



Supplement of

Effects of forcing differences and initial conditions on inter-model agreement in the VolMIP volc-pinatubo-full experiment

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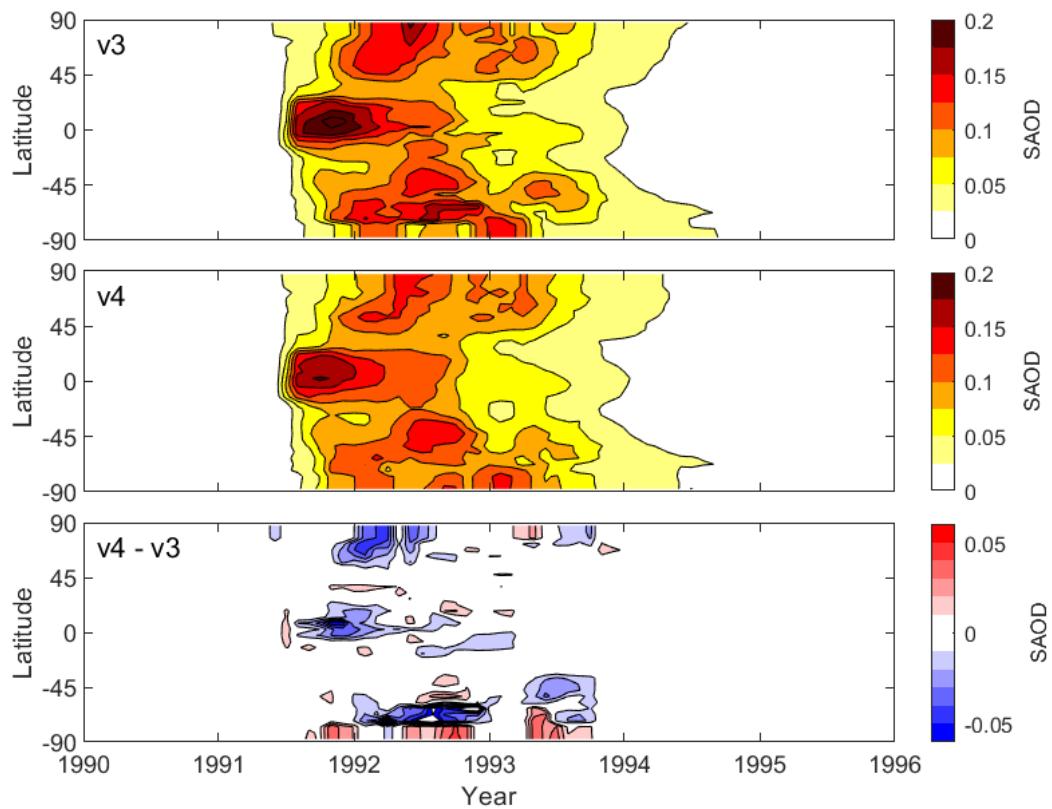


Figure S1 - Stratospheric aerosol optical depth for the Pinatubo period (1990-1996). Time-latitude evolution of monthly zonal-mean stratospheric aerosol optical depth (SAOD) at 550 nm from versions v3 and v4 of the CMIP6 volcanic forcing dataset (Luo, 2018a,b), and their differences.

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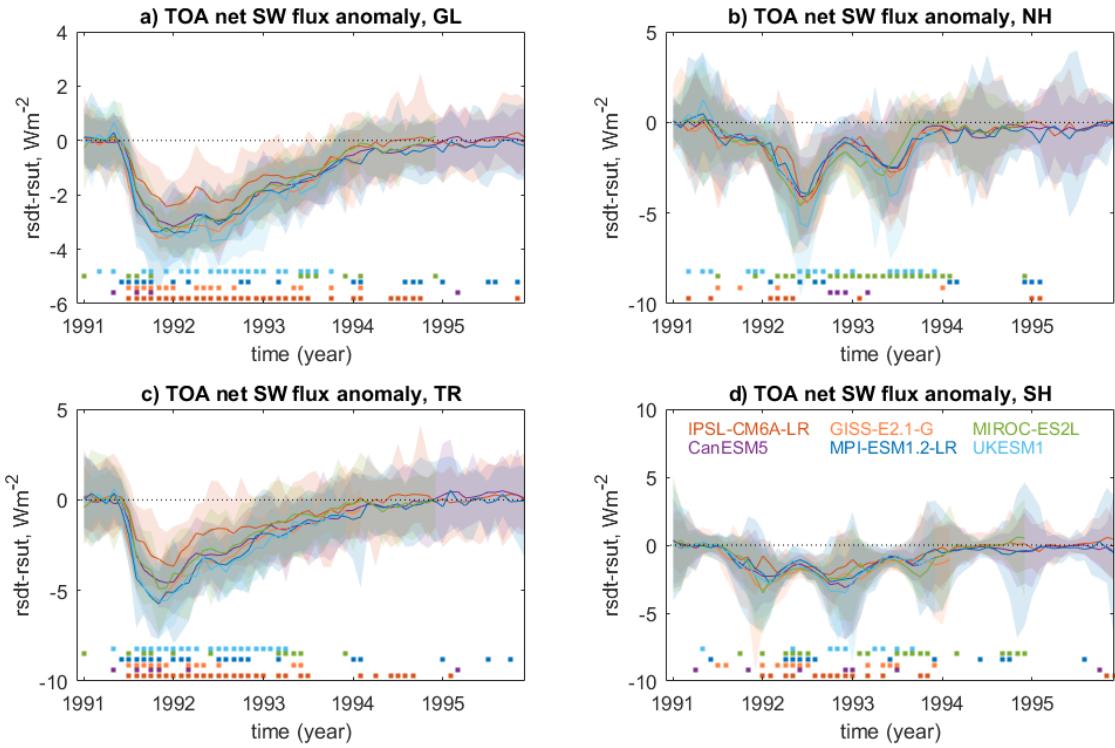
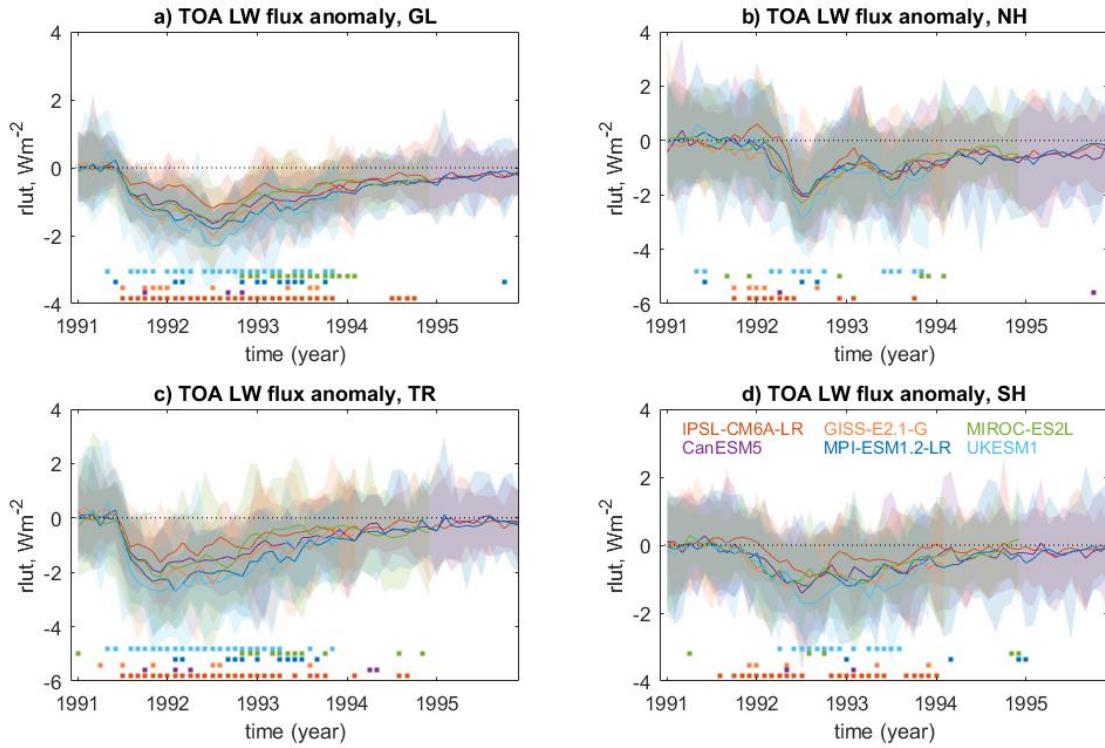


