Comparing the spatial structure of variability in two datasets against each other on the basis of EOF-modes

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Abstract

In analysis of climate variability or change it is often of interest how the spatial structure in modes of variability in two datasets differ from each other, e.g. between past and future climate or between models and observations. Often such analysis is based on Empirical Orthogonal Function (EOF) analysis or other simple indices of large-scale spatial structures.

Here we illustrate how the Distinct EOF (DEOF) method reveals changes in the modes of variability, like intensification of one pattern, a shift of a pattern and a change in the multivariate structure, each on the basis of a well-defined artificial example of isotropic diffusion and an example of climate change. These climate change studies are about the North Pacific SST, the North Atlantic SLP and the tropical Indo-Pacific precipitation.

How to compare the spatial structure of variability in two datasets against each other on the basis of EOF-modes?

1. Define anomalies for both datasets.
2. Do EOF-analysis for both datasets (e.g. Fig. 2a-d or Fig. 3a-b).
3. Define the EOF-modes of one dataset as the reference modes.
4. Project the reference EOF-modes onto the other dataset ➔ projected explained variances (e.g. dashed line in EV-spectrum in Fig. 2e or Fig. 3c).
5. Compute the DEOF-modes by pairwise rotation to maximize the differences in explained variance of this mode in the two data sets (e.g. DEOF in Fig. 2f or Fig. 3e).
6. Repeat steps 3 to 5 with the other dataset as the reference modes (Fig. 3d,f).
7. Compare the results with idealized examples (Fig. 2, 5 and 7) to understand the nature of the differences.
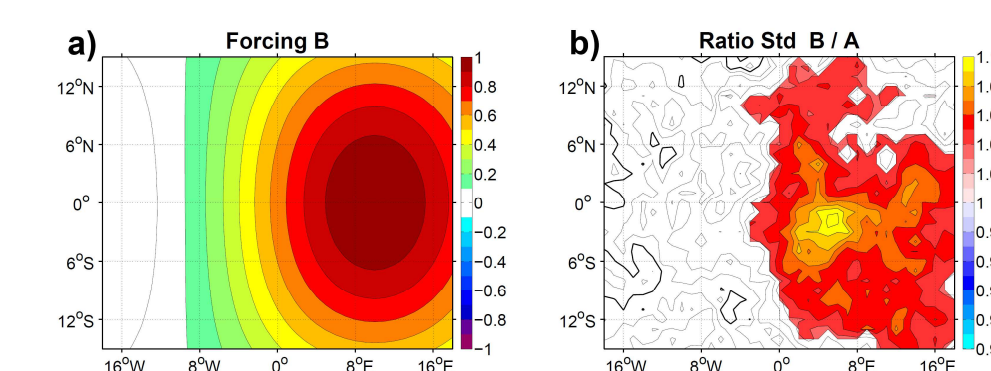
Intensification of a pattern

