

## Supplementary Materials

Interdecadal Pacific Oscillation responsible for the linkage of  
decadal changes in precipitation/moisture in arid central Asia and  
humid Asian monsoon region during the last millennium

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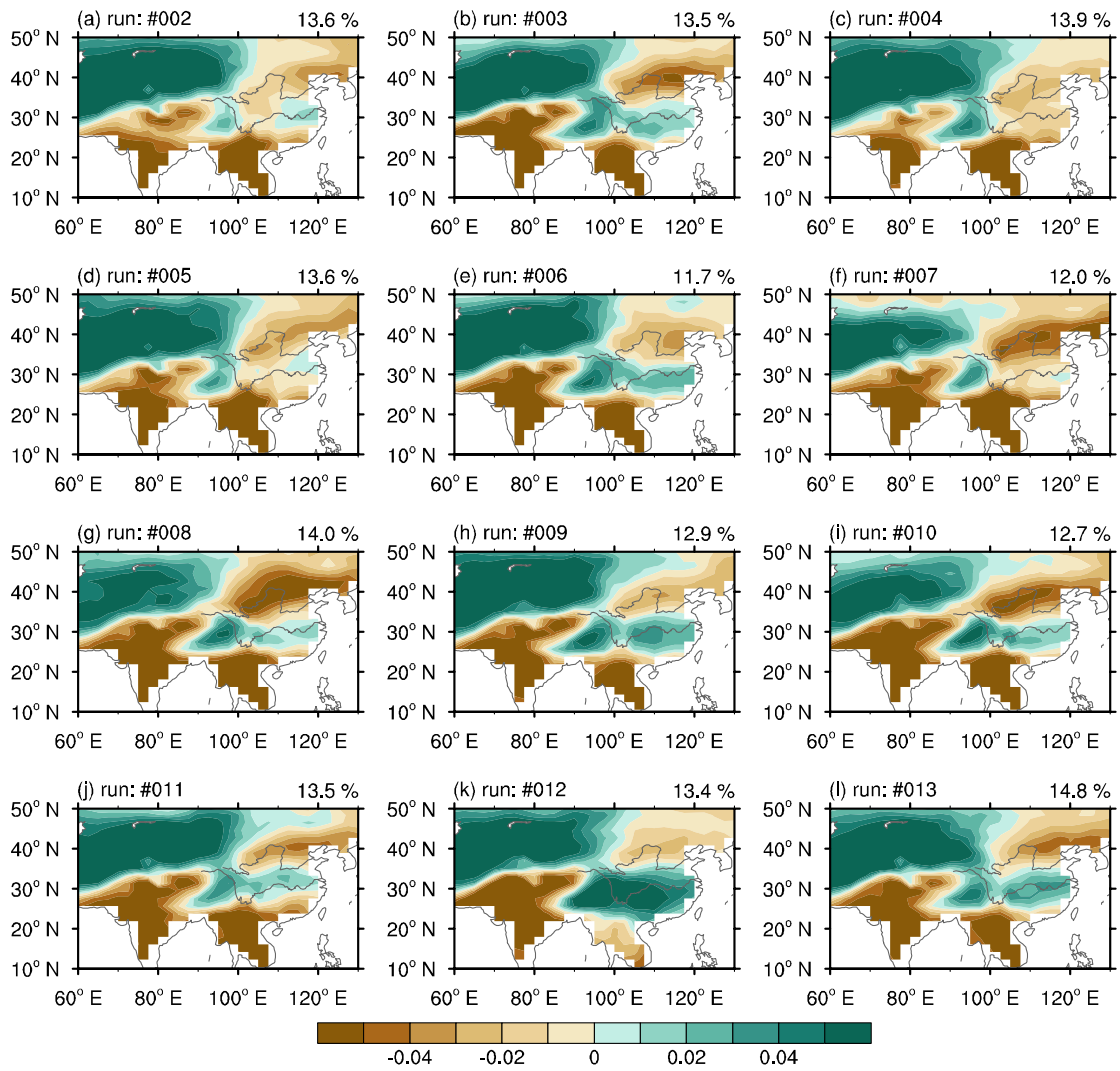
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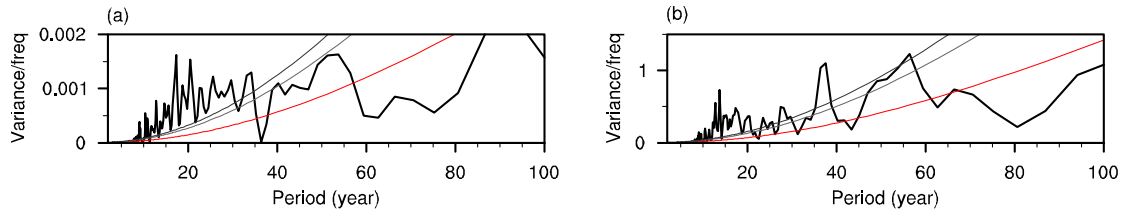
### Supplementary Figures 1–13



17

18 **Figure S1.** The simulated first leading precipitation mode. (a–l) EOF1 of the nine-year low-pass  
 19 Lanczos filtered annual precipitation in the CESM-LME 12 all-forcing simulations for the time  
 20 period 850–2005. The explained variances are given at the top-right.