Figure S2: same as Figure 4, left panels (full sky), but for the short-wave (SW) radiation only.



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Figure S3: same as Figure 4, left panels (full-sky), but for the long-wave (LW) radiation only.

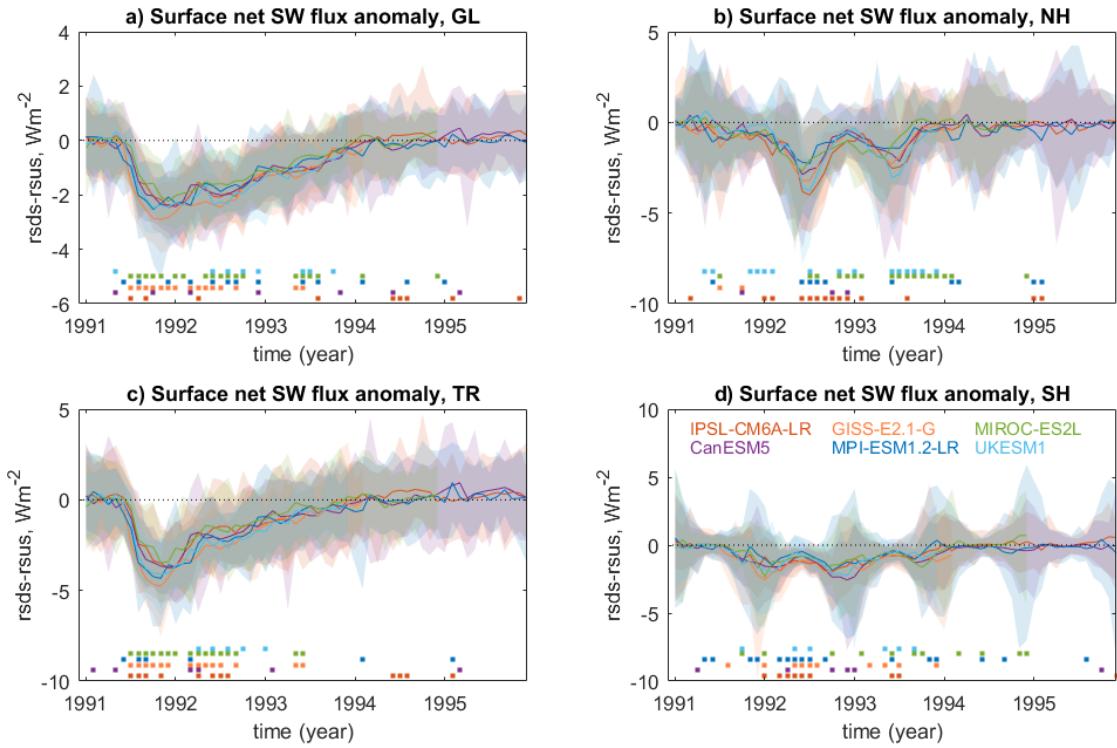
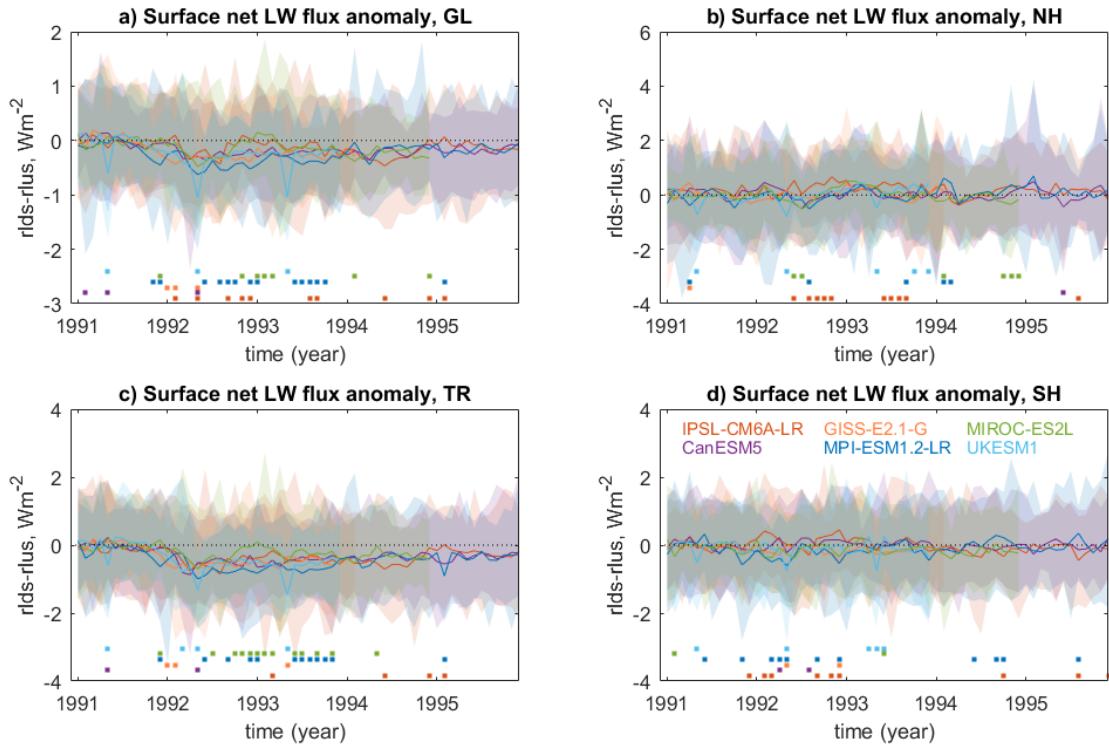