Figure 1: a) Forcing pattern in dataset $\mathcal{B}$ and in b) ratio of the standard deviation of the second dataset divided by the first dataset
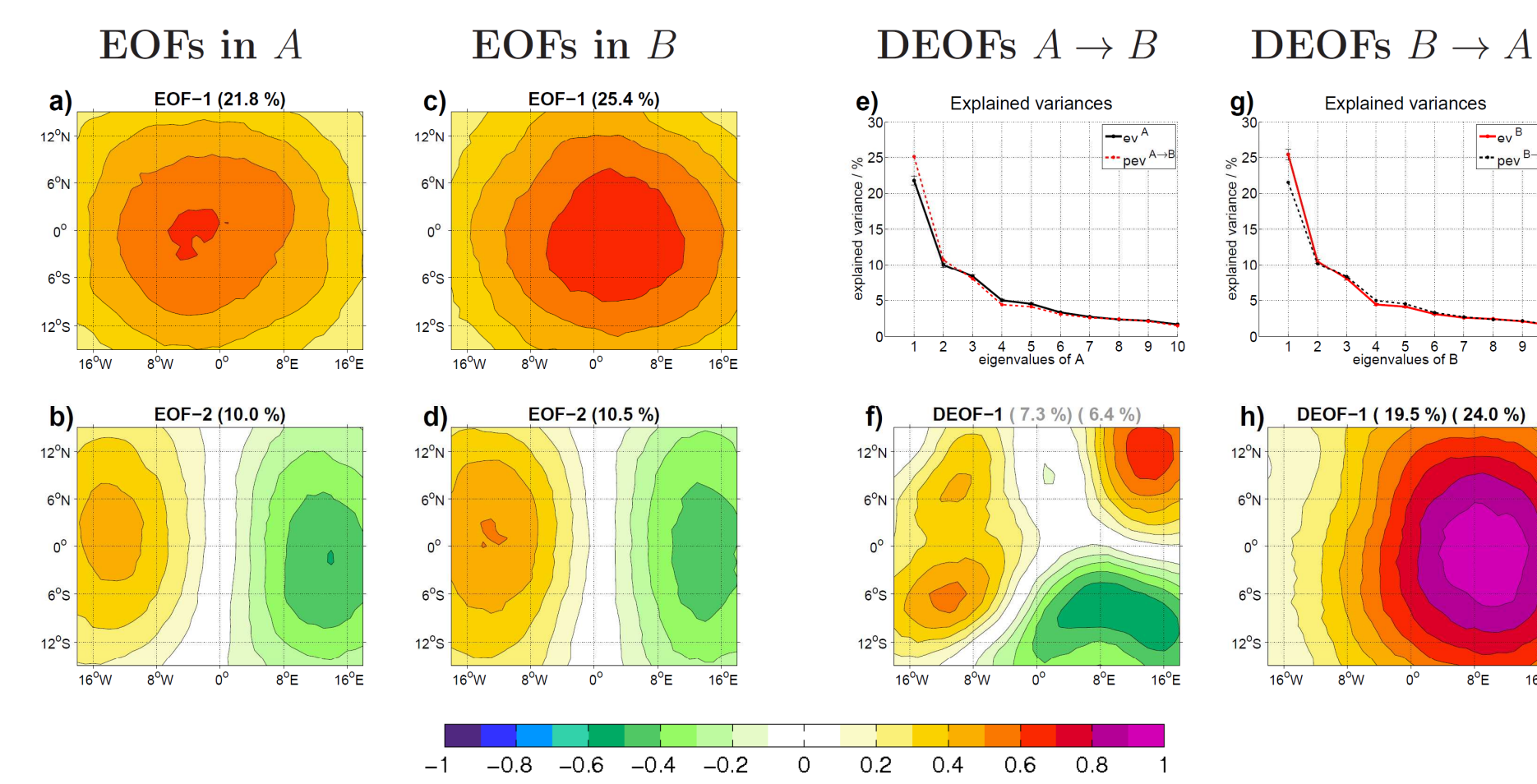

Figure 2: a-b) EOF patterns of dataset $\mathcal{A}$, c-d) EOF patterns of dataset $\mathcal{B}$, explained variance is given in brackets; e) the explained variances of the eigenvalues of dataset $\mathcal{A}$ (black) and explained variances of dataset $\mathcal{A}$ projected onto the eigenvalues of dataset $\mathcal{B}$ (red dashed); f) DEOF$^{\mathcal{A}\rightarrow\mathcal{B}}$ patterns; the explained variances $dev^{\mathcal{A}\rightarrow\mathcal{B}}(\mathcal{A})$ and $dev^{\mathcal{A}\rightarrow\mathcal{B}}(\mathcal{B})$ are given in the header in brackets; g) same as (e), but here showing the eigenvalues of dataset $\mathcal{B}$ (red) and the explained variances of dataset $\mathcal{B}$ projected onto the eigenvalues of dataset $\mathcal{A}$ (black dashed), h) same as f), but for the DEOF$^{\mathcal{B}\rightarrow\mathcal{A}}$ patterns.