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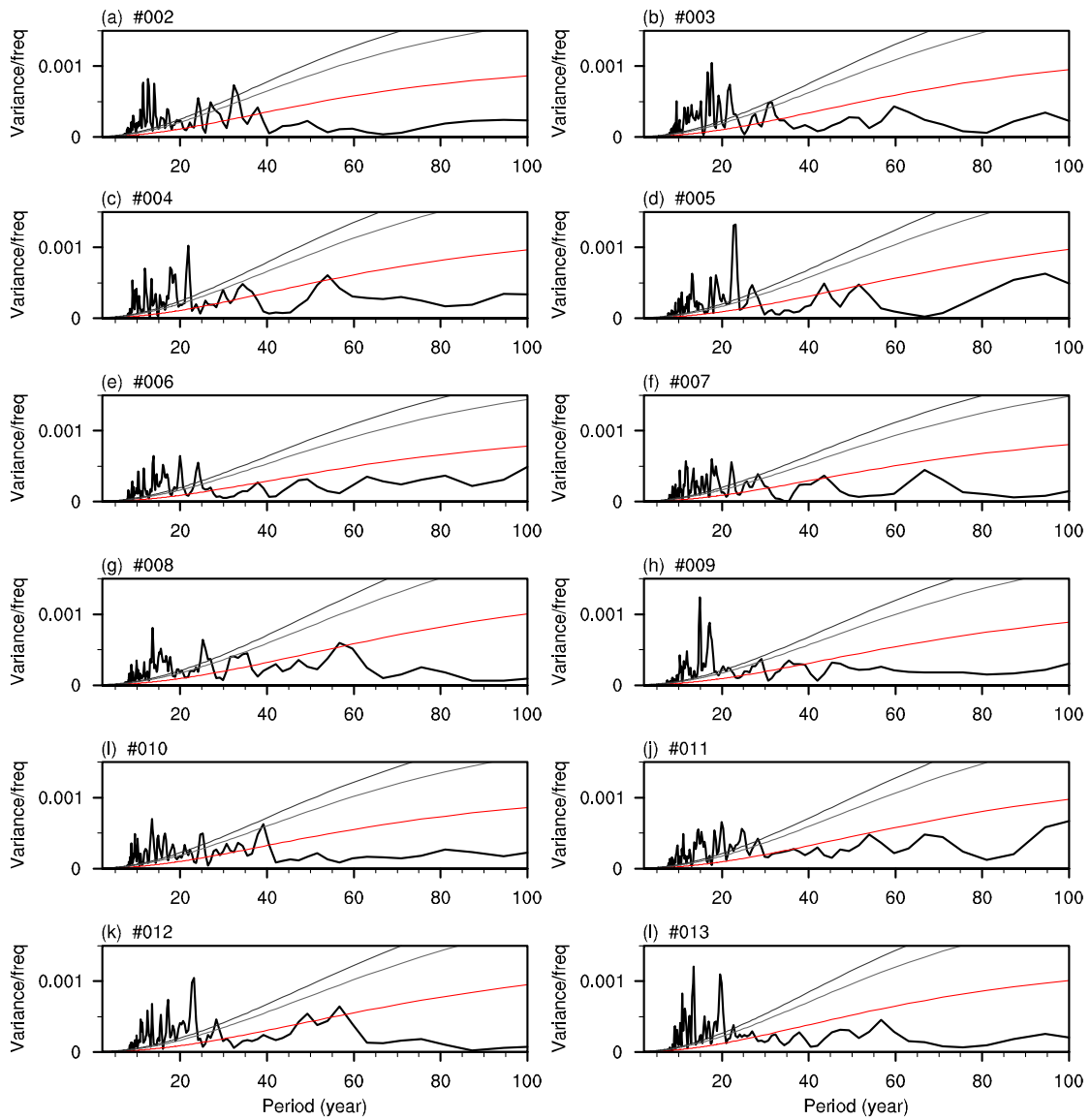
23 **Figure S2. (a)** Power spectrum of the time series of the leading decadal precipitation mode (black

24 line) and **(b)** power spectrum of the time series of the IPO index (black line) in the Last

25 Millennium Reanalysis dataset. The dark (light) gray line indicates the confidence curve at the 95%

26 (90%) confidence level and the red line shows the Markov red noise spectrum.