Figure S4: same as Figure 5, but for the short-wave (SW) radiation only.



50 Figure S5: same as Figure 5, but for the long-wave (LW) radiation only.

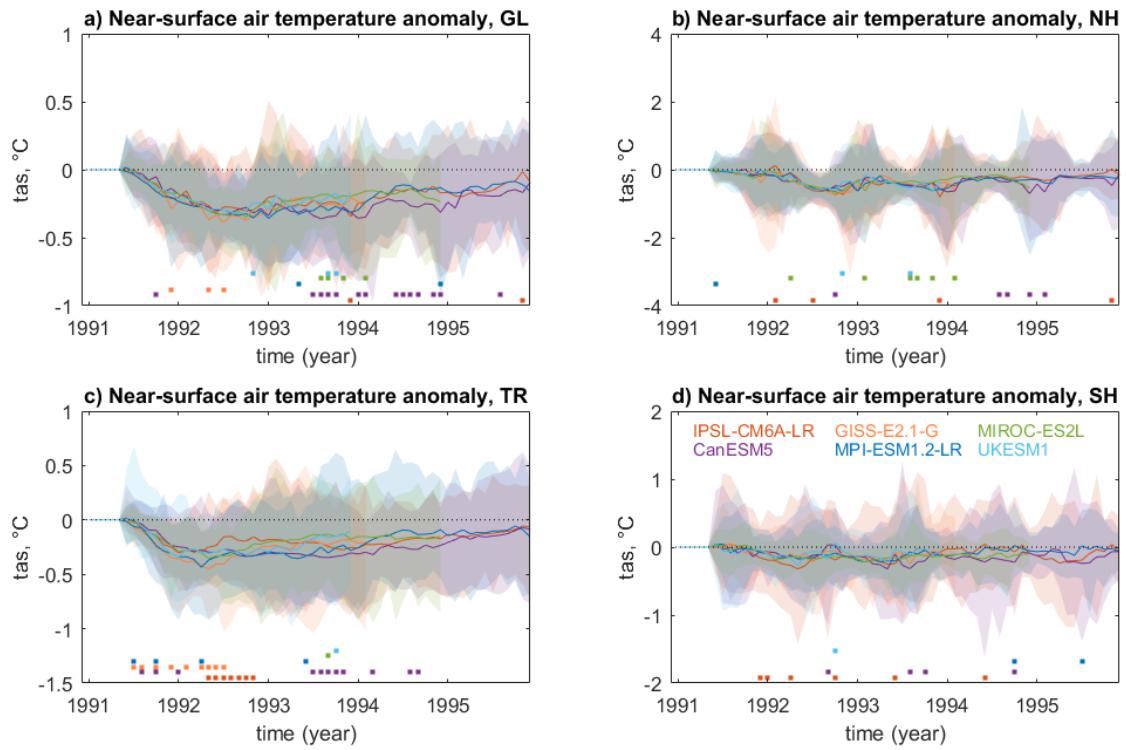


Figure S6: same as Figure 7, but for paired anomalies

