**Table S1.** List of forcings for ECHAM5/MPIOM model simulation.

| | |
|---|---|
| Greenhouse gases ($CO_2$, $CH_4$, $N_2O$) | MacFarling Meure et al. (2006) |
| Greenhouse gases (historical, anthropogenic) | Marland et al. (2003) |
| Ozone | Climatology of Paul et al. (1998) |
| Volcanic aerosols | Crowley et al. (2008) |
| Aerosol forcing | Background from Tanre et al. (1984) and post 1850 variations by Lefohn et al. (1999) |
| Total solar irradiance | Based on Muscheler et al. (2016, 2007) (see also Methods) |
| Land-use | Pongratz et al. (2008) with vegetation from Jungclaus et al. (2010) E1 ensemble member mil0010 |
| Orbital forcing | Variation Seculaires des Orbites Planetaires (VSOP) analytical solution by BRETAGNON and FRANCOU (1988) |

**Table S2.** Site details of ice core record records used in the reconstruction (Vinther et al., 2010).(*) BC indicates the at the core was drilled to bedrock.

| Drill site | Lat. ($^o$N) | Long. ($^o$W) | Elevation (m a.s.l.) | Acc. Rate (m ice/yr) | Time span |
|---|---|---|---|---|---|
| Crete | 71.12 | 37.32 | 3172 | 0.289 | 551-1974 |
| DYE-3 71 | 65.18 | 43.83 | 2480 | 0.56 | 1239-1971 |
| DYE-3 79 | 65.18 | 43.83 | 2480 | 0.56 | BC*-1979 |
| GRIP 89-1 | 72.58 | 37.64 | 3238 | 0.23 | 918-1989 |
| GRIP 89-3 | 72.58 | 37.64 | 3238 | 0.23 | BC*-1989 |
| GRIP 93 | 72.58 | 37.64 | 3238 | 0.23 | 1062-1993 |
| Milcent | 70.30 | 44.50 | 2410 | 0.54 | 1173-1973 |
| Renland | 71.27 | 26.73 | 2350 | 0.50 | BC*-1988 |

**Table S3.** Tropical eruptions during 1241-1970 CE of larger or similar magnitude as the 1991 Pinatubo eruption ($\sim$ -6 $Wm^{-2}$). All data from Sigl et al. (2015). UE indicates unknown source of eruption.

| Name | Year | Estimated magnitude [$Wm^{-2}$] |
|---|---|---|
| UE 1836 | 1836 | -6.57 |
| UE 1832 | 1832 | -6.46 |
| Tambora/Indonesia | 1815 | -17.20 |
| UE 1809 | 1809 | -12.01 |
| UE 1695 | 1695 | -10.24 |
| Parker/Philippines | 1641 | -11.84 |
| Huaynaputina/Peru | 1601 | -11.58 |
| Kuwae/Vanuatu | 1458 | -20.55 |
| El Chichon?/Mexico | 1345 | -9.40 |
| Quilotoa?/Ecuador | 1286 | -9.69 |
| UE 1276 | 1276 | -7.71 |
| Samalas/Indonisia | 1258 | -32.79 |