EOFs in 20C / EOFs in 21C
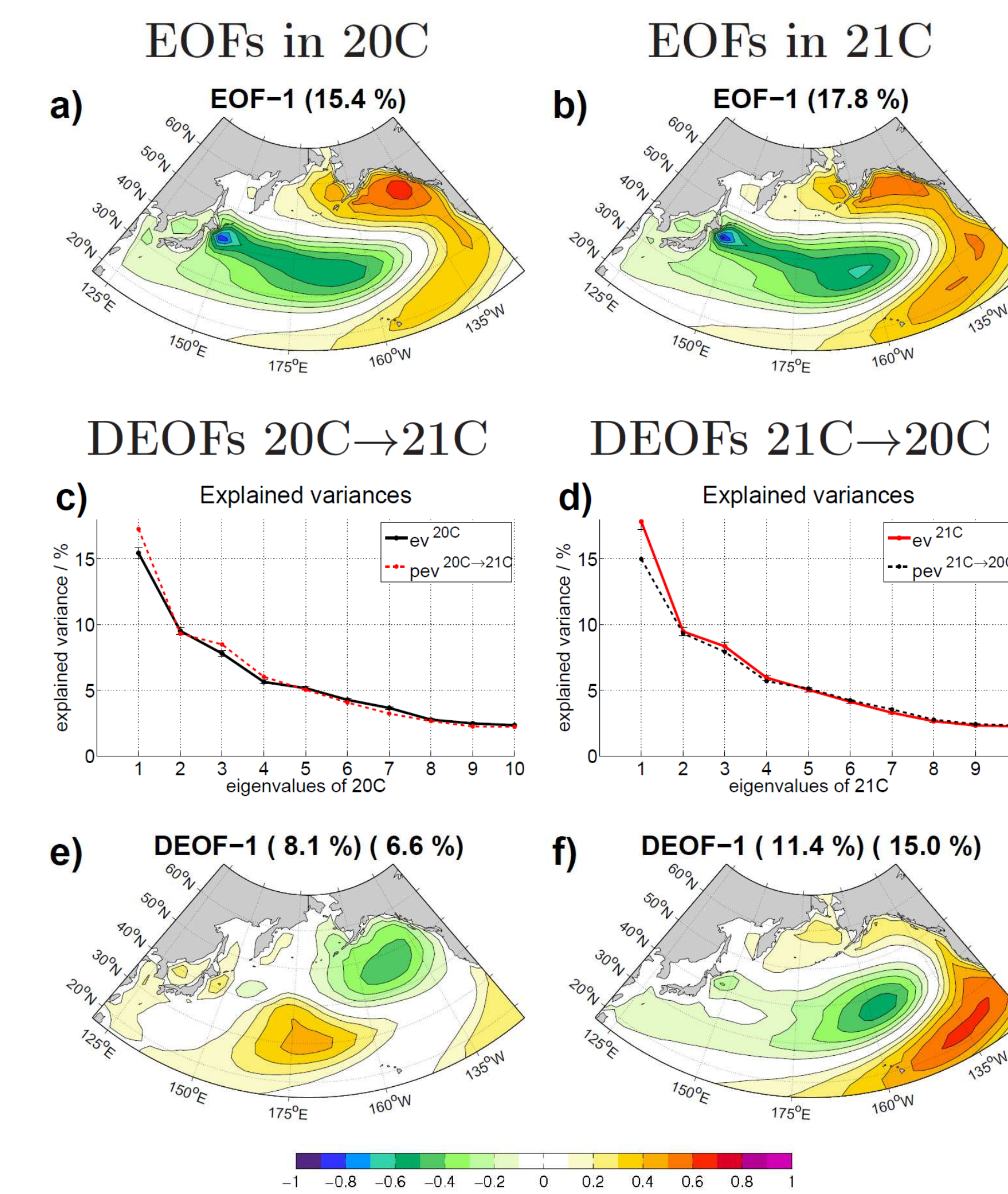

DEOFs 20C→21C / DEOFs 21C→20C

Figure 3: Same as Fig. 2, but here for North Pacific SST in the period 