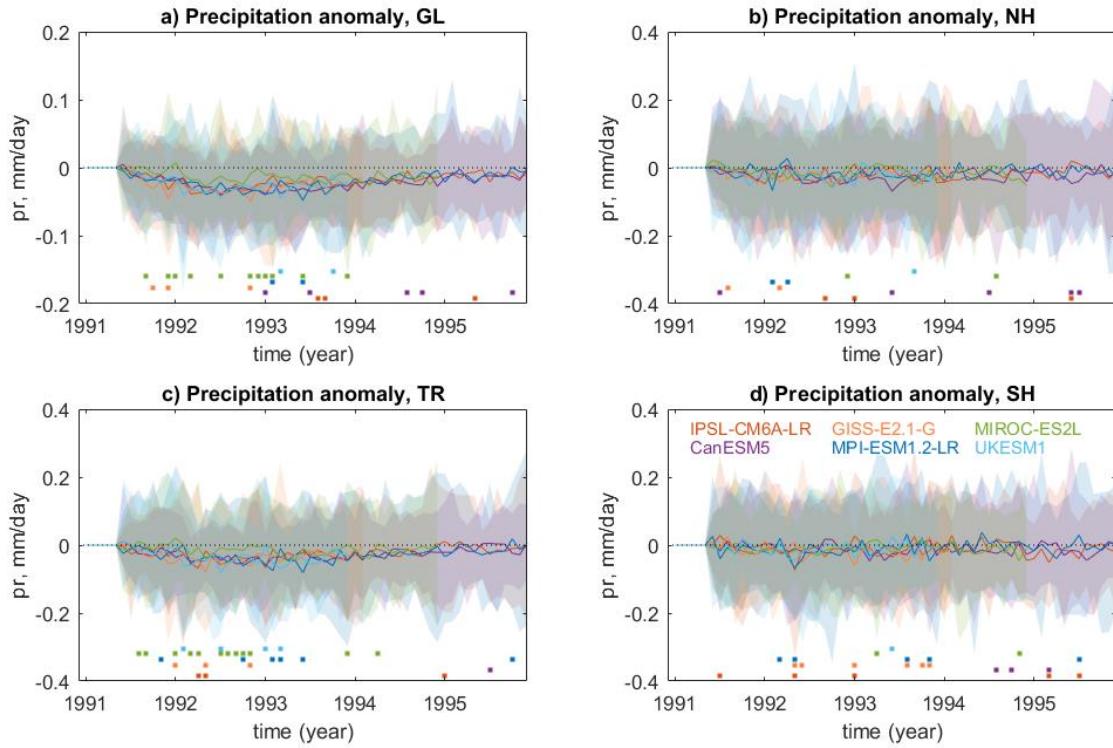


Figure S7: same as Figure 8, but for paired anomalies

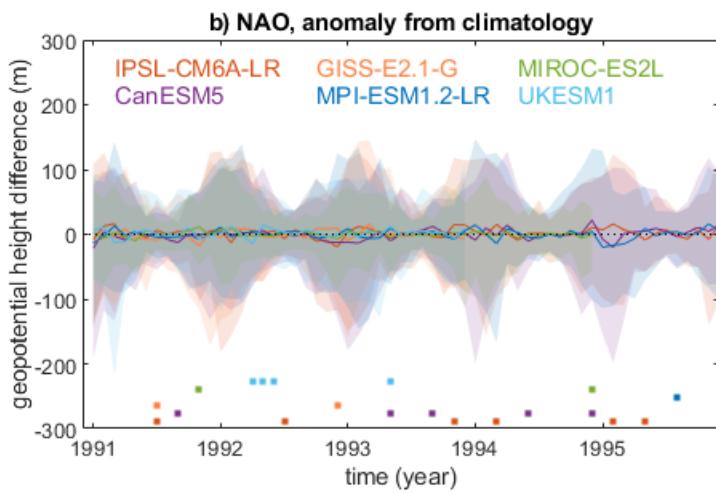
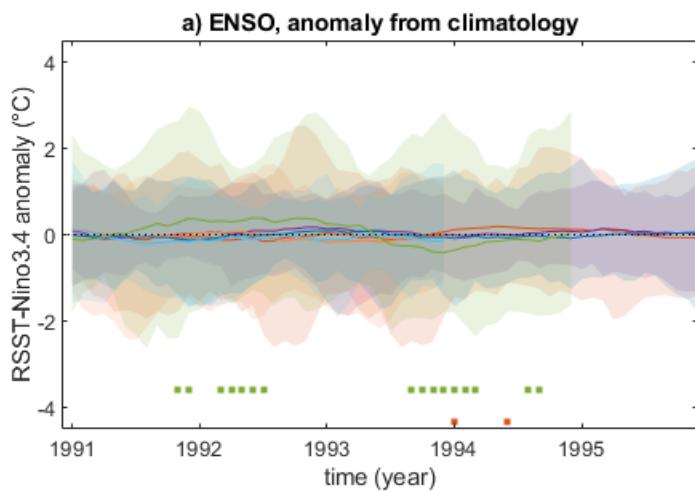
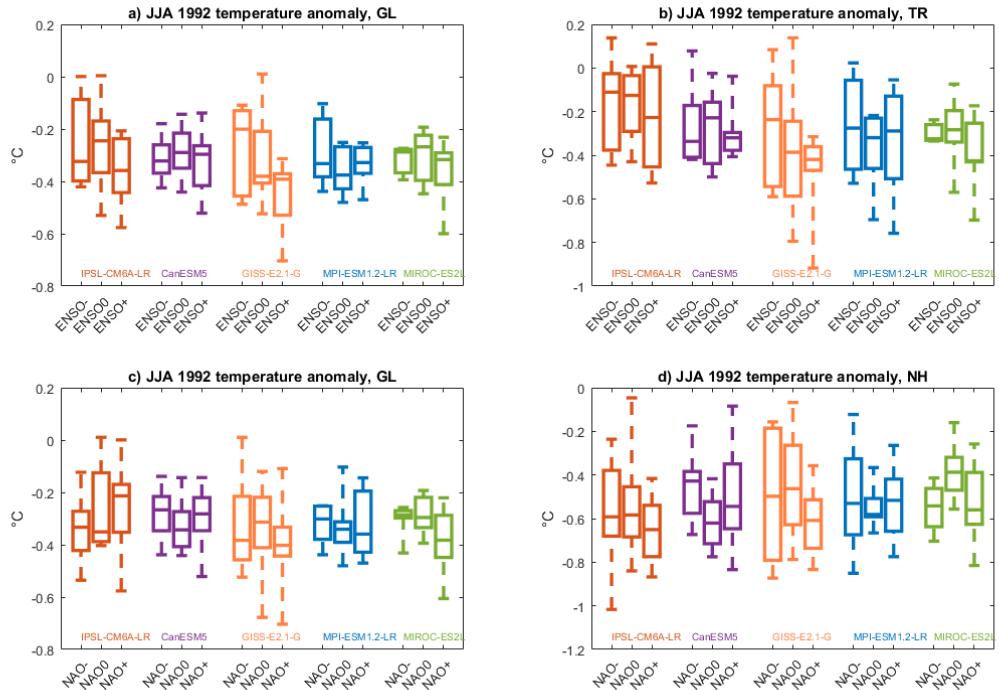
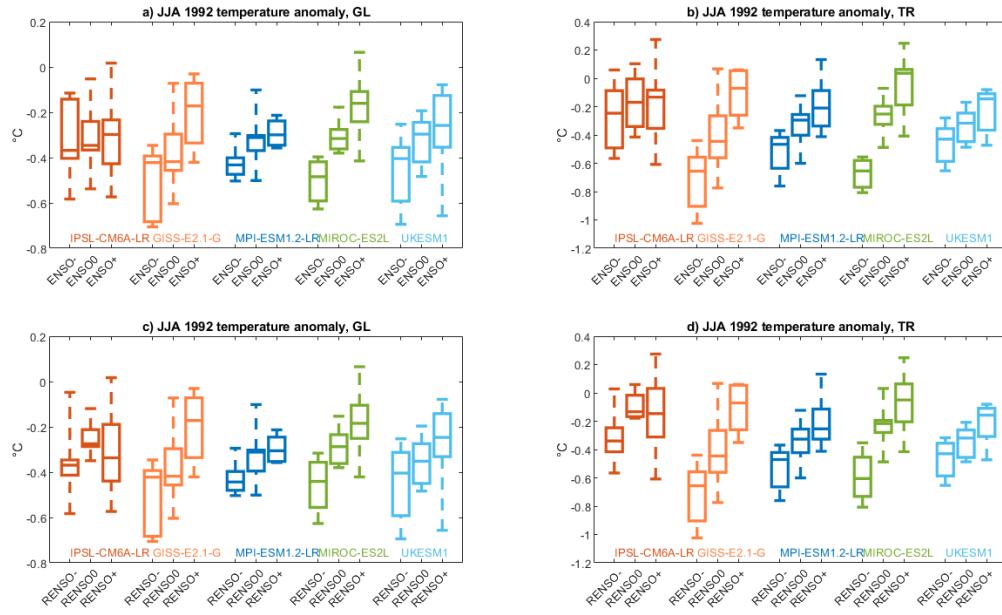