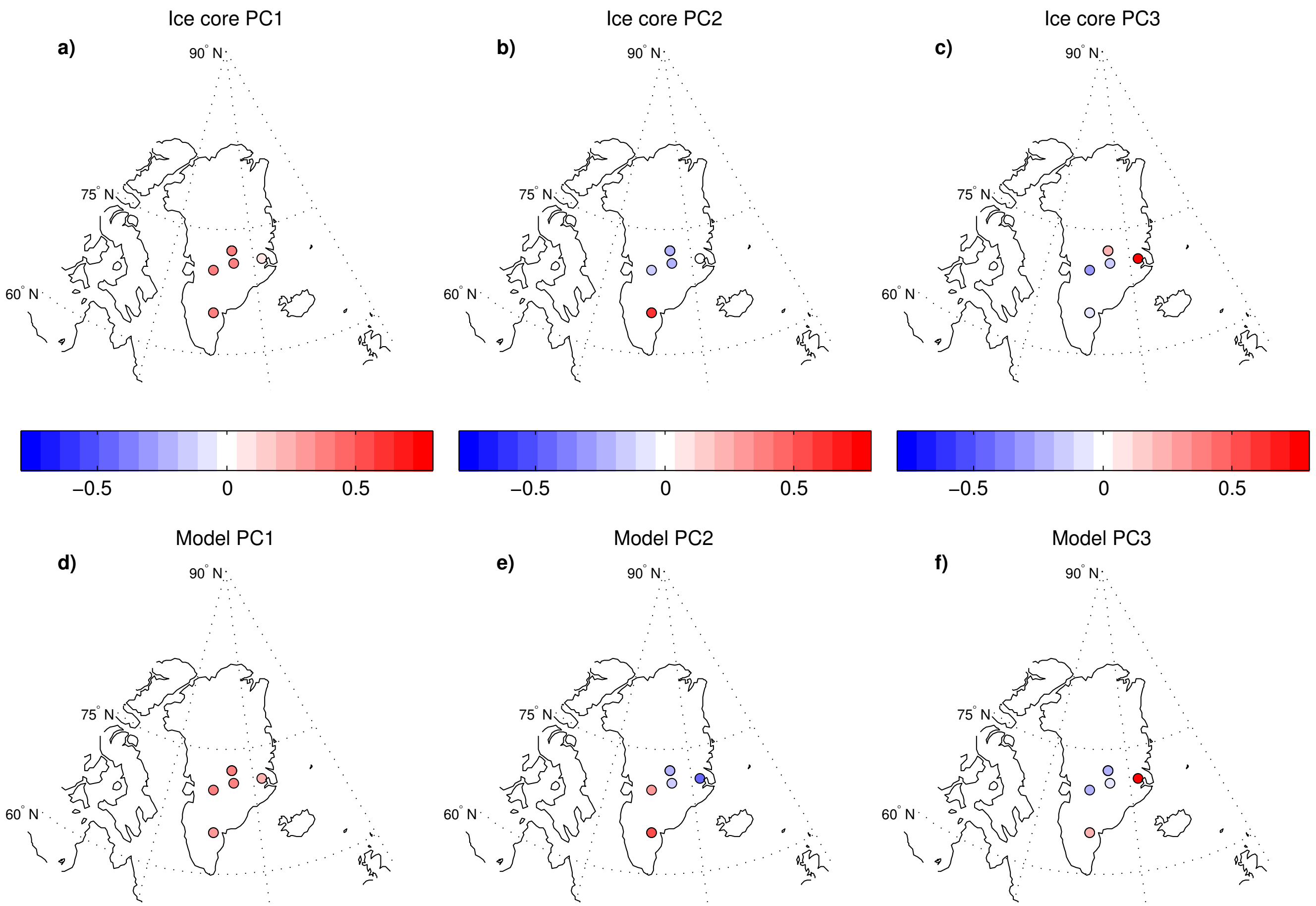


**Figure S1.** Spatial patterns of the three main modes of variability in the $\delta^{18}$O ice core records used in this study and the modeled modes of variability using the corresponding sites. The pattern of the loadings on ice core $\delta^{18}$O PCs are shown in (**a, b, c**) and modeled loadings on $\delta^{18}$O PCs at the ice core sites are shown in (**d, e, f**).