1950-1999 (20C) compared with the period 2050-2099 of the A1B scenario (21C) of a CMIP3 multimodel ensemble.
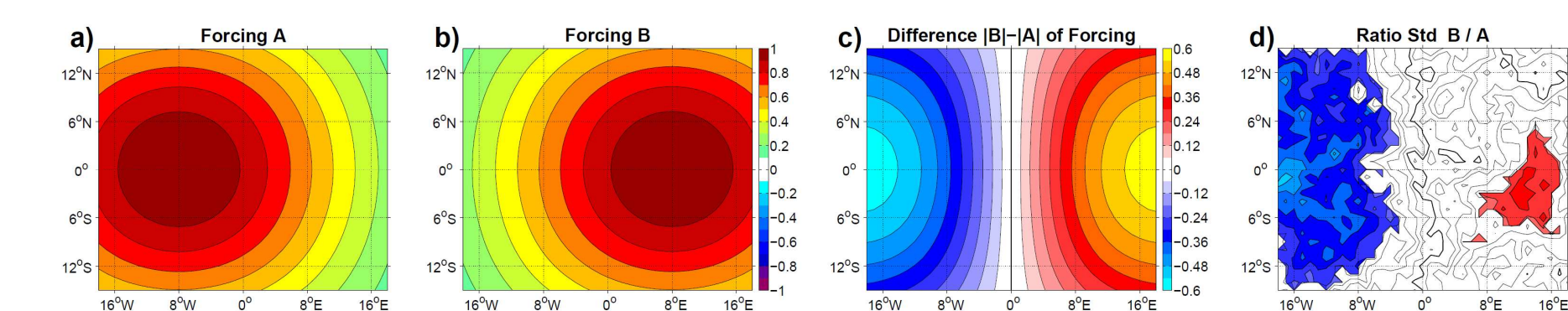
Pattern shift