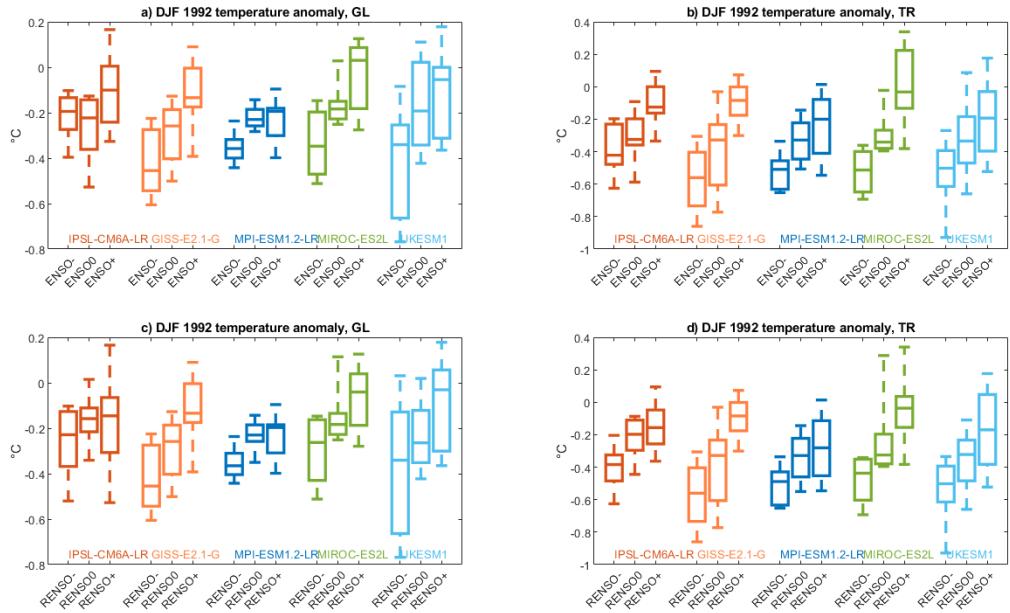
Figure S8: same as Figure 9a,b, but for anomalies to the climatology of the piControl chunks corresponding to the volc-pinatubo-full simulations.



60 **Figure S9: same as Figure 11, but for the paired anomalies of the second post-eruption boreal summer (1992 JJA).**