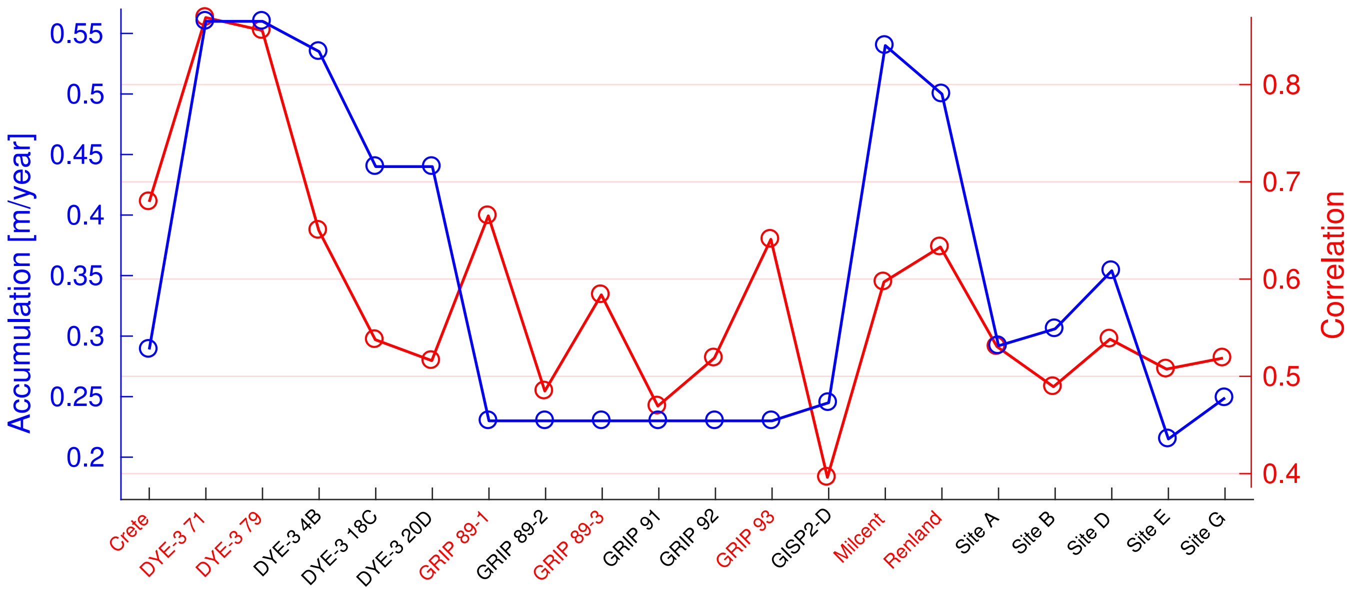


**Figure S2.** Accumulation at ice core sites (blue) and correlation between reconstructed winter $\delta^{18}$O and ice core winter $\delta^{18}$O (Vinther et al., 2010) 1778-1970 (red). The names of the ice core sites used in the reconstruction are written in red.