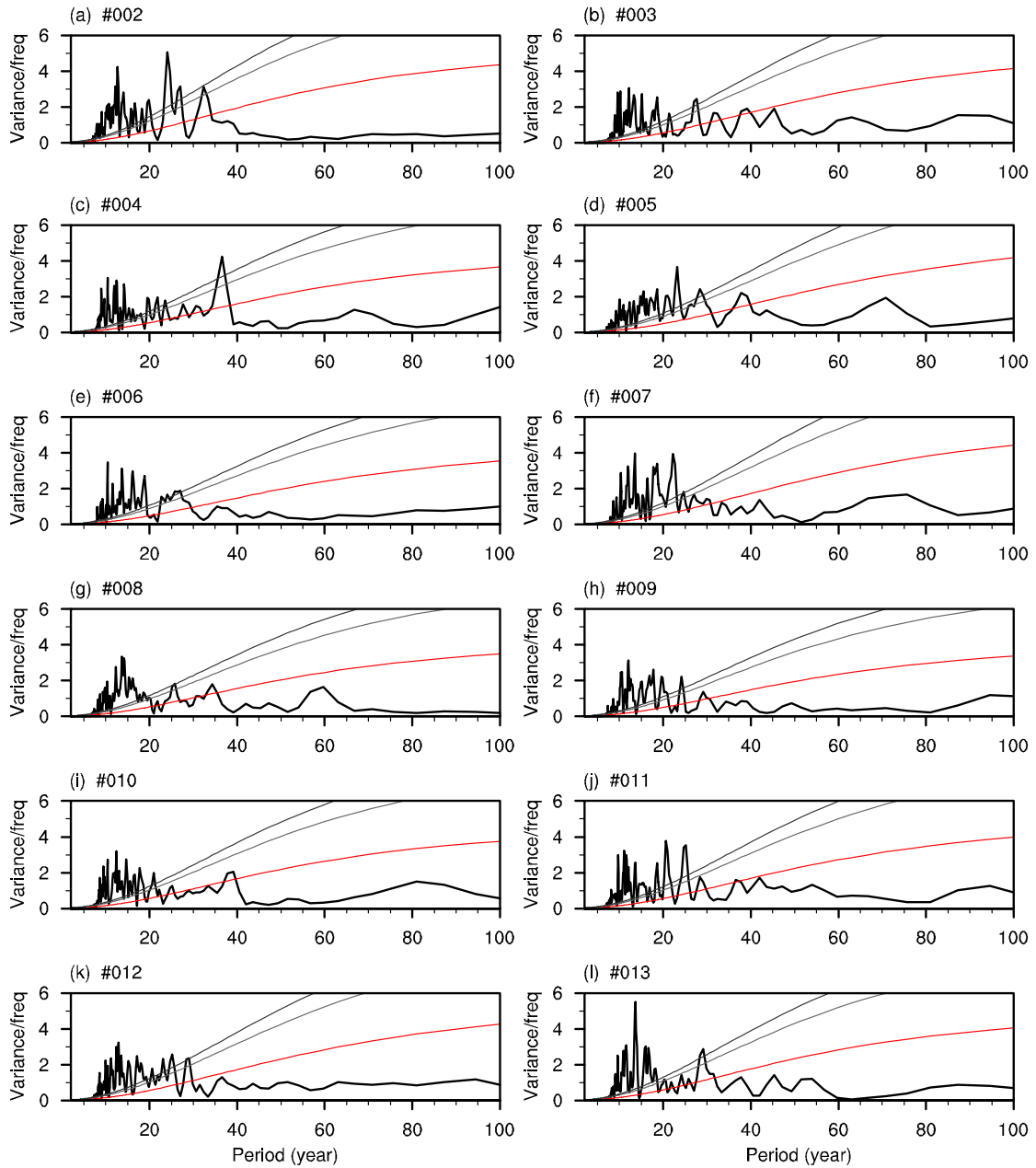
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29 **Figure S3.** Power spectrum of the time series of the leading decadal precipitation mode (black  
 30 lines) in the CISM-LME 12 all-forcing simulations. The dark (light) gray lines indicate the  
 31 confidence curve at the 95% (90%) confidence level and the red lines show the Markov red noise  
 32 spectrum.

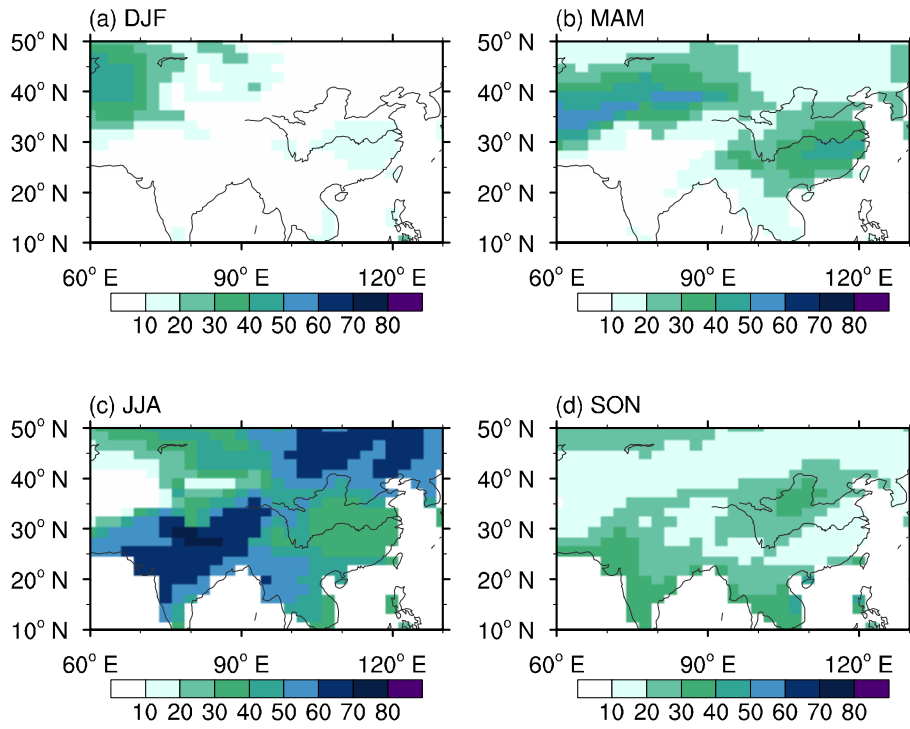
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35 **Figure S4.** Power spectrum of the time series of the IPO index (black lines) in the CESM-LME 12  
 36 all-forcing simulations. The dark (light) gray lines indicate the confidence curve at the 95% (90%)  
 37 confidence level and the red lines show the Markov red noise spectrum.

