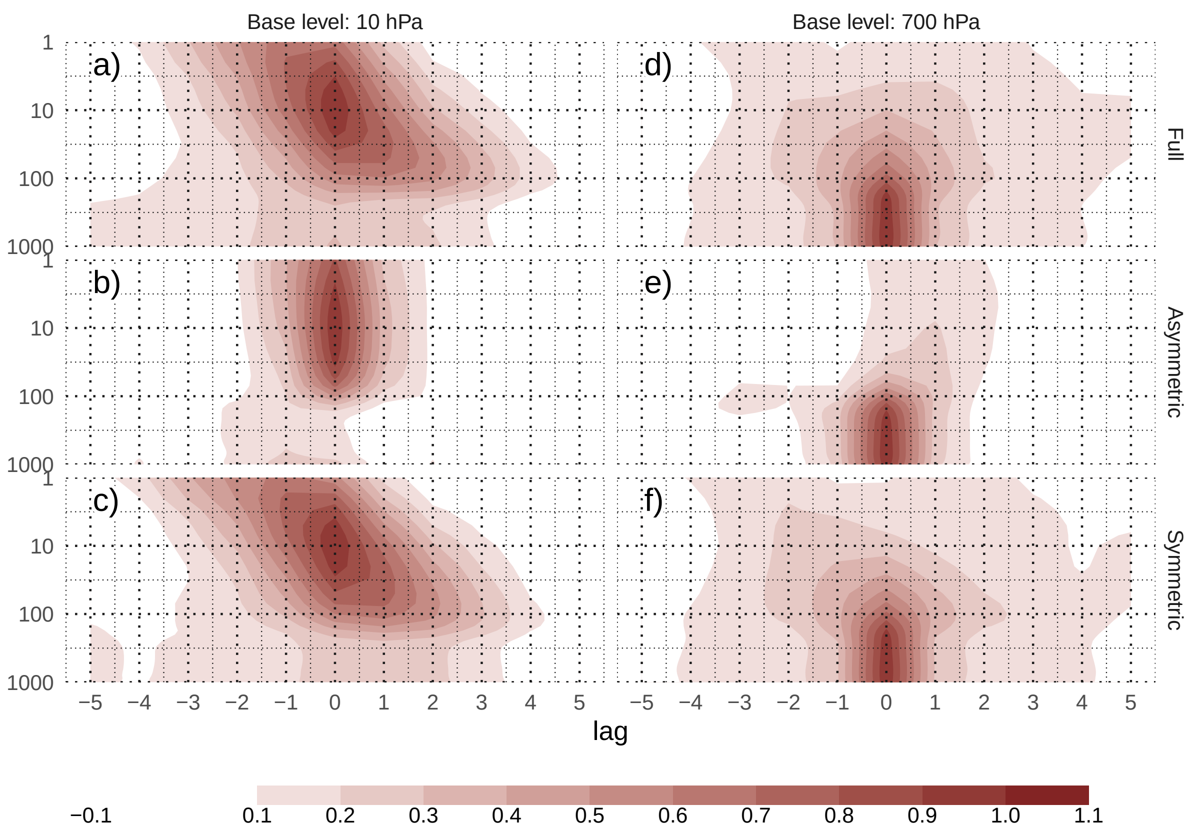