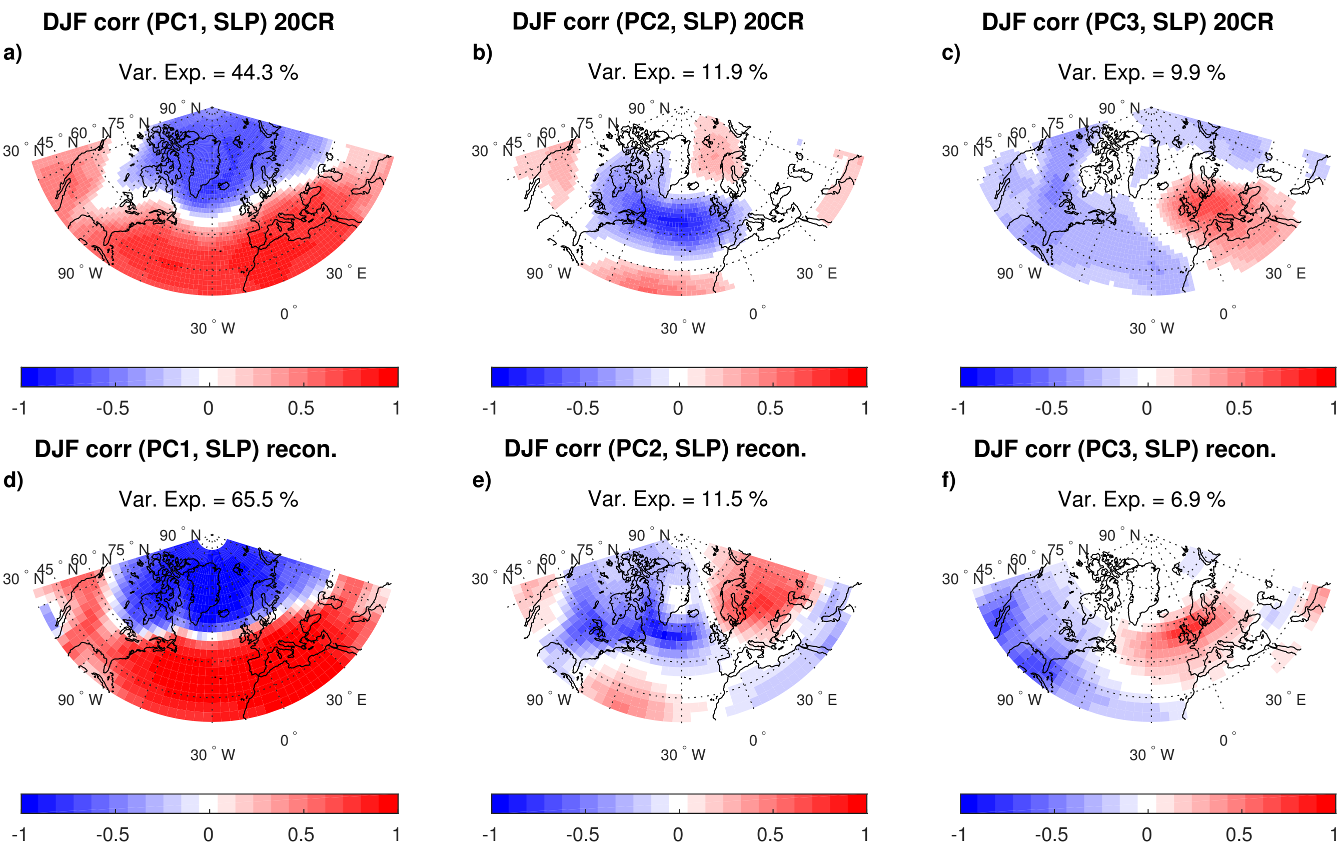


**Figure S3.** **a** Grid point correlation between 20CR SLP PC1 and 20CR SLP, **b** grid point correlation between 20CR SLP PC2 and 20CR SLP, and **c** grid point correlation between 20CR SLP PC3 and 20CR SLP. **d, e, f** same as **a, b, c** but for reconstructed PC1, PC2, PC3 and SLP. The explained variability of the PCs is indicated by each subplot. Only significant values of correlation are plotted ($p < 0.05$).

