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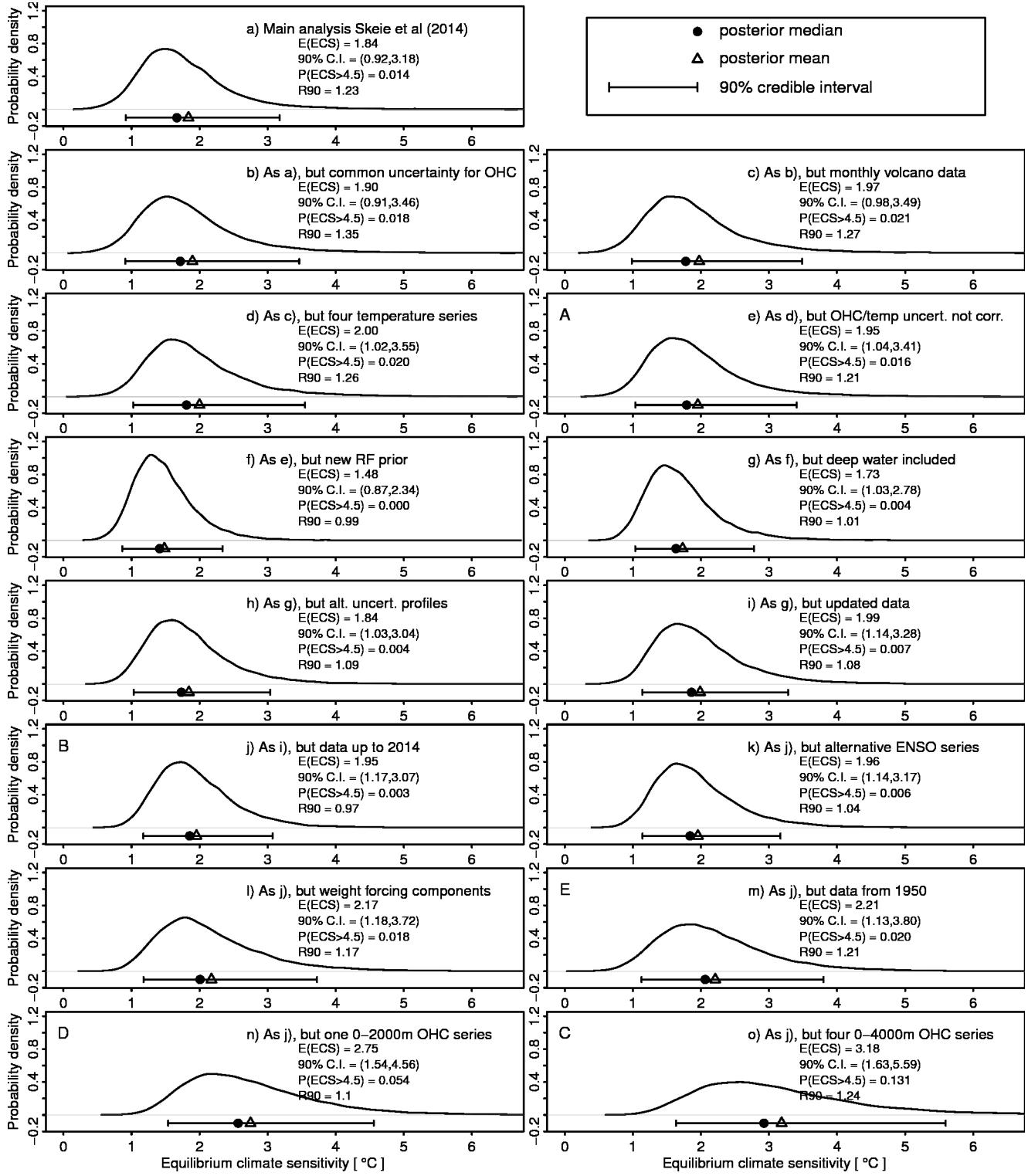
*Supplement of*

## **Climate sensitivity estimates – sensitivity to radiative forcing time series and observational data**

**Ragnhild Bieltvedt Skeie et al.**

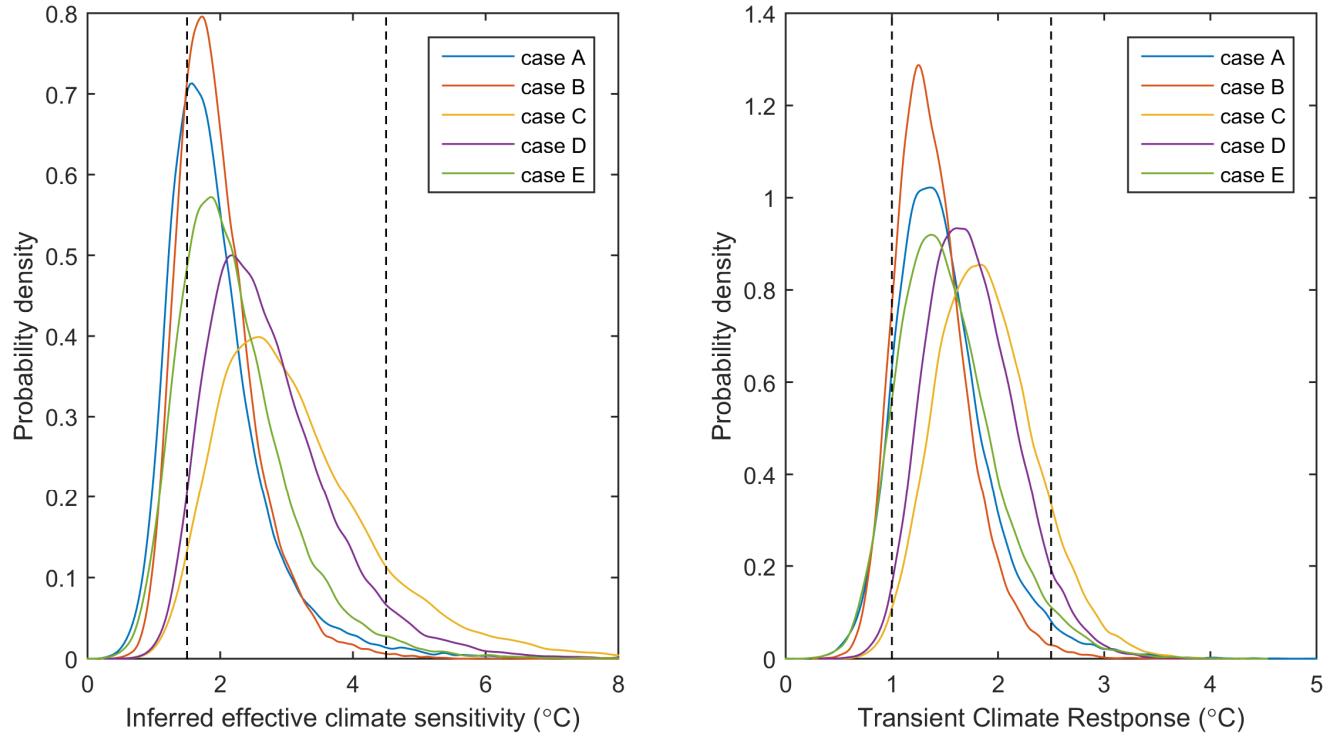
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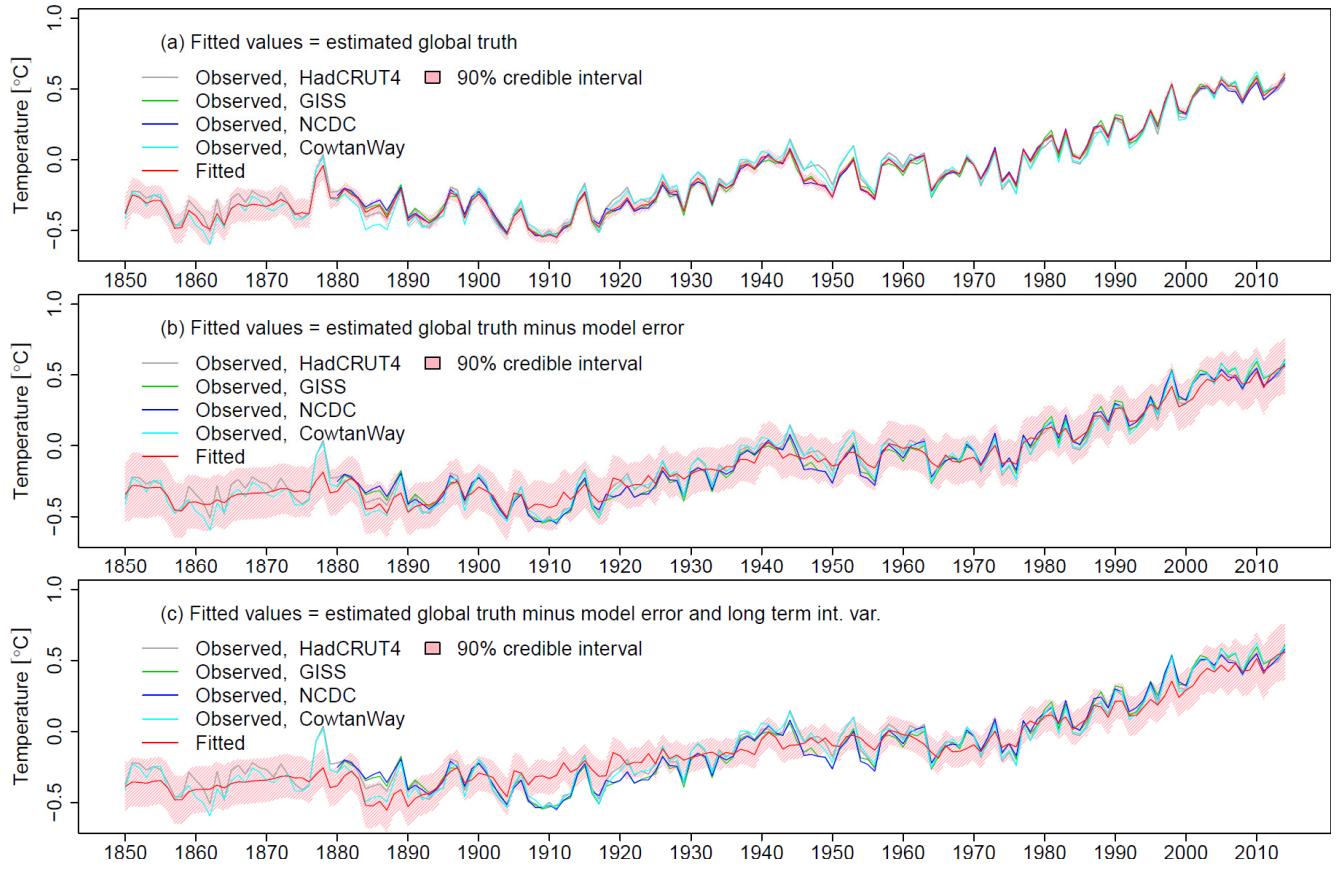


**Figure S1.** Posterior distributions for the  $\text{ECS}_{\text{inf}}$  for all the analyses in this work. In **(a)** the