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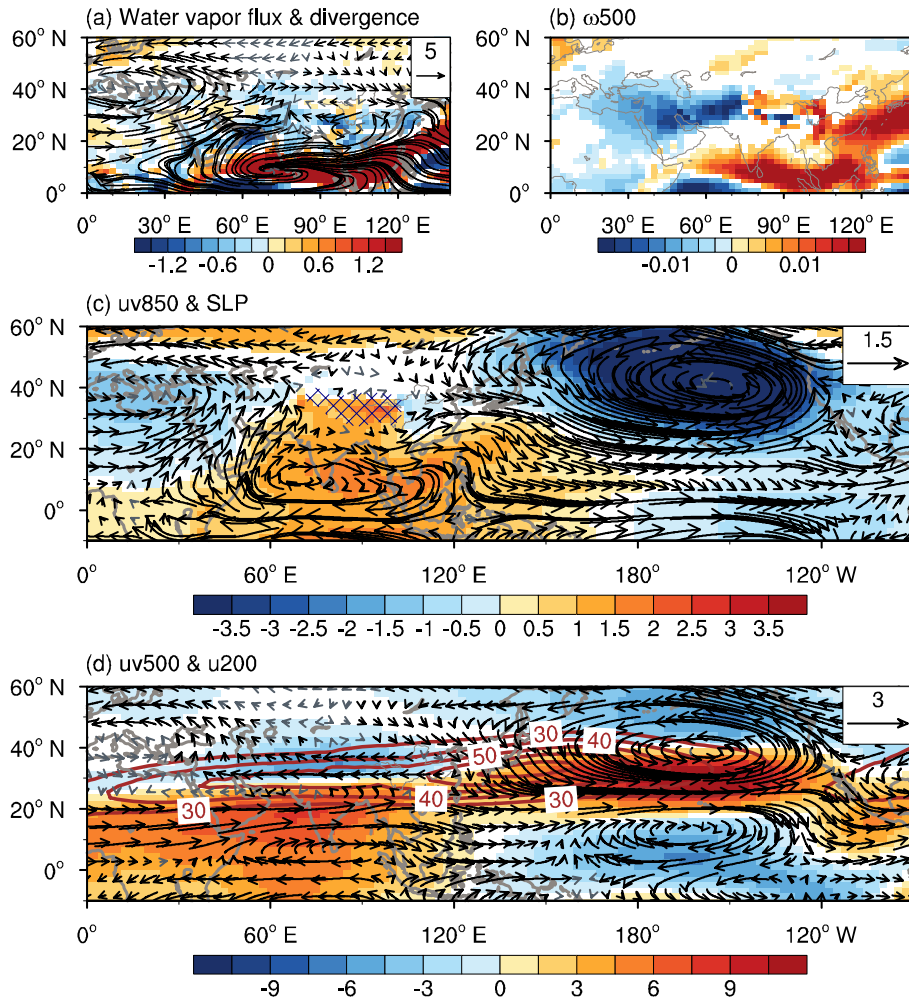
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40 **Figure S5.** Average values of the percentage of the annual precipitation accounted for by (a)

41 winter, (b) spring, (c) summer and (d) autumn precipitation in the CESM-LME all-forcing

42 simulations.

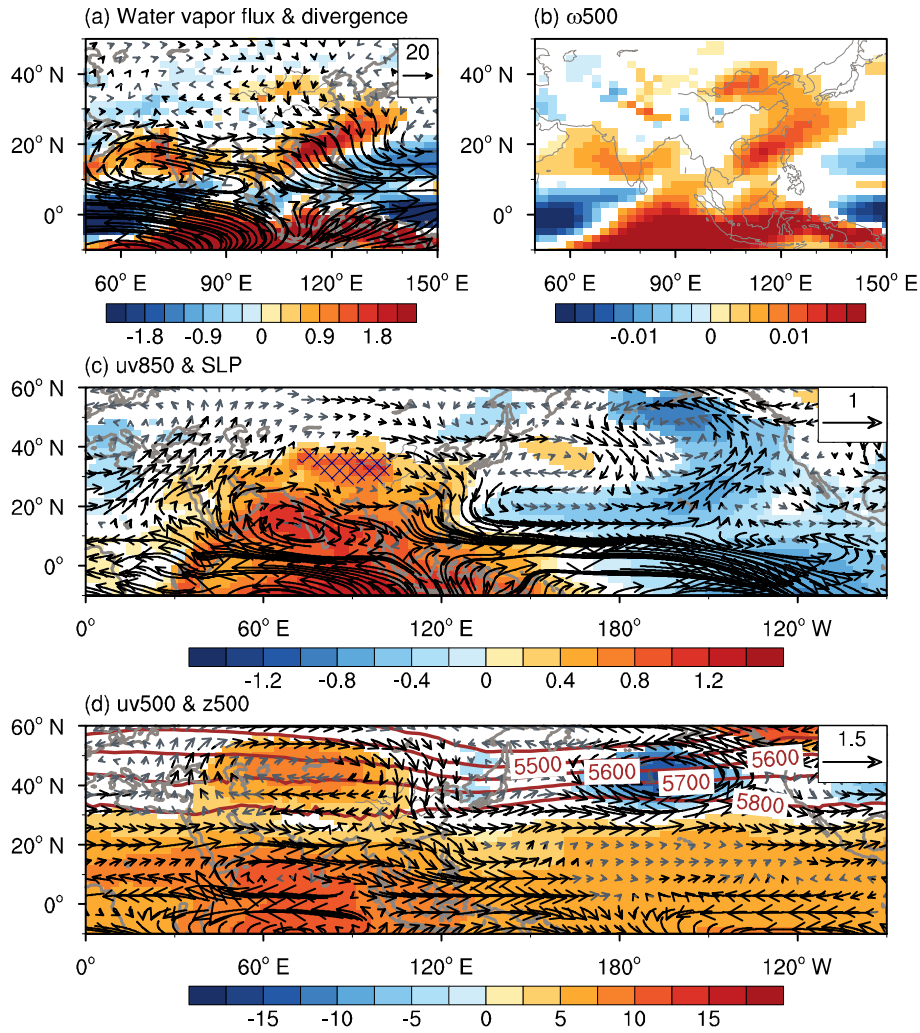
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45 **Figure S6.** Simulated winter atmospheric circulation anomalies during the positive phases of the  
 46 IPO. Regressed maps of anomalous (a) vertically integrated water vapor flux from 1000 to 300  
 47 hPa (vectors; units:  $\text{kg m}^{-1} \text{s}^{-1}$ ) and its divergence (shading; units:  $10^{-5} \text{kg m}^{-2} \text{s}^{-1}$ ), (b) 500 hPa  
 48 vertical velocity ( $\omega_{500}$ ) (units:  $\text{Pa s}^{-1}$ ), (c) 850 hPa wind (uv850) (vectors; units:  $\text{m s}^{-1}$ ) and SLP  
 49 (shading; units: hPa), (d) 500 hPa wind (uv500) (vectors; units:  $\text{m s}^{-1}$ ) and 200 hPa zonal wind  
 50 (u200) (shading; units:  $\text{m s}^{-1}$ ) onto the time series of the IPO index simulated by the CESM-LME  
 51 all-forcing runs. The blue hatched patterns in part (c) indicate the region with an altitude  $>3000$  m.  
 52 The brown contours in part (d) are the climatological 200 hPa zonal wind (units:  $\text{m s}^{-1}$ ). The  
 53 shading shows that the significant anomalies at the 95% confidence level simulated by at least  
 54 two-thirds of the members agree on the sign of the average. The black vectors show that the  
 55 significant anomalies at the 95% confidence level simulated by at least two-thirds of the members  
 56 agree on the sign of the average for the zonal or meridional component.