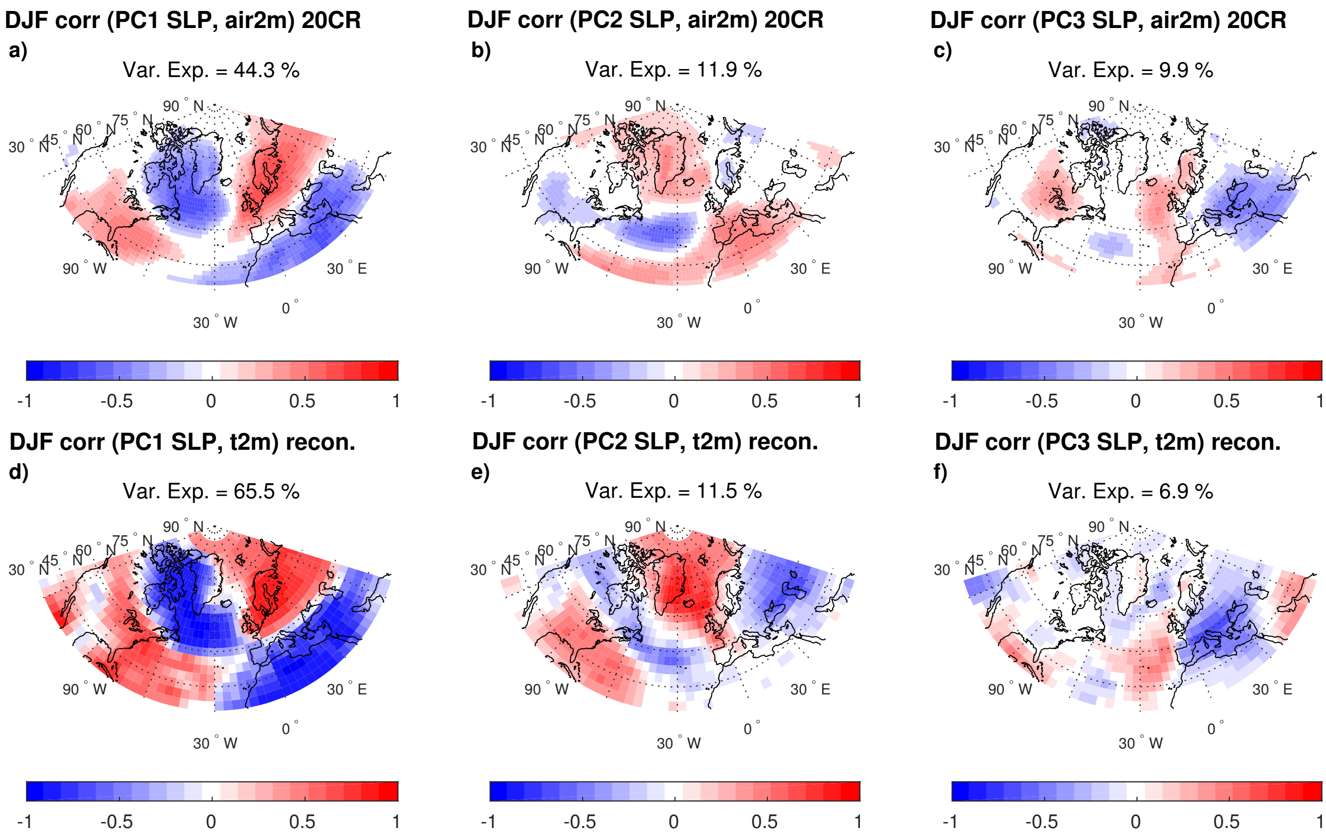


**Figure S4.** Same as Figure S1 but for correlation between PC1 (**a, d**), PC2 (**b, e**) and PC3 (**c, f**) of SLP and T2m. Only significant values of correlation are plotted ($p < 0.05$).

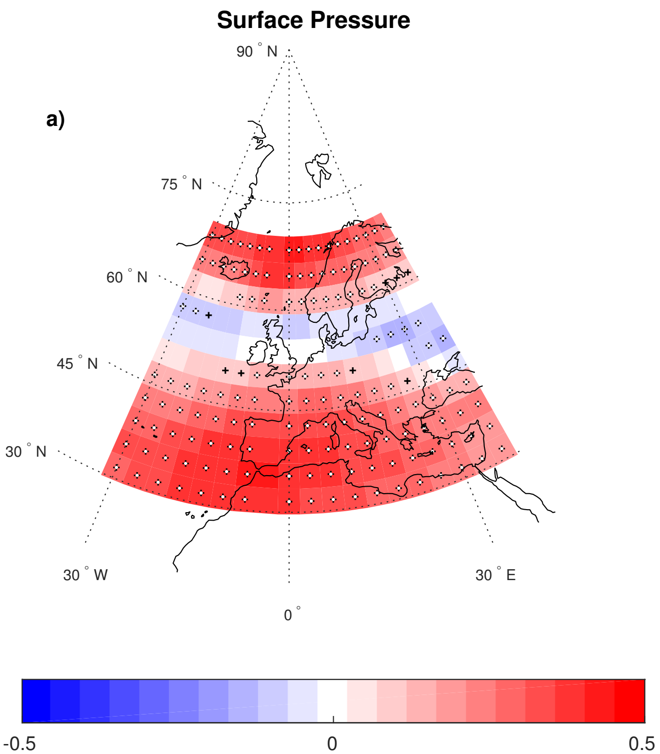


**Figure S5. a** Grid point correlation between reconstructed SLP (this study) and reconstructed SLP by Luterbacher et al. (2001). **b** Same as **a**, but for T2m (Luterbacher et al., 2004). The data covers the period (1659-1970) with the data by interpolated Luterbacher et al. to the model grid of our reconstruction (lat. x lon. ~$3.85^o$ x $3.85^o$). The black stippling indicates significance of $p < 0.1$ and the white indicates $p < 0.05$.