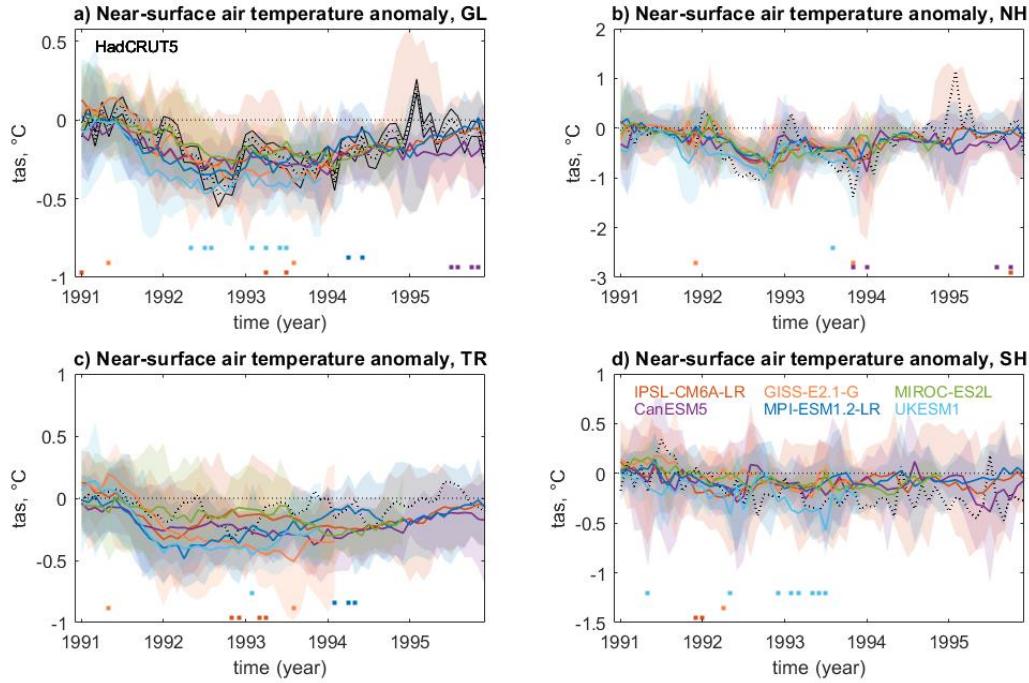


65 **Figure S10: same as Figure 11 but comparing two different indices for ENSO: the Nino3.4 index (labelled ENSO) defined by the VolMIP protocol, and the RSST-Nino3.4 index (labelled RENSO) that better captures ENSO dynamics.**



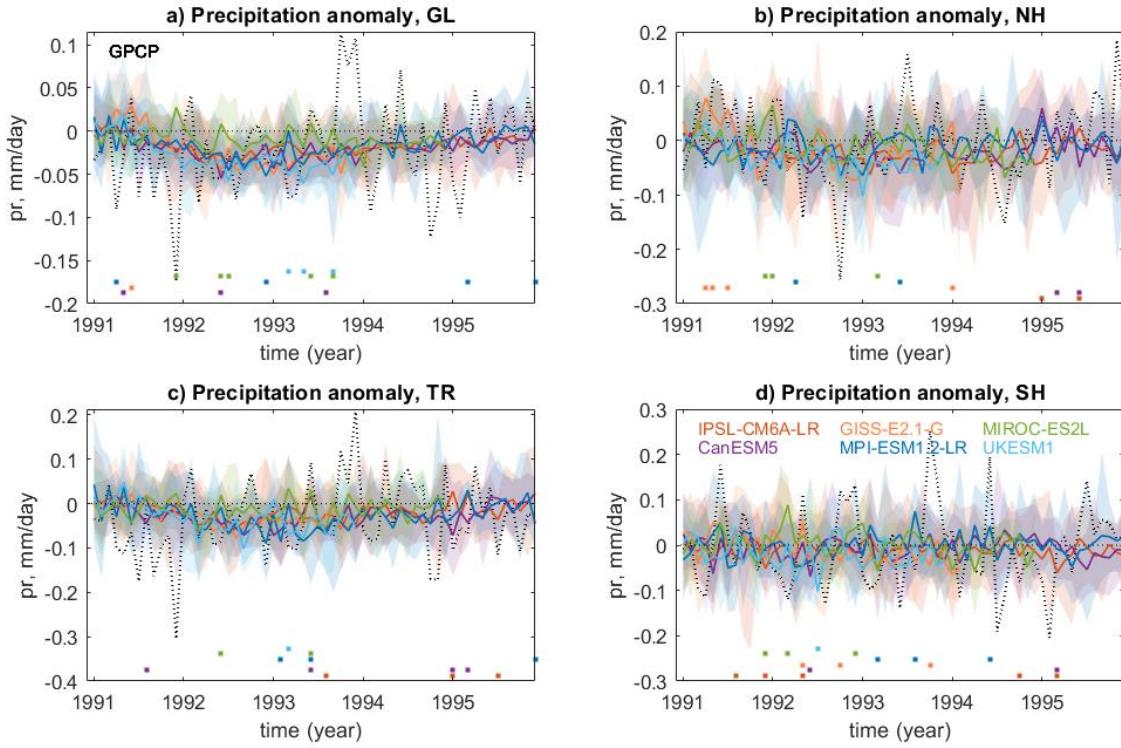
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Figure S11: same as Figure S10, but for first post-eruption winter (DJF 1992) anomalies.



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Figure S12: Same as Figure 7, but for ensemble members with a neutral phase of ENSO (DJF Nino3.4 anomaly between -0.25 °C and +0.25 °C) in the last pre-eruption winter only to match the observed state of ENSO in DJF 1991.



80 **Figure S13:** Same as Figure 8, but for ensemble members with a neutral phase of ENSO (DJF Nino3.4 anomaly between -0.25 °C and +0.25 °C) in the last pre-eruption winter only to match the observed state of ENSO in DJF 1991.

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IPSL-CM6A-LR

piControl years: 3050-3549

piControl years for branching volc-pinatubo-full simulations (r1...r25):

3066	3067	3070	3075	3128	3133	3149	3153	3155	3165	3178	3183	3189	3195	3236	3238
3243	3254	3262	3266	3274	3291	3313	3328	3329							

ENSO in piControl at peak of volcanic forcing (r1...r25):

1.3139	-1.0531	-0.1963	-2.1193	-0.2131	-0.5085	-0.0440	0.4131	-0.5327	0.1132	0.7283	0.1704	-0.4421	-0.0116	-0.2539	-0.3385
1.4598	1.3714	-1.9204	1.6965	0.9626	-0.5727	-0.5658	0.1826	0.6122							

NAO in piControl at peak of volcanic forcing (r1...r25):

-1.2929	-0.6619	1.4525	-0.3721	-0.4161	-0.1115	0.1238	-0.8107	0.2886	-0.6648	0.2805	-2.0535	-1.5312	0.8440	0.4152	-0.8767
2.1633	0.8811	1.2474	0.7124	1.4799	0.7151	-0.1870	-1.1045	-0.5697							

CanESM5

piControl years: 5550-6600

piControl years for branching volc-pinatubo-full simulations (r1...r25):