Figure 4: a) Forcing pattern in dataset $\mathcal{A}$, in b) forcing pattern in dataset $\mathcal{B}$, in c) the difference between the forcings $\mathcal{B}$-$\mathcal{A}$ and in d) ratio of the standard deviation of the second dataset divided by the first dataset
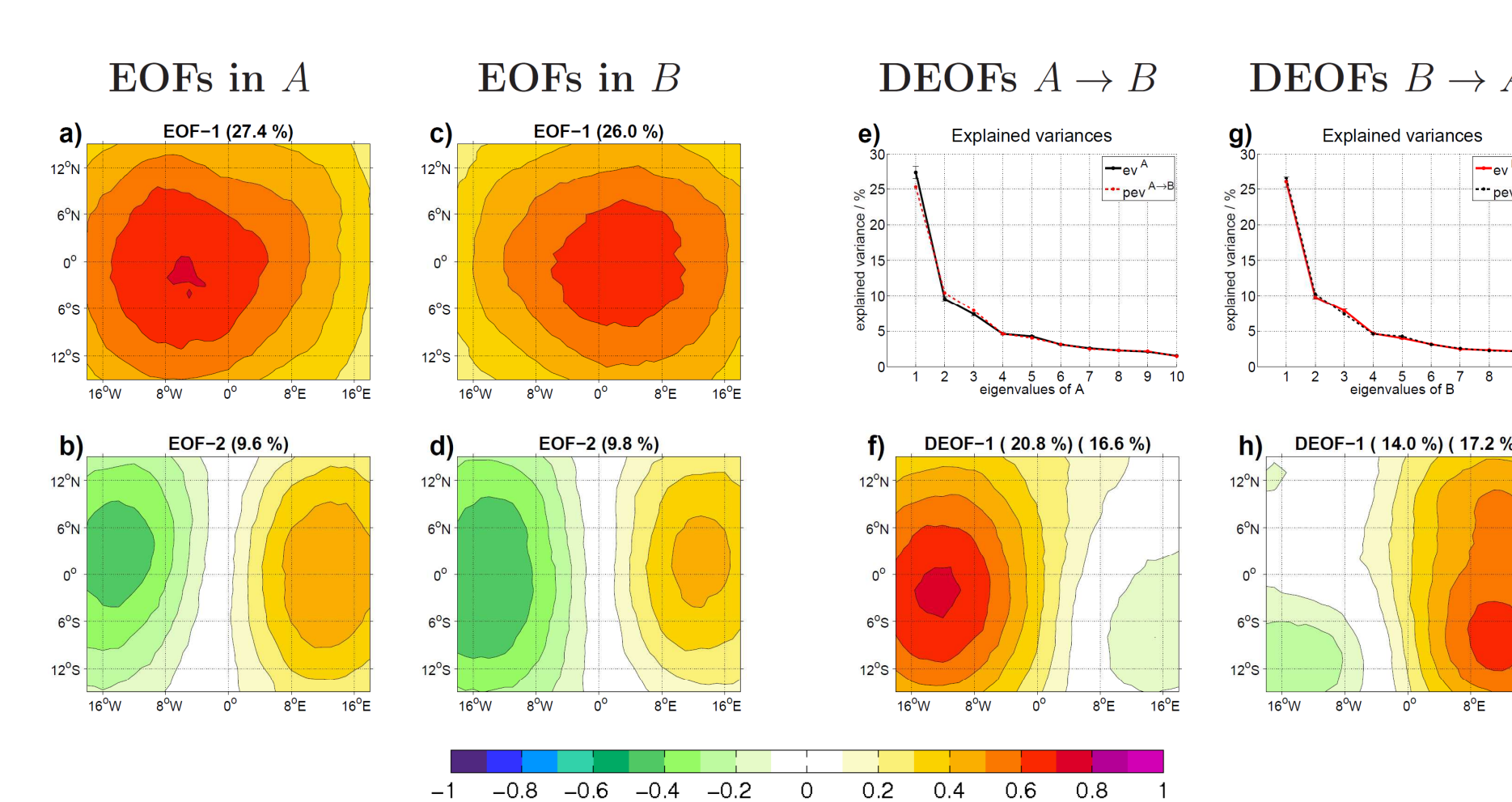