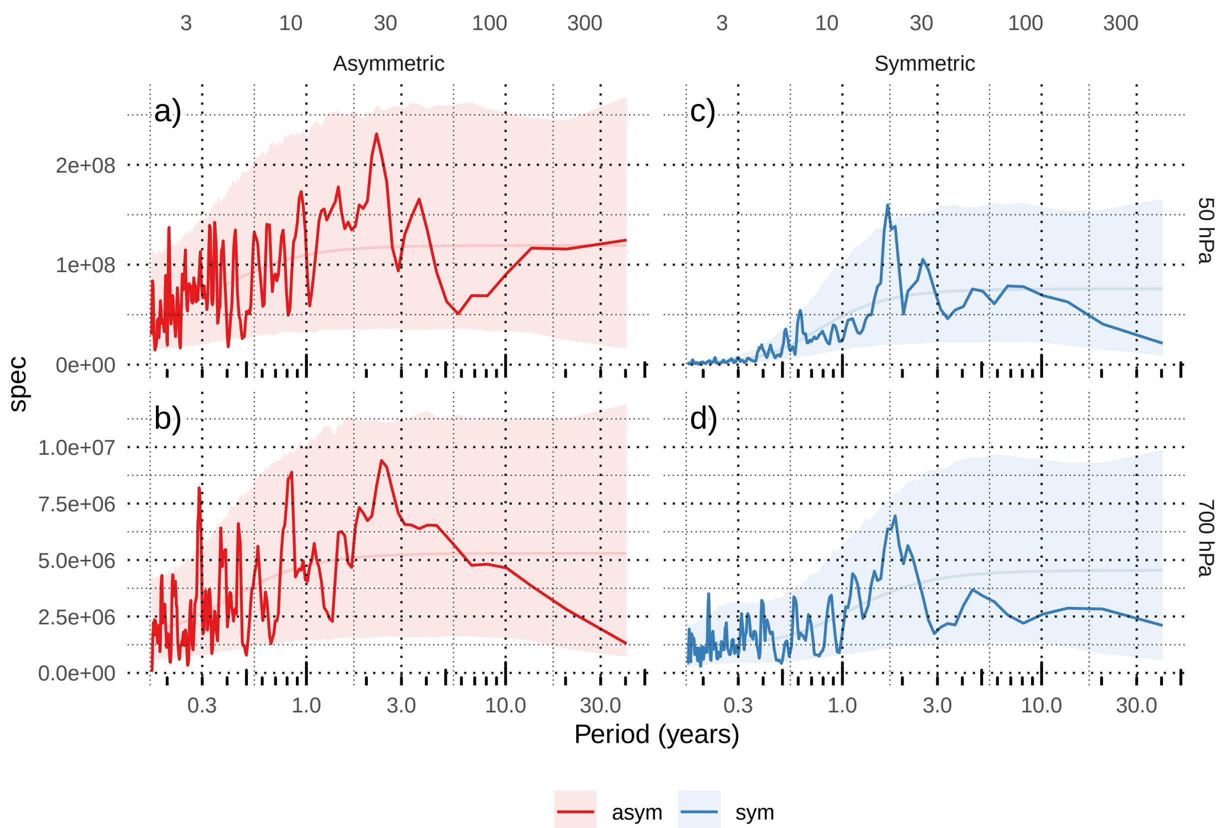