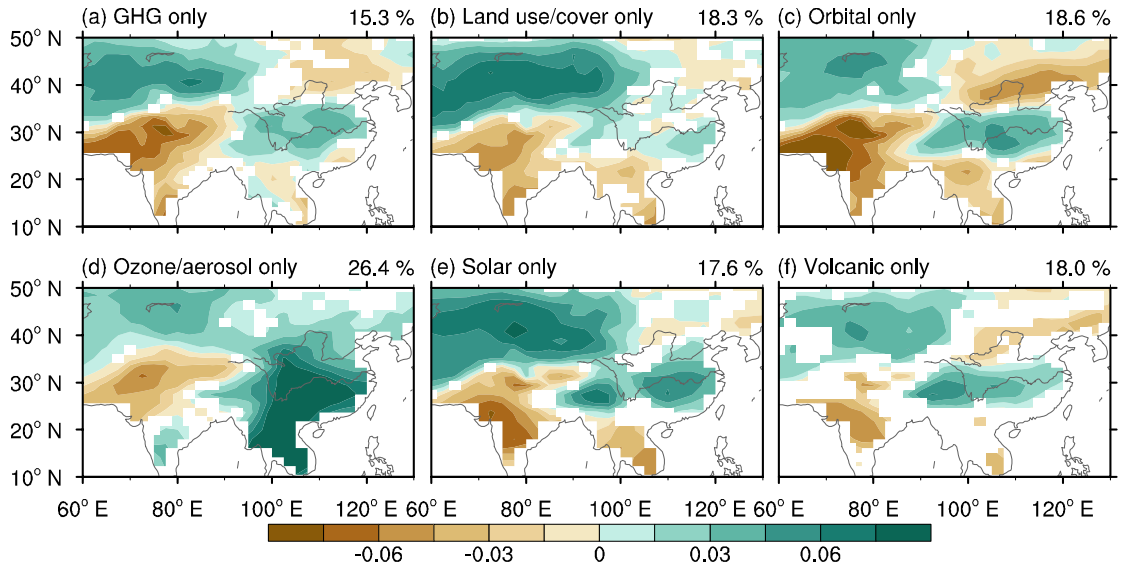
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59 **Figure S7.** Simulated autumn atmospheric circulation anomalies during the positive phases of the  
 60 IPO. Regressed maps of anomalous (a) vertically integrated water vapor flux from 1000 to 300  
 61 hPa (vectors; units:  $\text{kg m}^{-1} \text{s}^{-1}$ ) and its divergence (shading; units:  $10^{-5} \text{kg m}^{-2} \text{s}^{-1}$ ), (b) 500 hPa  
 62 vertical velocity ( $\omega_{500}$ ) (units:  $\text{Pa s}^{-1}$ ), (c) 850 hPa wind (uv850) (vectors; units:  $\text{m s}^{-1}$ ) and SLP  
 63 (shading; units: hPa), and (d) 500 hPa wind (uv500) (vectors; units:  $\text{m s}^{-1}$ ) and 500 hPa  
 64 geopotential height (z500) (shading; units: m) onto the time series of the IPO index simulated by  
 65 the CESM-LME all-forcing runs. The blue hatched patterns in part (c) indicate the region with an  
 66 altitude  $>3000$  m. The brown contours in part (d) are the climatological 500 hPa geopotential  
 67 height (units: m). The shading shows that the significant anomalies at the 95% confidence level  
 68 simulated by at least two-thirds of the members agree on the sign of the average. The black  
 69 vectors show that the significant anomalies at the 95% confidence level simulated by at least  
 70 two-thirds of the members agree on the sign of the average for the zonal or meridional component.