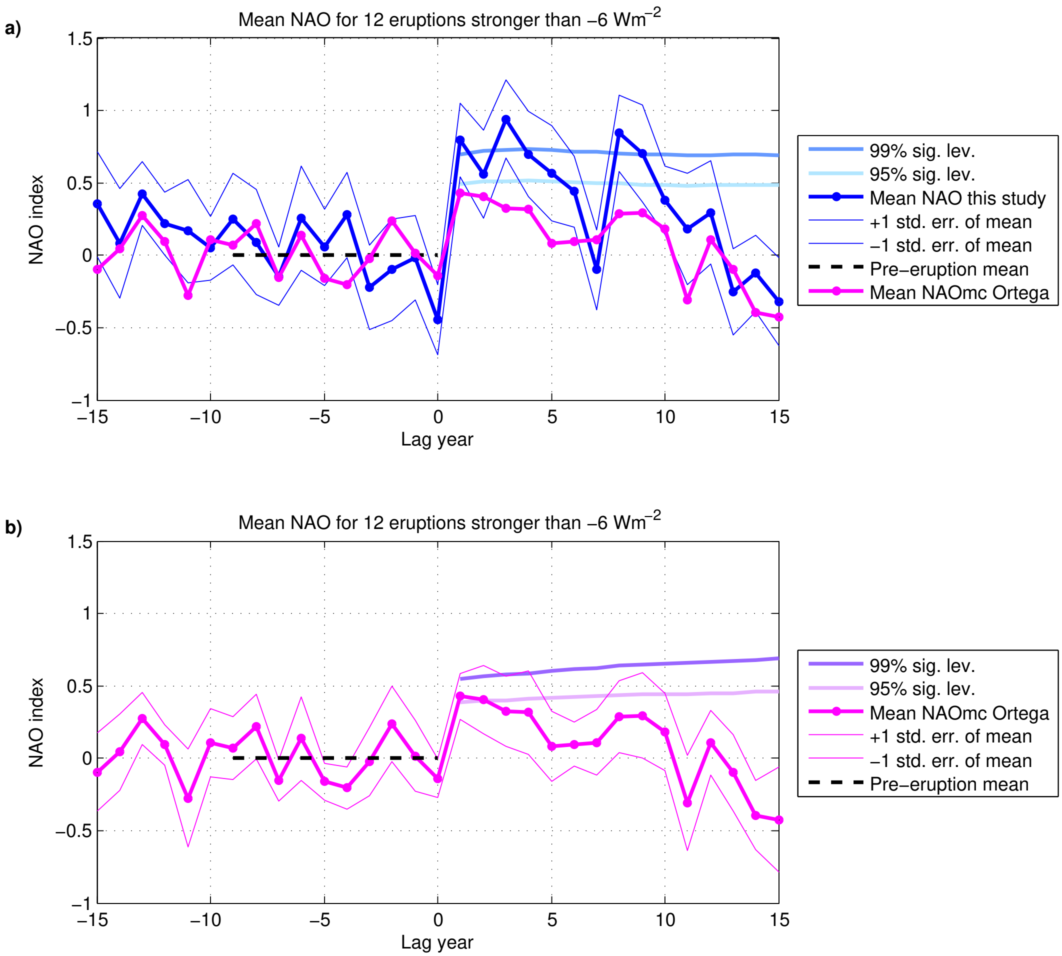


**Figure S6.** Superimposed epoch analysis of the mean response in NAO to the 12 largest tropical volcanic eruptions (Sigl et al., 2015) (Table S3). **a** Mean response in reconstructed NAO (blue) with the time series normalized to the mean NAO of the 10 years preceding the eruption. For comparison the same analysis is carried out for the NAOmc reconstruction (magenta) by Ortega et al. (2015). The significance levels in **a** are estimated from 100,000 random samples of 12 years drawn from the reconstructed NAO. **b** Same analysis as in **a**. but carried out for the NAOmc reconstruction (magenta) by Ortega et al. (2015) including significance levels. Note the sloping significance levels in figure **b** compared to figure **a** due to larger auto-correlation of the reconstruction by Ortega et al. (2015).