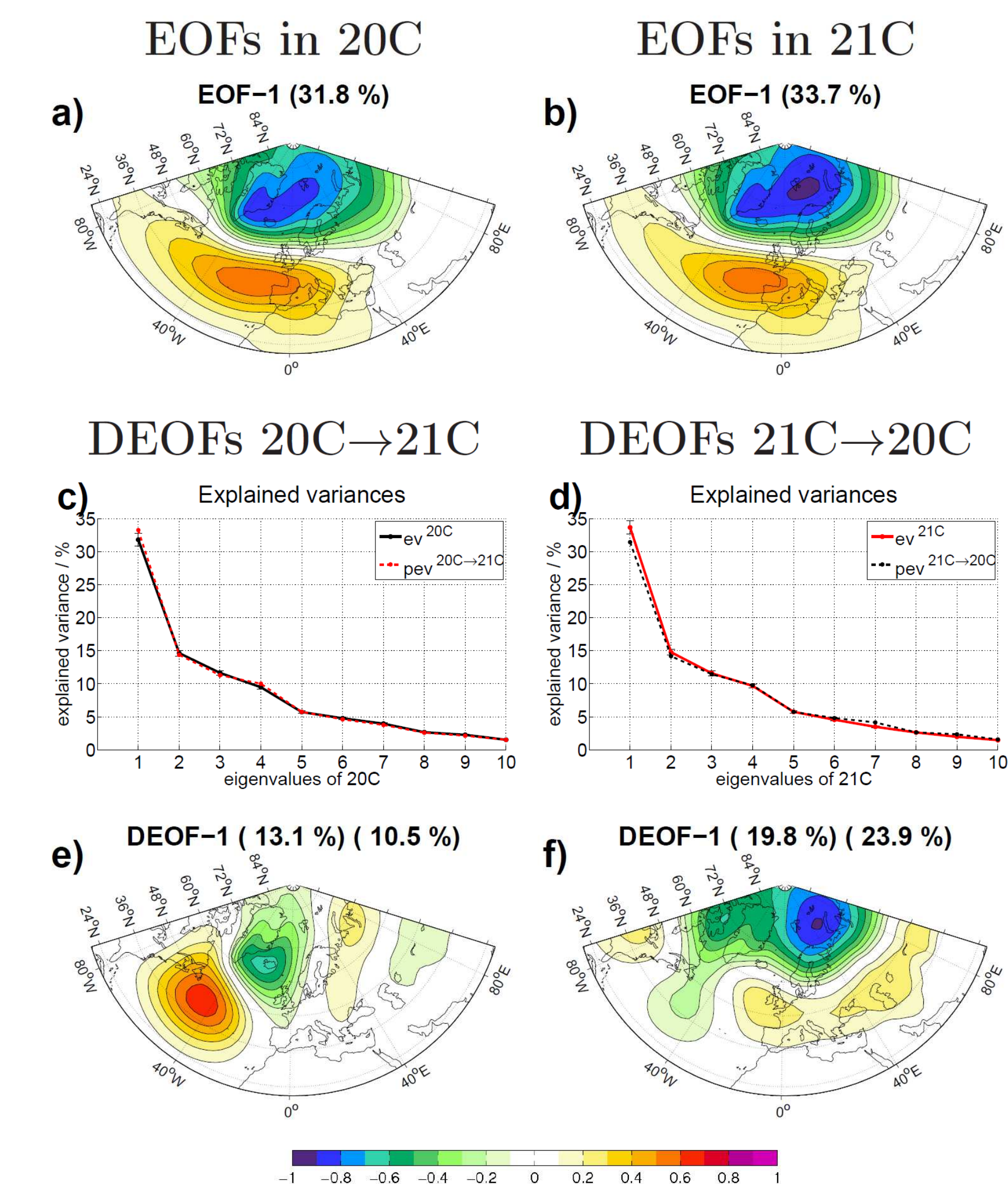**Figure 5**: Same as Fig. 2, but here for the two forcings in Fig. 4.

EOFs in 20C / EOFs in 21C

DEOFs 20C→21C / DEOFs 21C→20C

Figure 6: Same as Fig. 3, but here for winter SLP over the North Atlantic region.