5551	5556	5574	5621	5642	5786	5789	5803	5844	5864	5880	5882	5898	5916	5964	5991
6007	6031	6032	6042	6057	6072	6091	6246	6257							

ENSO in piControl at peak of volcanic forcing (r1...r25):

-0.8288	0.1170	-0.7785	-0.3561	-0.3718	0.3808	-1.0078	0.4037	-0.5227	0.2512	-1.0210	0.0081	0.3116	1.3941	-0.0432	0.6103
0.9762	0.1065	1.5553	0.5986	-0.0113	0.9199	0.3258	1.0485	-0.3335							

NAO in piControl at peak of volcanic forcing (r1...r25):

-0.0024	0.1248	1.1421	0.2102	-0.5941	-0.2473	0.4951	-1.6006	1.4169	0.1279	1.4832	-0.9399	-0.5158	0.6277	1.3587	-0.5490
1.1062	-0.0363	-0.9572	1.0708	-0.2096	-0.7007	-1.3256	-1.8337	0.9438							

GISS-E2.1-G

piControl years: 8000-8399

piControl years for branching volc-pinatubo-full simulations (r1...r25):

8265	8356	8237	8071	8020	8101	8154	8270	8006	8255	8324	8275	8099	8115	8316	8086
8225	8203	8120	8164	8129	8266	8235	8194	8140							

ENSO in piControl at peak of volcanic forcing (r1...r25):

1.6656	1.0798	1.5310	1.6895	1.5014	1.5881	1.3629	1.2435	1.3704	-0.1191	0.0265	0.1047	-0.0901	-0.0518	0.1238	-0.1976
0.0366	-0.0311	-1.7577	-1.0752	-1.2003	-2.1684	-1.7046	-1.6290	-1.2595							

NAO in piControl at peak of volcanic forcing (r1...r25):

1.3580	1.6283	1.1564	-0.1837	-0.0133	0.1039	-1.9816	-2.0507	-1.7689	2.4215	1.9280	1.7769	-0.0328	-0.1232	-0.0855	-2.4412
1.9107	-1.8078	1.8767	2.4255	2.2691	0.0815	0.0967	0.1165	-3.0981							

MIROC-ES2L

piControl years: 1850-2349

piControl years for branching volc-pinatubo-full simulations (r1...r25):

1850 1860 1870 1880 1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010 2020 2030 2040 2050 2060 2070 2080 2090

ENSO in piControl at peak of volcanic forcing (r1...r25):

1.8228	-0.1039	-0.2263	2.5544	-0.2400	-1.2204	-1.3833	-0.1663	-0.0613	-1.6920	-0.3837	0.2486	0.6072	1.0409	0.6776	0.0966
1.4073	0.8944	-0.0913	1.0763	-0.2224	0.5695	0.5273	2.5359	-0.0665							

NAO in piControl at peak of volcanic forcing (r1...r25):

1.3019	-1.9210	0.5377	3.3539	-0.5376	-1.6559	-1.2357	1.0338	0.2341	0.3928	-0.3156	0.6071	0.5883	-1.0759	1.0171	0.0571
0.1807	0.0298	1.6525	0.5665	-0.4734	-0.7913	-0.5133	2.1205	0.3701							

MPI-ESM1.2-LR

piControl years: 1850-2349

piControl years for branching volc-pinatubo-full simulations (r1...r25):

1864	1908	1913	1932	1988	2004	2023	2027	2035	2042	2050	2074	2112	2139	2141	2148	2154
2166	2197	2201	2238	2287	2309	2317	2330									

ENSO in piControl at peak of volcanic forcing (r1...r25):

0.6669	-0.4345	0.1066	1.4150	0.7834	-0.1420	-2.0246	-2.3107	1.5930	-0.6053	-1.2501	1.3876	-1.0291	0.6707	-1.2416	0.7300	-
0.5309	-1.5277	-0.1226	-0.2122	0.1908	-0.9364	-0.7752	0.0250	0.4131								

NAO in piControl at peak of volcanic forcing (r1...r25):

-0.7656	1.4055	-1.7679	0.5932	-0.5884	-0.4532	1.0468	1.0862	2.5800	1.5606	-1.3373	-0.8160	0.2365	-0.2919	0.0837	-0.7036	
0.0623	-0.4074	0.3647	0.9894	0.0339	-0.3146	-0.9058	-0.6542	0.8744								

UKESM1

piControl years: 2600-3199

piControl years for branching volc-pinatubo-full simulations (r1...r25):

3174	3064	3067	3128	3116	3171	3138	3153	3052	3135	3141	3193	3058	3055	3061	3085	
3094	3049	3177	3165	3122	3073	3103	3076	3180								

ENSO in piControl at peak of volcanic forcing (r1...r25):

-0.6876	-1.3638	-0.6773	-0.4667	-0.1178	-0.3035	0.9558	0.9433	0.5625	-2.0329	-1.0158	-1.6912	-0.3406	-0.4220	0.3547	1.9542	
1.2563	0.9145	-1.9467	-2.0207	-1.0640	0.2111	0.0190										

NAO in piControl at peak of volcanic forcing (r1...r25):

-0.1421	-0.5491	0.0252	-0.4216	-0.2242	-0.4547	-1.9968	-1.2025	-0.6443	-0.0187	-0.8508	0.0146	-0.3255	-0.2657	-0.6545	0.3652	-
0.6569	0.0445	1.4182	1.2662	2.2894	1.6505	1.4297										

Supplementary Table S1 – Relevant information about the volc-pinatubo-full simulations and associated piControl simulation.