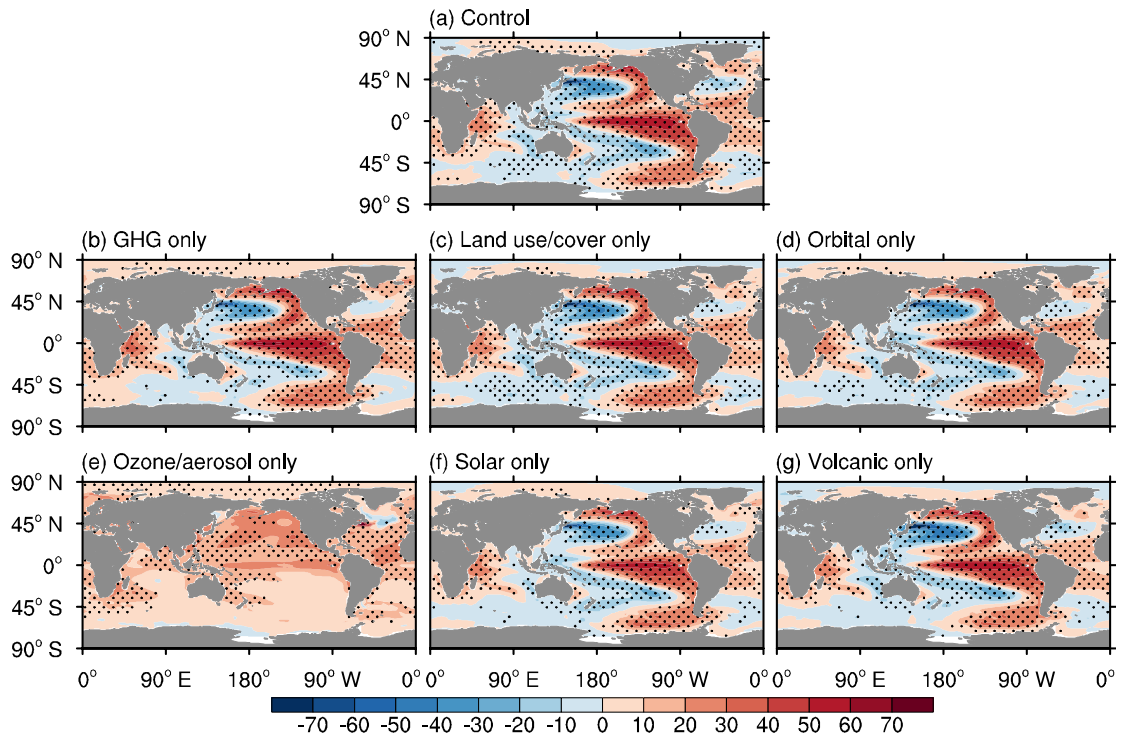




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72 **Figure S8.** The leading decadal precipitation mode for the time period 1850–2005 in the  
 73 single-forcing simulations. (a–f) The average EOF1 of the nine-year low-pass Lanczos filtered  
 74 annual precipitation in six subsets of the single-forcing simulations. The averaged explained  
 75 variance is given at the top-right. The shading shows where at least two-thirds of the members  
 76 agree on the sign of the average of multiple members.

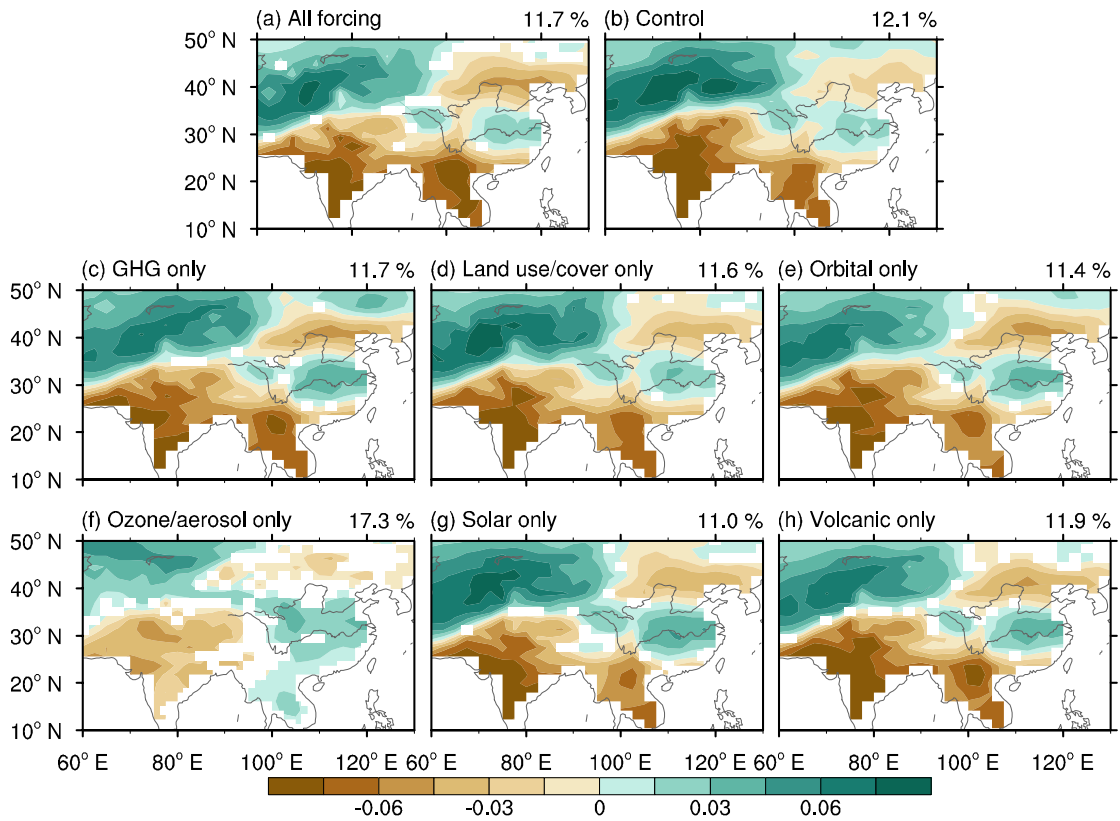
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79 **Figure S9.** The SST anomalies (units: °C) regressed onto the time series of the leading decadal  
 80 precipitation mode in the **(a)** control simulation and **(b–g)** six subsets of the single-forcing  
 81 simulations. The dots in part **(a)** show significant anomalies at the 95% confidence level and the  
 82 dots in parts **(b–g)** denote that the significant anomalies at the 95% confidence level simulated by  
 83 at least two-thirds of the members agree on the sign of the average value.

