

Supplementary Information

Table S1. Mean fluxes for key circulation parameters during a cross-section of the simulations. Means are taken over the last 2 years of the respective simulation (see Fig. S2 for typical variation of some of these). All fluxes are in Sv and air temperature (T) in °C. ST=sub-tropical, SP=sub-polar, SH=Southern Hemisphere. All dates are ka BP.

Experiment	16	18	20	22	24	26	28	30
Winter Air T 40-50°N	10.34	10.63	10.85	10.95	10.91	10.78	10.61	10.46
Winter Air T 40-50°S	7.41	7.38	7.34	7.29	7.24	7.22	7.24	7.27
AMOC	14.37	14.35	14.29	14.25	14.29	14.36	14.44	14.52
Atlantic sub- tropical gyre	43.22	43.29	43.34	43.35	43.34	43.31	43.27	43.23
Atlantic sub- polar gyre	20.27	20.10	19.92	19.85	19.94	20.11	20.31	20.51
Gibraltar exchange	0.34	0.33	0.33	0.32	0.33	0.33	0.33	0.33
Pacific overturning	8.53	8.74	9.16	9.55	9.63	9.41	9.05	8.70
Pacific sub- tropical gyre	39.64	39.65	39.70	39.76	39.76	39.71	39.65	39.61
Pacific sub- polar gyre	16.20	16.16	16.07	15.97	15.93	16.00	16.10	16.19
Indonesian Throughflow	7.26	7.12	7.06	7.02	6.92	6.89	6.94	6.99
SH overturning	17.28	17.39	17.49	17.50	17.46	17.44	17.37	17.27
Drake Passage	112.73	112.61	112.54	112.61	112.47	112.36	112.35	112.32

Figure S1. Variation of orbital parameters over the past 50,000 years. Also shown, in the bottom panel, is the impact on daily July insolation at the top of the atmosphere at 65°N. The period of 31-16 ka BP studied here is marked by the double-headed arrow.

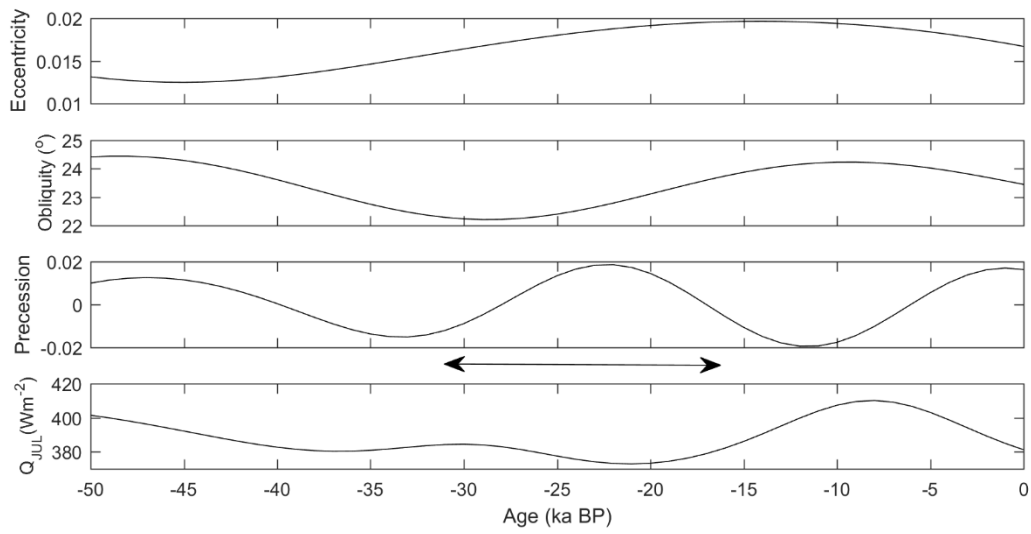


Figure S2. Plots of four major large-scale ocean parameters in the North Atlantic region during the transition from the last 10 years of the spin-up (where the orbital parameters are as for 21 ka BP) through 10 years of forcing with orbital parameters for 31 ka BP. Note that by year 5 of the new state the variables are approaching a new annual cycle equilibrium. This is the largest parameter change relative to the spin-up phase.