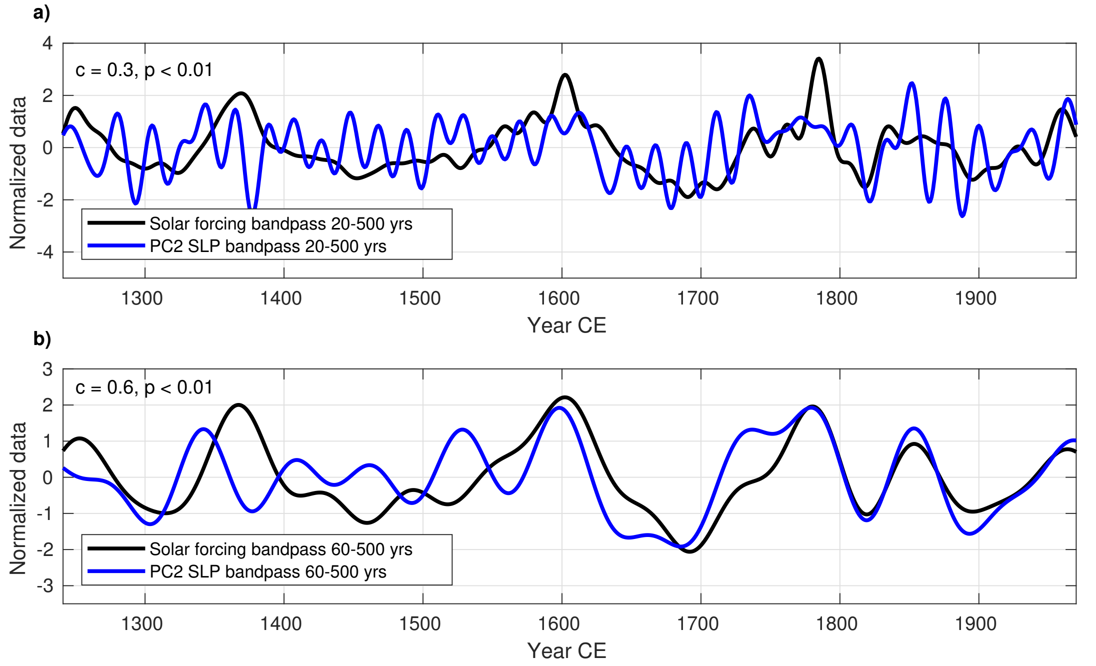


**Figure S7.** PC2 of reconstructed SLP plotted with reconstructed solar forcing (Muscheler et al., 2016) using a band-pass filter for **a** 20-500 year periodicities, and **b** 60-500 year periodicities. All correlations are for detrended data and p-values calculated with the random-phase test by Ebisuzaki (1997) to take into account auto-correlation.

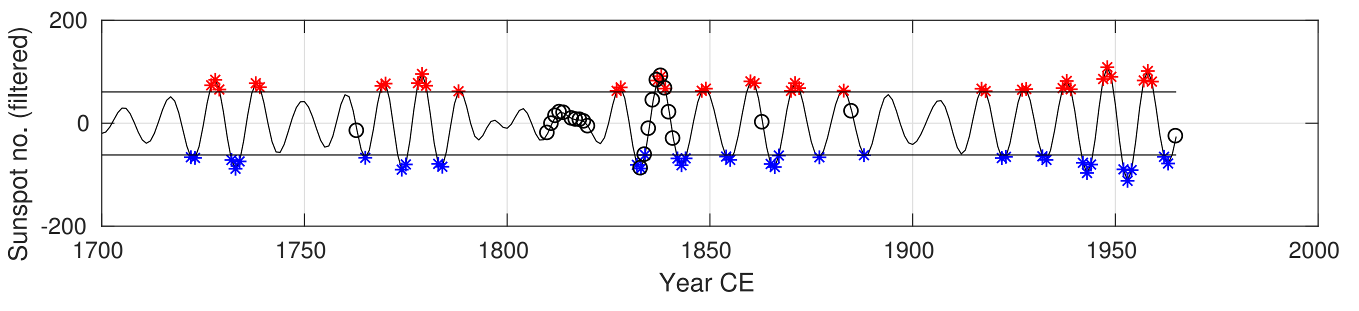


**Figure S8.** Band-pass filtered (8-13 year periodicity) sunspot number (Clette and Lefèvre, 2016) and years selected for solar maximum (red) and solar minimum (blue). We pick a maximum of three years around each maximum and minimum, and furthermore employ a threshold of 1.25 standard deviations. The horizontal lines mark $\pm$ 1.25 standard deviations. The motivation for the threshold of 1.25 standard deviation is to obtain the most extreme values of solar maximum and minimum, while still selecting enough years to get good sampling statistics. We removed 5 years following major tropical volcanic eruptions ($< -6$ $Wm^{-2}$) and 1 year following minor tropical volcanic eruptions ($> -6$ $Wm^{-2}$) from the analysis. These years are marked with black circles.