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86 **Figure S10.** The simulated leading decadal soil moisture mode for the time period 850–2005. **(a)**

87 The average EOF1 of the nine-year low-pass Lanczos filtered soil moisture content (top 10 cm of

88 soil) in the all-forcing simulations. The averaged explained variance is given at the top-right. **(b)**

89 EOF1 of the nine-year low-pass Lanczos filtered soil moisture content in the control simulation.

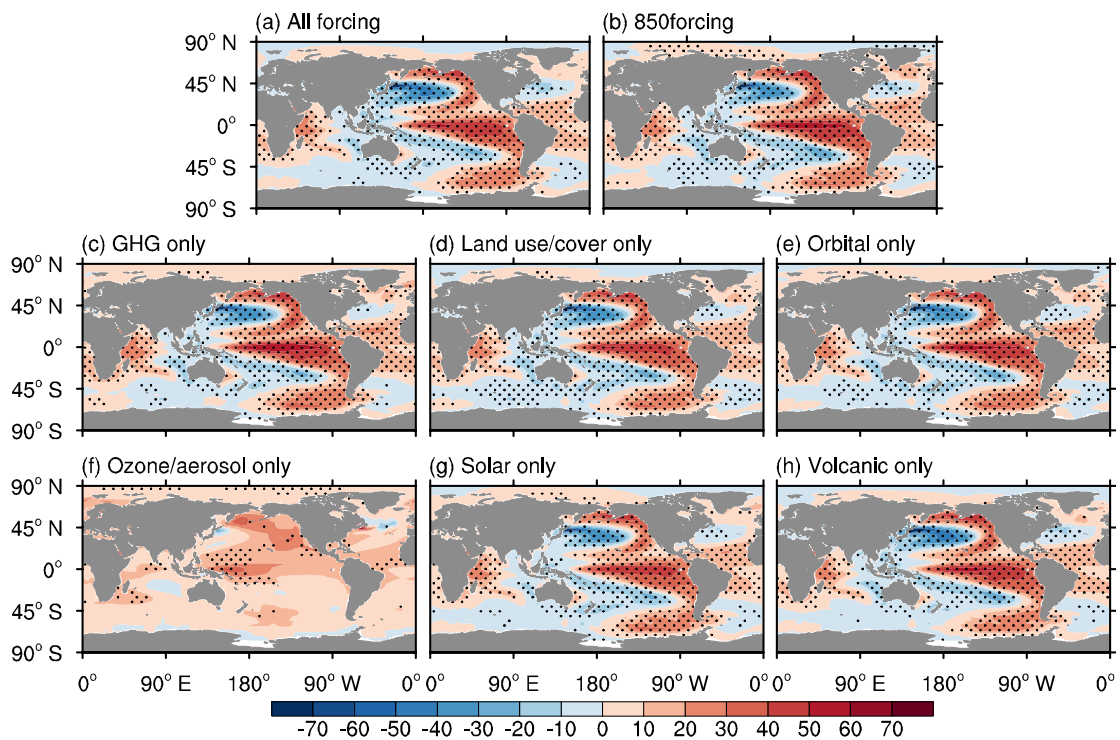
90 The explained variance is given at the top-right. **(c–h)** The average EOF1 of the nine-year

91 low-pass Lanczos filtered soil moisture content in six subsets of the single-forcing simulations.

92 The averaged explained variance is given at the top-right. The shading in parts **(a, c–h)** shows

93 where at least two-thirds of the members agree on the sign of the average of multiple members.

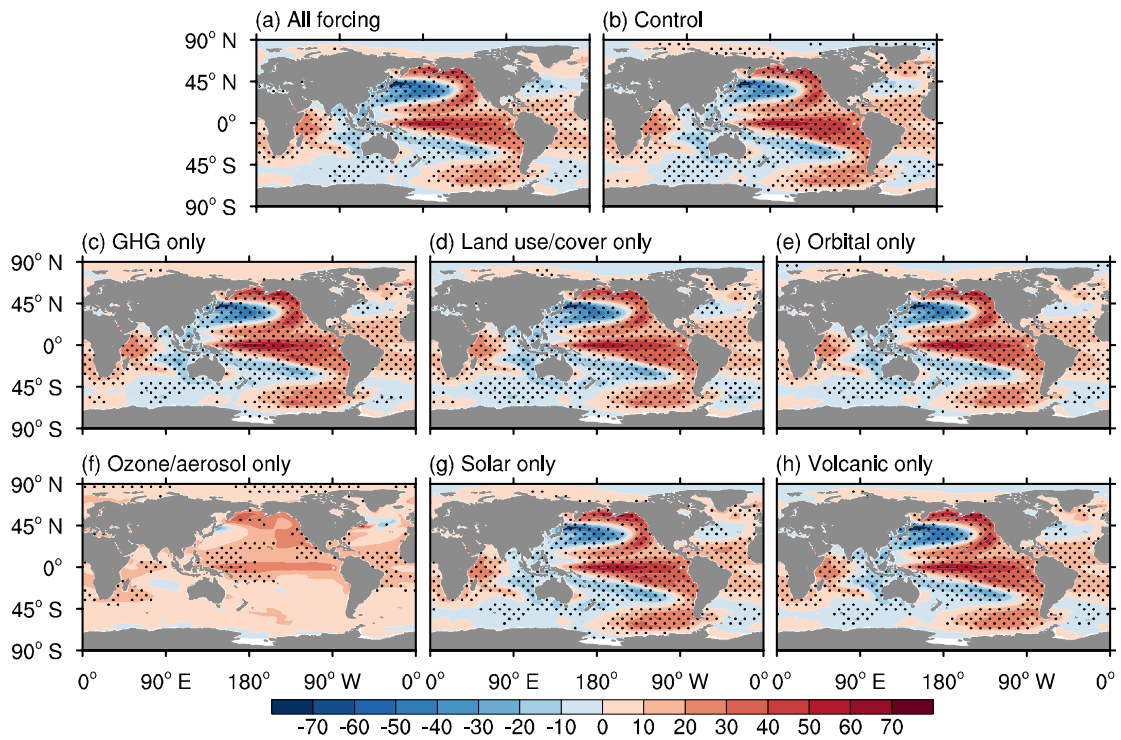
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96 **Figure S11.** The SST anomalies (units: °C) regressed onto the time series of the leading decadal  
 97 aridity index mode in the (a) all-forcing simulations, (b) control simulation, and (c-h) six subsets  
 98 of the single-forcing simulations. The dots in part (b) show significant anomalies at the 95%  
 99 confidence level and the dots in parts (a, c-h) denote that the significant anomalies at the 95%  
 100 confidence level simulated by at least two-thirds of the members agree on the sign of the average  
 101 value.