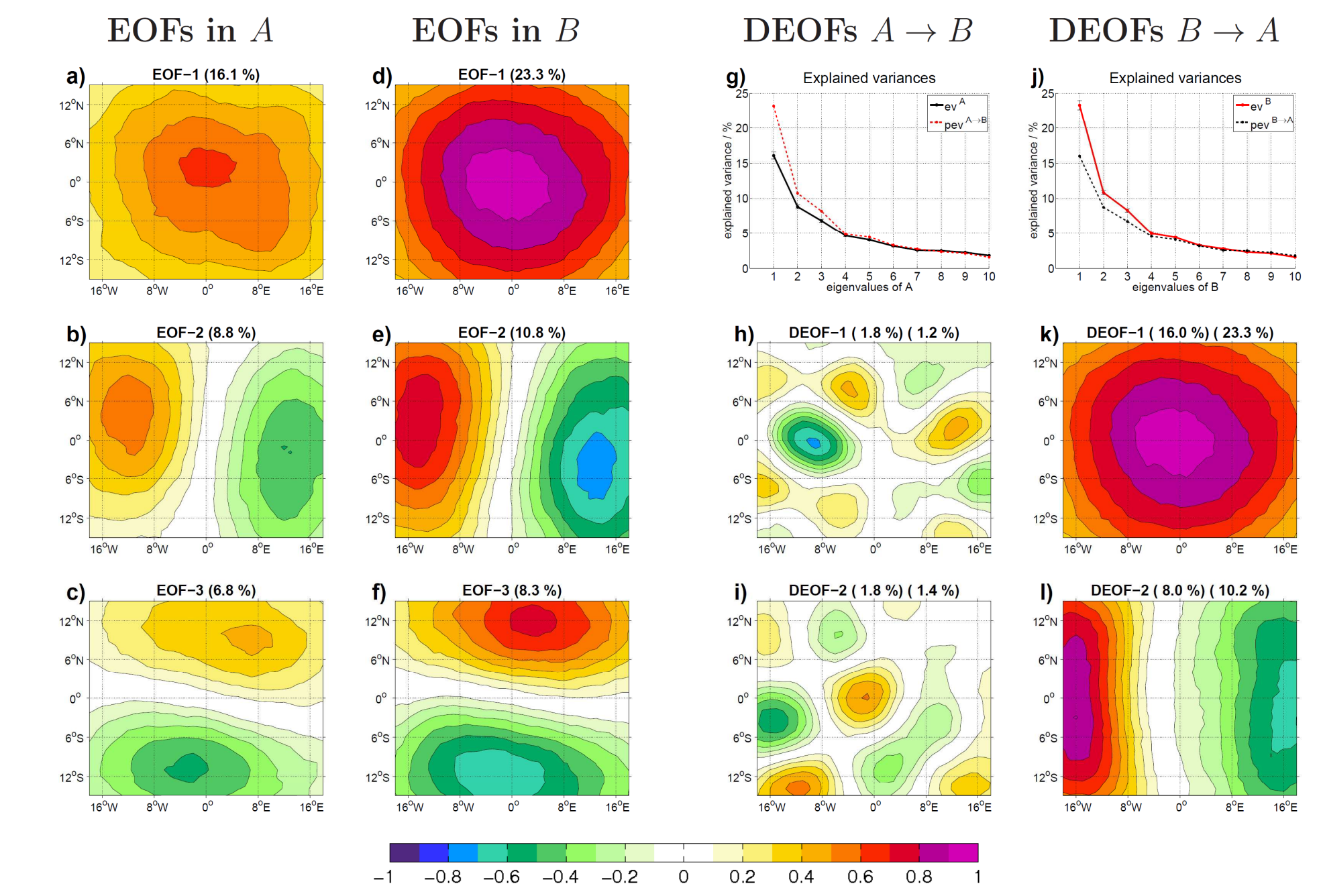## Change in the multivariate structure

Figure 7: Same as Fig. 2, but here with no forcing patterns, but different decorrelation lengths (about 7 grid point in dataset $\mathcal{A}$ and about 10 grid points in dataset $\mathcal{B}$).
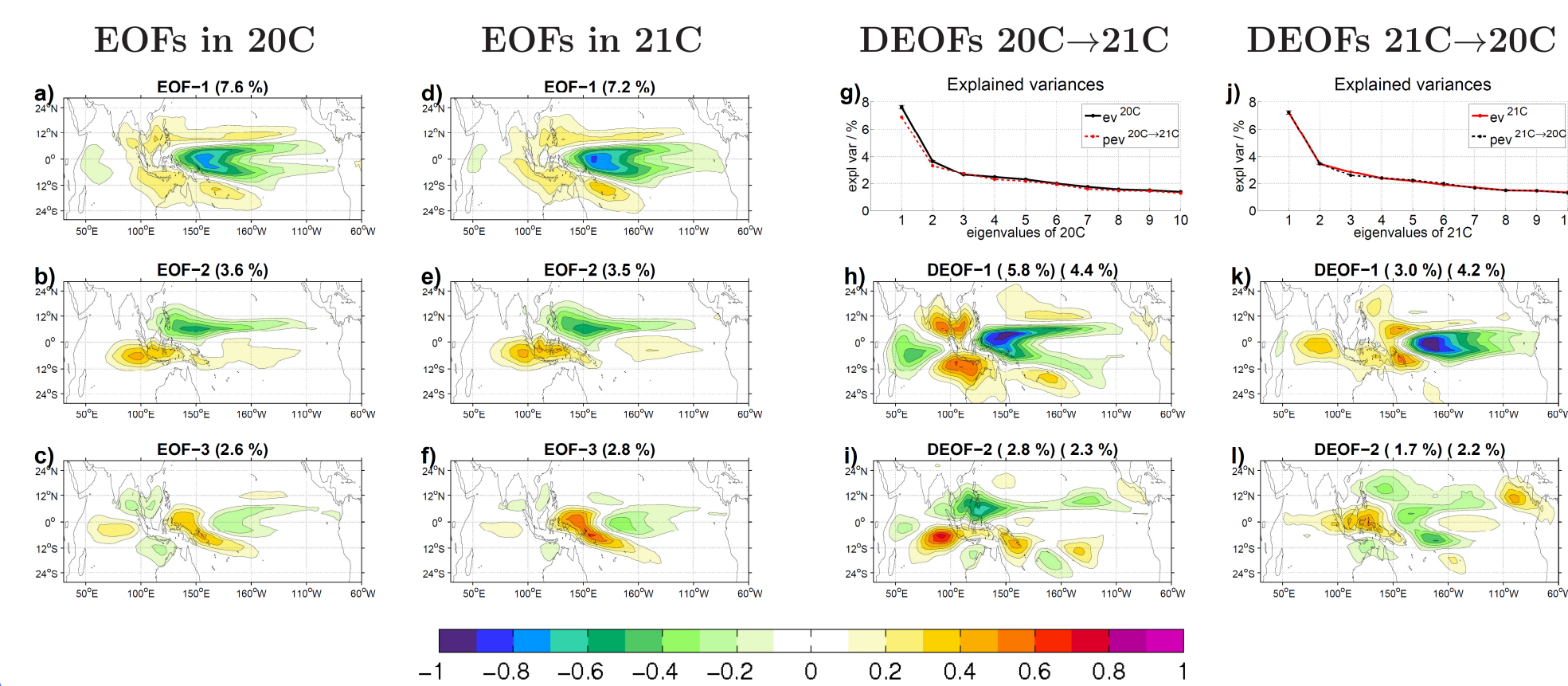

Figure 8: Same as Fig. 3, but here for precipitation over the Tropical Indo-Pacific region.

Intensification of a pattern:

- One or more eigenvalues will be more dominant in one dataset relative to the other dataset.
- One (only one!) DEOF-mode will be significantly dominant in the one dataset relative to the other dataset.

Pattern shift:

- One or more eigenvalues will be more dominant in both datasets relative to the other dataset.
- One (only one!) DEOF-mode will be significantly dominant in each of the two datasets.
- The DEOF-modes peak at the locations where the variance is increased most relative to the other dataset, marking the location shift.

Change in the multivariate structure:

- Most leading eigenvalues will be more dominant in one dataset relative to the other dataset.
- The higher-ranked eigenvalues of the other data set maybe more dominating than in the first dataset.
- Two or more DEOF-modes will be significantly dominant in the first dataset relative to the other dataset.
- More than one large-scale leading EOF-mode will be more dominant than in the other dataset.

Reference: Bayr, T., and D. Dommenget (2013), Comparing the spatial structure of variability in two datasets against each other on the basis of EOF-modes, *Climate Dynamics*, doi:10.1007/s00382-013-1708-x.

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