FIG. 13. Cross-correlation functions for each index and two differnet base levels.



146 Fig. A2. Fourier spectrum of each timeseries. The shading indicates de 95% area derived by fitting an AR
147 process to each series and bootstrapping 5000 simulated samples.

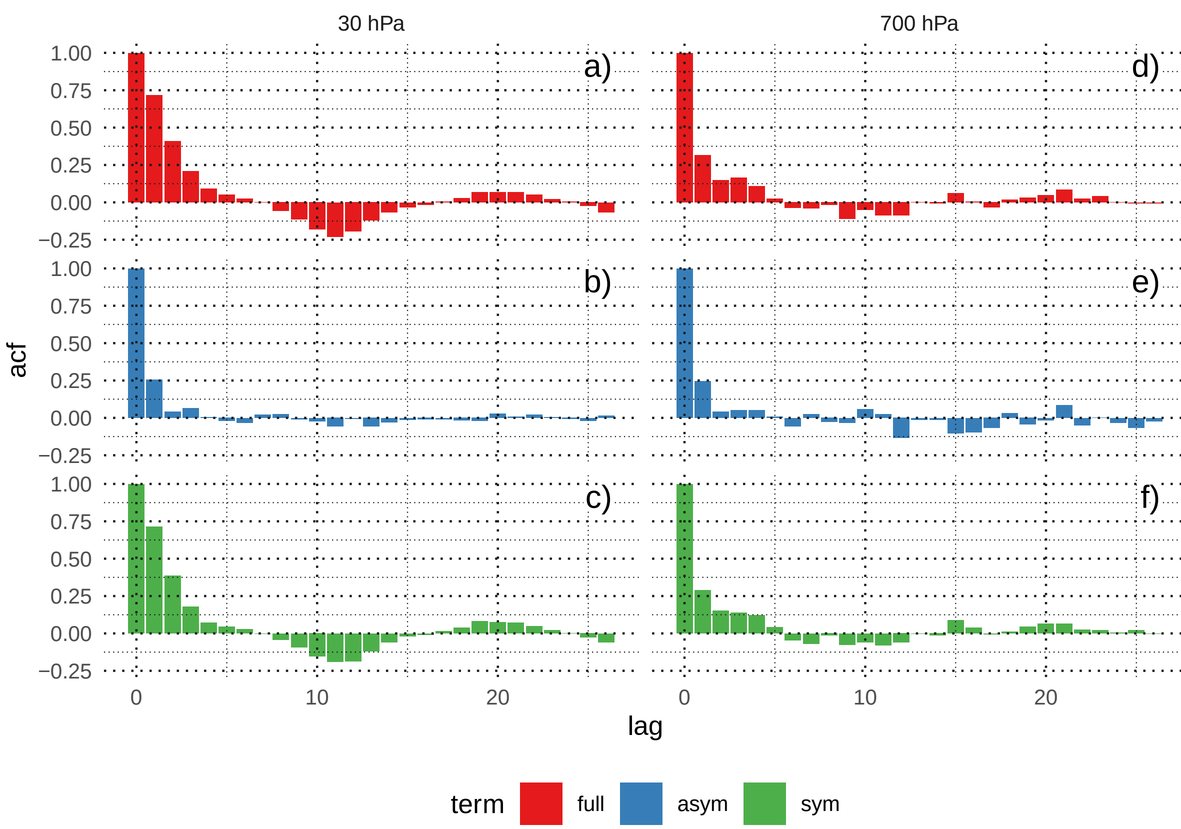


Fig. A3. Autocorrelation functions of each timeseries

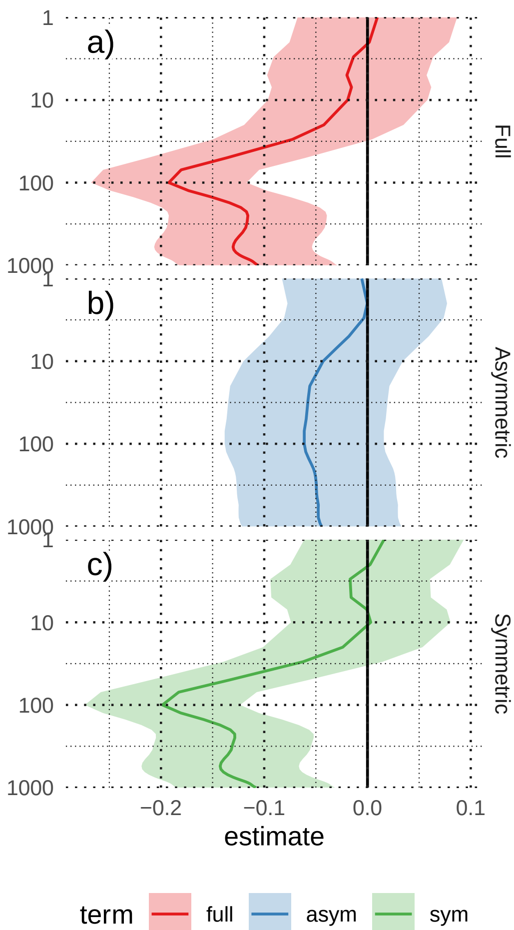


Fig. A4. Trends for each index at each level. Shading indicates the 95% confidence interval.