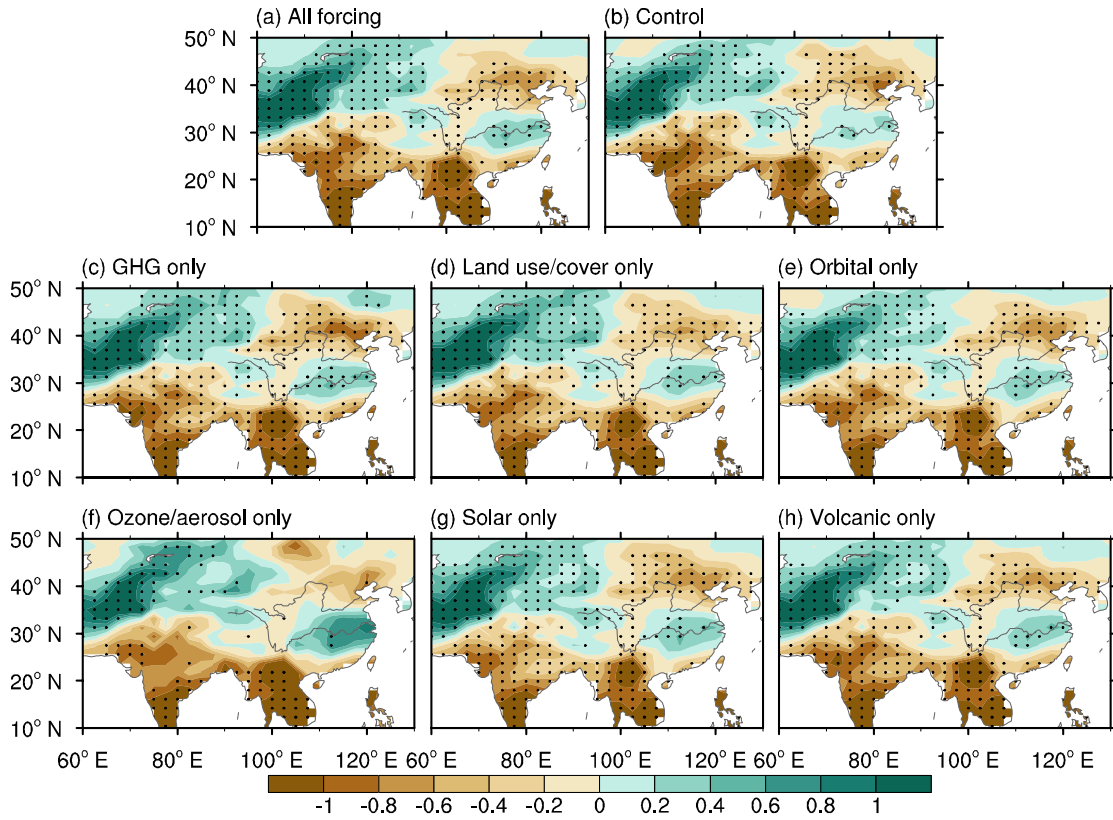
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104 **Figure S12.** The SST anomalies (units: °C) regressed onto the time series of the leading decadal  
 105 soil moisture mode in the (a) all-forcing simulations, (b) control simulation, and (c–h) six subsets  
 106 of the single-forcing simulations. The dots in part (b) show significant anomalies at the 95%  
 107 confidence level and the dots in parts (a, c–h) denote that the significant anomalies at the 95%  
 108 confidence level simulated by at least two-thirds of the members agree on the sign of the average  
 109 value.

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112 **Figure S13.** Simulated soil moisture anomalies during the positive phases of the IPO. The soil  
 113 moisture anomalies (units:  $\text{kg m}^{-2}$ ) regressed onto the time series of the IPO index in the **(a)**  
 114 all-forcing simulations, **(b)** control simulation, and **(c–h)** six subsets of the single-forcing  
 115 simulations. The dots in part **(b)** show significant anomalies at the 95% confidence level and the  
 116 dots in parts **(a, c–h)** denote that the significant anomalies at the 95% confidence level simulated  
 117 by at least two-thirds of the members agree on the sign of the average value.