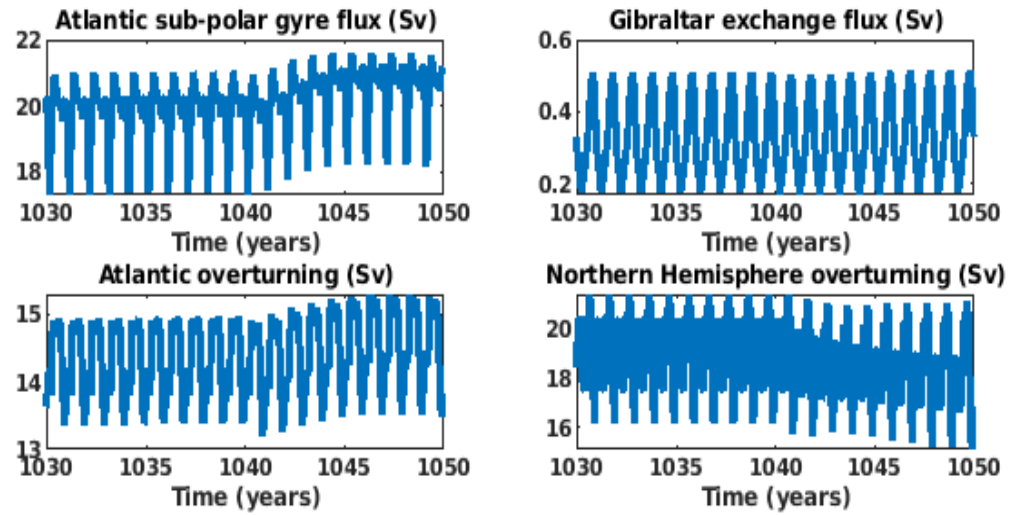


Figure S3. The mean 30 m ocean current over the last two years of a selection of simulations is shown for the NE Atlantic (16, 20, 26 and 30 ka BP). Arrow length is linearly related to speed, with longest $\sim 30 \text{ cm s}^{-1}$. The data is shown over the model x and y grids.

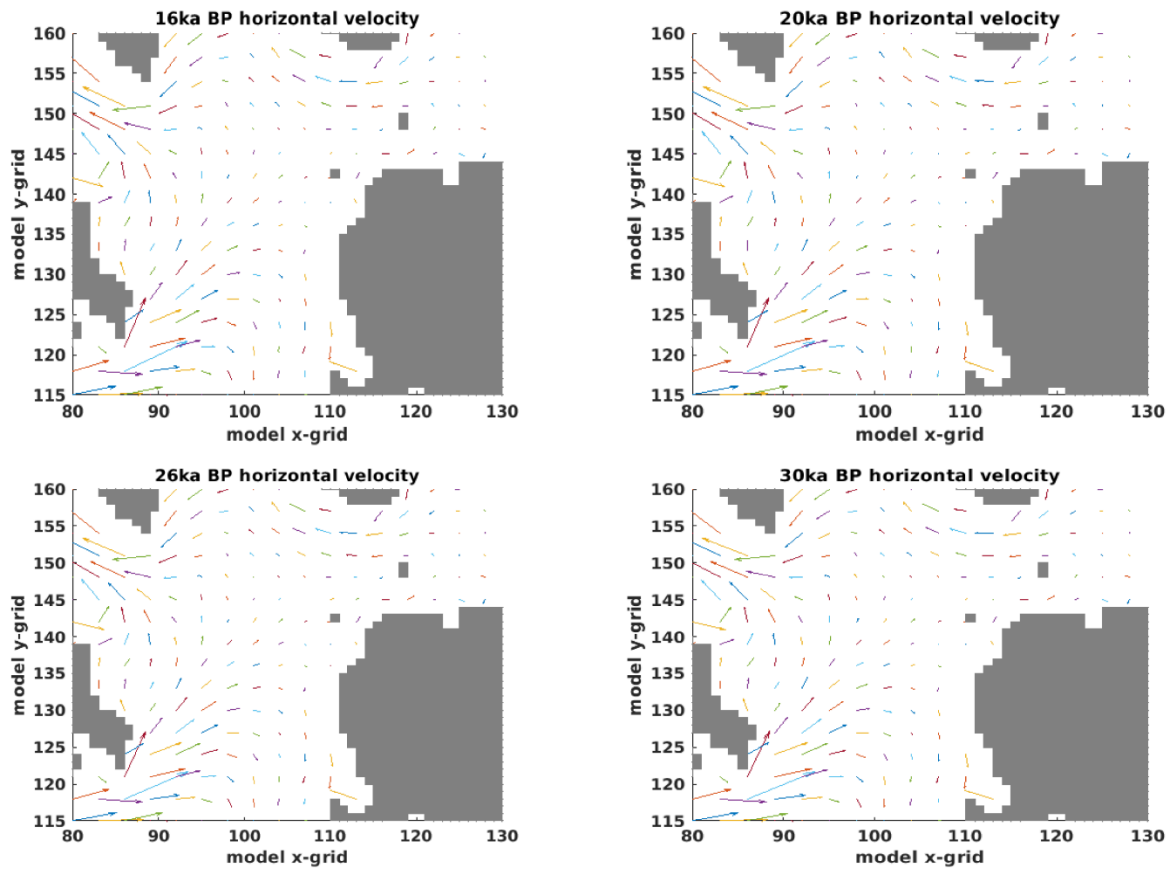


Figure S4. Bar charts of the IRD source variation over time within 2° of the 5 IRD marine cores, using modelled iceberg mass (in Tg) as a proxy. This simulation also includes the Porcupine and Irish Sea modified release sites, shown in Fig. 7. Note that the dotted line is the total BIIS iceberg flux (in km³ yr⁻¹; see right-hand scale), as reconstructed in Fig. 3. See Figs. 1 and 3 for release sites.