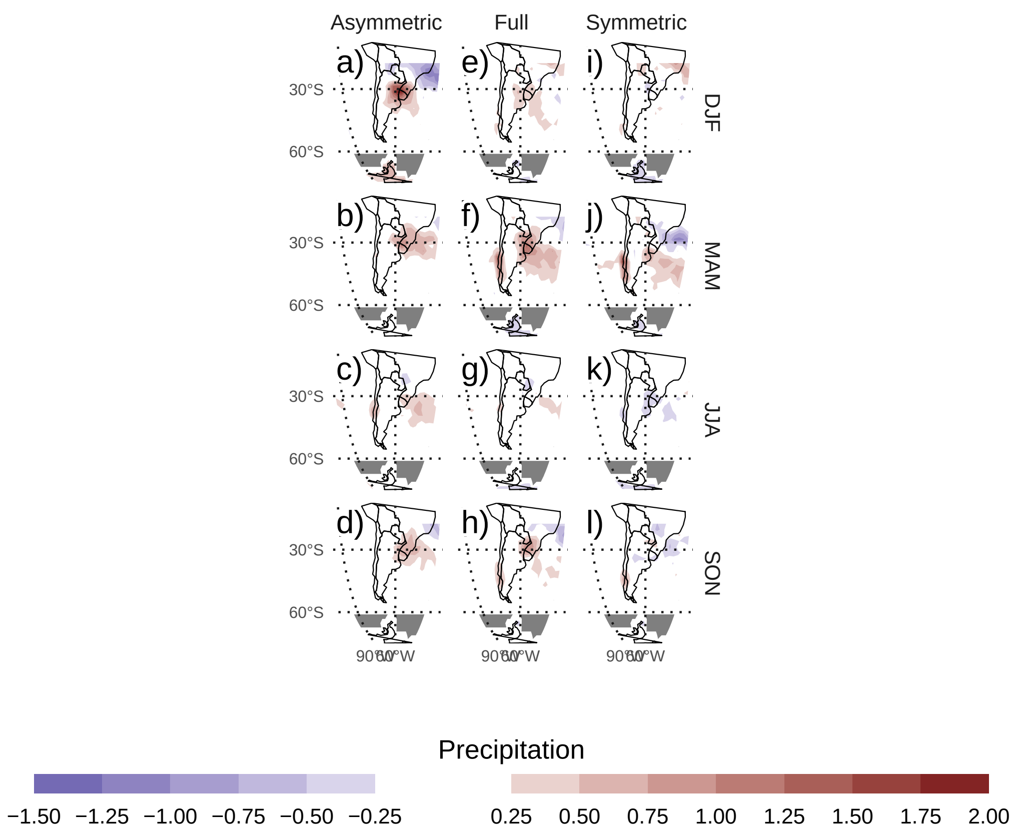


Fig. A5. Regression pattern of precipiation with Asymmetric and Symmetric SAM. P-values smaller than 0.05 (controlling for Flase Detection Rate) as hatched areas.

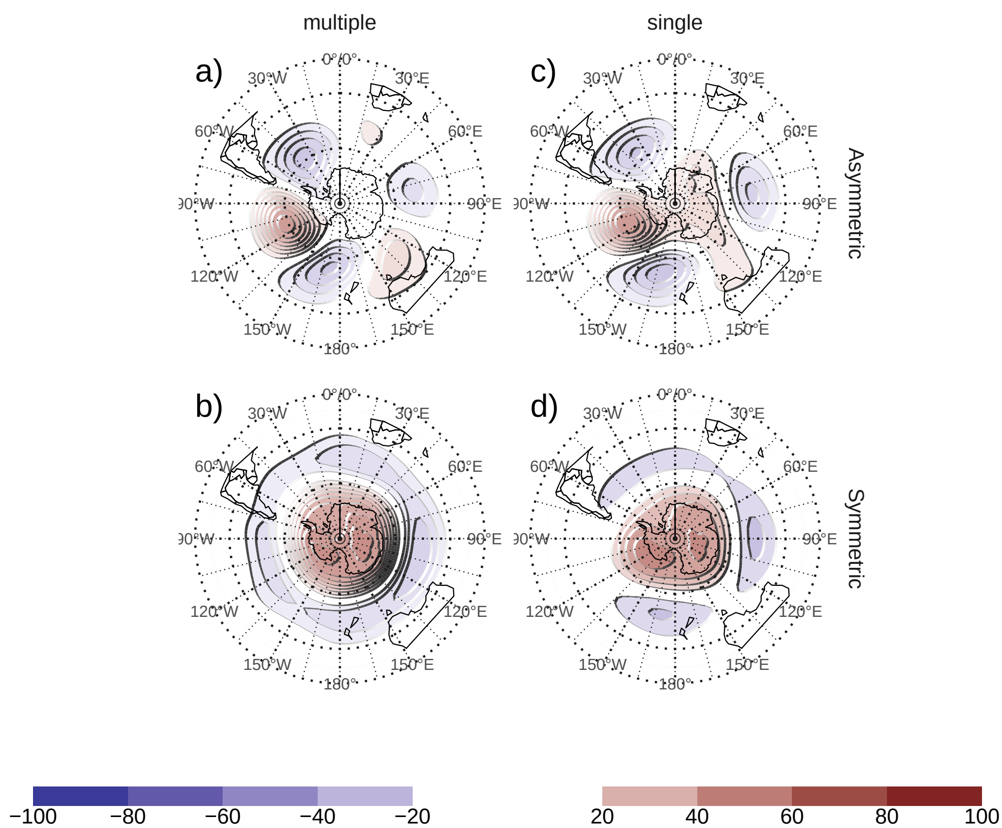


Fig. A6. Regressions maps resulting from performing one multiple regression (a. and b.) and from performing two simple regressions (c. and d.)