Model Realization	IPSL-CM6A-LR	CanESM5	GISS-E2.1-G	MPI-ESM1.2-LR	MIROC-ES2L	UKESM1
1	-0.2190	-0.3010	-0.1718	-0.3566	-0.1604	-0.4443
2	-0.3736	-0.3117	-0.4092	-0.3107	-0.2753	-0.2545
3	-0.3461	-0.3207	-0.0486	-0.3017	-0.3802	-0.2528
4	<i>-0.1196</i>	-0.2647	-0.2398	-0.2996	0.0496	-0.3320
5	-0.0476	-0.2735	-0.0794	-0.2589	-0.2768	-0.4836
6	<i>-0.2101</i>	-0.1607	-0.0305	-0.3888	-0.3968	-0.4067
7	-0.1492	-0.3830	-0.3111	-0.3571	-0.4843	-0.2346
8	-0.2747	-0.1459	-0.4208	-0.4737	-0.3705	-0.0784
9	-0.3682	-0.2899	-0.1345	-0.3577	-0.1752	-0.2579
10	-0.5435	-0.4150	-0.2406	-0.4211	-0.6267	-0.4040
11	-0.3751	-0.4211	-0.4540	-0.5034	-0.3158	-0.3885
12	-0.3492	-0.1904	-0.4644	-0.2131	-0.3225	-0.6944
13	-0.2899	-0.1699	-0.3151	-0.2945	-0.1047	-0.1963
14	-0.3700	-0.1688	-0.3341	-0.2315	-0.2510	-0.4555
15	-0.2290	-0.3922	-0.4178	-0.4733	-0.2969	-0.1933
16	-0.3563	-0.2029	-0.0721	-0.3117	-0.3351	-0.2859
17	-0.2980	-0.4162	-0.4241	-0.4009	-0.2130	-0.0898
18	-0.2775	-0.2390	-0.6036	-0.4100	-0.2084	-0.3768
19	<i>-0.4133</i>	-0.0726	-0.6956	-0.3120	-0.2210	-0.6231
20	-0.4446	-0.4759	-0.6449	-0.5013	-0.4209	-0.5815
21	0.0172	-0.2895	-0.3458	-0.3033	-0.3785	-0.4043
22	<i>-0.1152</i>	-0.1607	-0.7054	-0.4433	-0.1198	-0.2601
23	-0.5830	-0.3250	-0.3978	-0.4995	-0.1519	-0.2886
24	-0.4340	-0.3544	-0.4219	-0.1014	0.0654	-0.2964
25	-0.5733	-0.3712	-0.3911	-0.3491	-0.2873	-0.6568

Supplementary Table S2 – Global-mean near-surface air temperature anomalies ($^{\circ}\text{C}$) for the second post-eruption boreal summer (JJA 1992) in the volc-pinatubo-full multi-model ensemble against the ENSO sampling conditions identified by the VolMIP protocol (normal fonts: neutral ENSO; italics: negative ENSO; bold fonts: positive ENSO). ENSO sampling conditions are identified by standardized winter-average (DJF) Nino3.4 states (positive if >0.5 , negative if <-0.5 , neutral/zero if in between) during the first post-eruption winter under unperturbed conditions (see Sect. 2.2). The data are used in Figure 11.

Model Realization	IPSL-CM6A-LR	CanESM5	GISS-E2.1-G	MPI-ESM1.2-LR	MIROC-ES2L	UKESM1
1	-0.0292	-0.0498	-0.0077	-0.0125	-0.0127	-0.0447
2	-0.0465	-0.0166	-0.0367	-0.0224	-0.0231	-0.0341
3	-0.05	<i>-0.031</i>	-0.0049	-0.0233	-0.0328	-0.0424
4	-0.0182	-0.0201	-0.0419	-0.0306	0.0126	-0.017
5	-0.0254	-0.0353	-0.007	-0.022	-0.0219	-0.0202
6	<i>-0.0194</i>	-0.0094	-0.0277	-0.0472	-0.0274	-0.0389
7	-0.0192	<i>-0.0421</i>	-0.0342	-0.0193	-0.0352	-0.0117
8	-0.0578	-0.0199	-0.018	-0.0442	-0.027	-0.0128
9	-0.0402	<i>-0.0215</i>	0.0053	-0.0263	-0.0087	-0.0315
10	-0.0479	-0.0386	-0.0275	-0.0398	<i>-0.0467</i>	-0.035
11	-0.029	-0.0472	-0.0463	-0.0665	-0.0177	-0.0377
12	-0.0423	-0.0476	-0.0371	-0.0465	0.0017	-0.061
13	-0.0298	-0.0388	-0.0542	-0.0338	-0.0039	-0.0381
14	-0.0394	-0.0421	-0.0251	-0.0418	-0.0166	-0.0466
15	-0.0312	-0.0324	-0.0379	-0.0437	-0.0085	-0.0191
16	-0.0424	-0.0279	-0.0128	-0.0459	-0.0224	-0.0143
17	-0.0265	-0.0527	-0.068	-0.0277	-0.0373	-0.0118
18	-0.0489	-0.022	-0.0402	-0.0413	-0.016	-0.0527
19	-0.0635	-0.0155	-0.0397	-0.0306	0.0278	-0.0838
20	-0.0299	-0.0231	-0.0401	-0.0442	-0.0394	-0.0626
21	-0.0016	-0.0289	<i>-0.0393</i>	-0.0199	-0.0182	-0.0437
22	<i>-0.0113</i>	-0.0333	<i>-0.0619</i>	-0.0387	-0.0019	-0.0327
23	-0.0625	-0.0505	<i>-0.0533</i>	-0.0302	0.0108	-0.0378
24	-0.0386	-0.0311	<i>-0.0468</i>	-0.0168	0.0388	-0.0329
25	-0.0634	-0.055	<i>-0.0395</i>	-0.0178	-0.006	-0.0494

Supplementary Table S3 – Global-mean total precipitation anomalies (mm/day) for the second post-eruption boreal summer (JJA 1992) in the **volc-pinatubo-full** multi-model ensemble against the ENSO sampling conditions identified by the VolMIP protocol (normal fonts: neutral ENSO; italics: negative ENSO; bold fonts: positive ENSO). ENSO sampling conditions are identified by standardized winter-average (DJF) Nino3.4 states (positive if >0.5, negative if <-0.5, neutral/zero if in between) during the first post-eruption winter under unperturbed conditions (see Sect. 2.2).