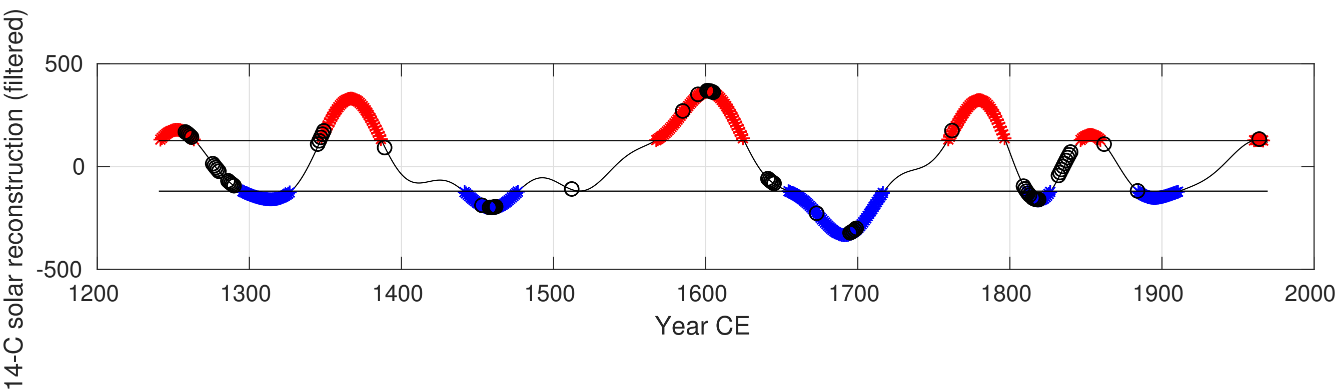


**Figure S9.** Band-pass filtered (60-500 year periodicity) $^{14}C$ data (Muscheler et al., 2016) and years selected for solar maximum (red) and solar minimum (blue). The horizontal lines mark $\pm$ 0.75 standard deviations. The motivation for the threshold of 0.75 standard deviation is to obtain the most extreme values of solar maximum and minimum, while still selecting enough years to get good sampling statistics. We removed 5 years following major tropical volcanic eruptions ($<$ -6 $Wm^{-2}$) and 1 year following minor tropical volcanic eruptions ($>$ -6 $Wm^{-2}$) from the analysis. These years are marked with black circles.

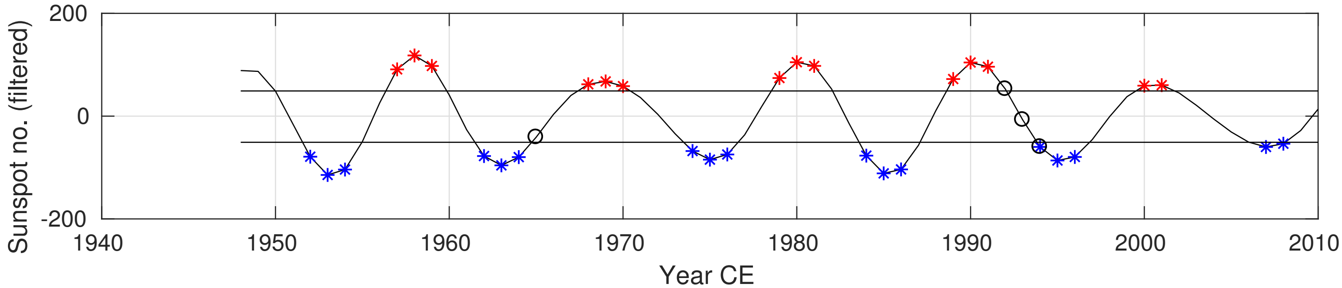


**Figure S10.** Band-pass filtered (8-13 year periodicity) sunspot number (Clette and Lefèvre, 2016) and years selected for solar maximum (red) and solar minimum (blue) for Figure 5 (20CR (1948-2010) atmospheric response to solar forcing). We pick a maximum of three years around each maximum and minimum, and furthermore employ a threshold of 0.75 standard deviations. The horizontal lines mark ± 0.75 standard deviations. The motivation for the threshold of 0.75 standard deviations is to obtain the most extreme values of solar maximum and minimum, while still selecting enough years to get good sampling statistics. We removed the 3 years following the Pinatubo eruption in 1991 and 1 year following the Agung eruption in 1964. These years are marked with black circles.

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