main results from Skeie et al. (2014), **(b)** assumed a common observational uncertainty profile for the OHC data, **(c)** replaced yearly volcanic forcing with monthly forcing data, **(d)** included an additional data series for hemispheric temperature, **(e)** assume zero correlation for the temperature and OHC observational errors which is the starting point in the main text (case A), **(f)** replaced the original forcing priors with forcing priors from IPCC AR5 **(g)** included ORAS4 data above and below 700 meter **(h)** use the original ORAS4 standard error for OHC above and below 700 meter, **(i)** use updated observational data , **(j)** use observational data

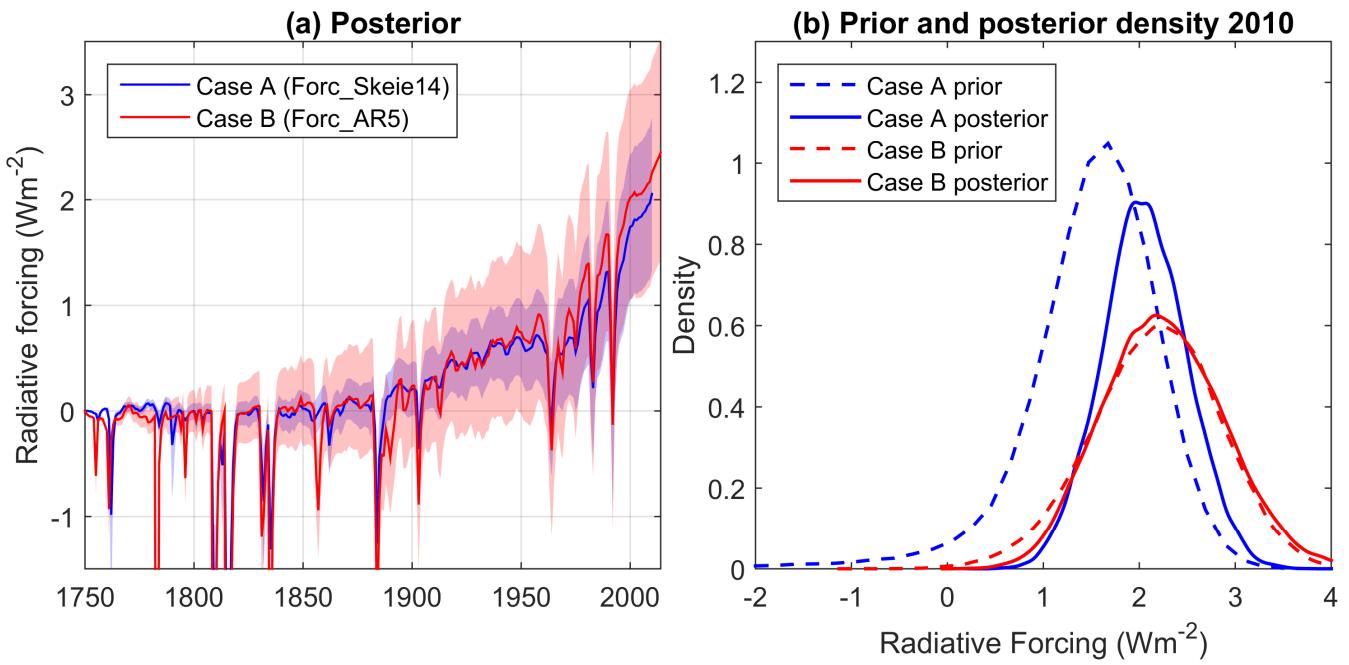
up to and including 2014 (case B), (k) using an alternative ENSO index (NINO3.4), (l) use different weights for the forcing components, (m) exclude observational data prior to 1950 (case E), (n) use only Levitus2000 OHC data (case D) and (o) use four total OHC observational time series but without separating above and below 700 meter (case C). The estimated mean of  $ECS_{inf}$ , the 90% C.I. and the probability of  $ECS_{inf}$  being larger than  $4.5^{\circ}\text{C}$  are given in the text box of each panel as well as the relative uncertainty measure R90 defined as the width of the 90% C.I. divided by the posterior mean. The 90% C.I. (the error bar) and estimated posterior mean (triangle) and median (black dot) are also indicated in each panel. The upper-case letter in the upper left corner indicates the main cases.



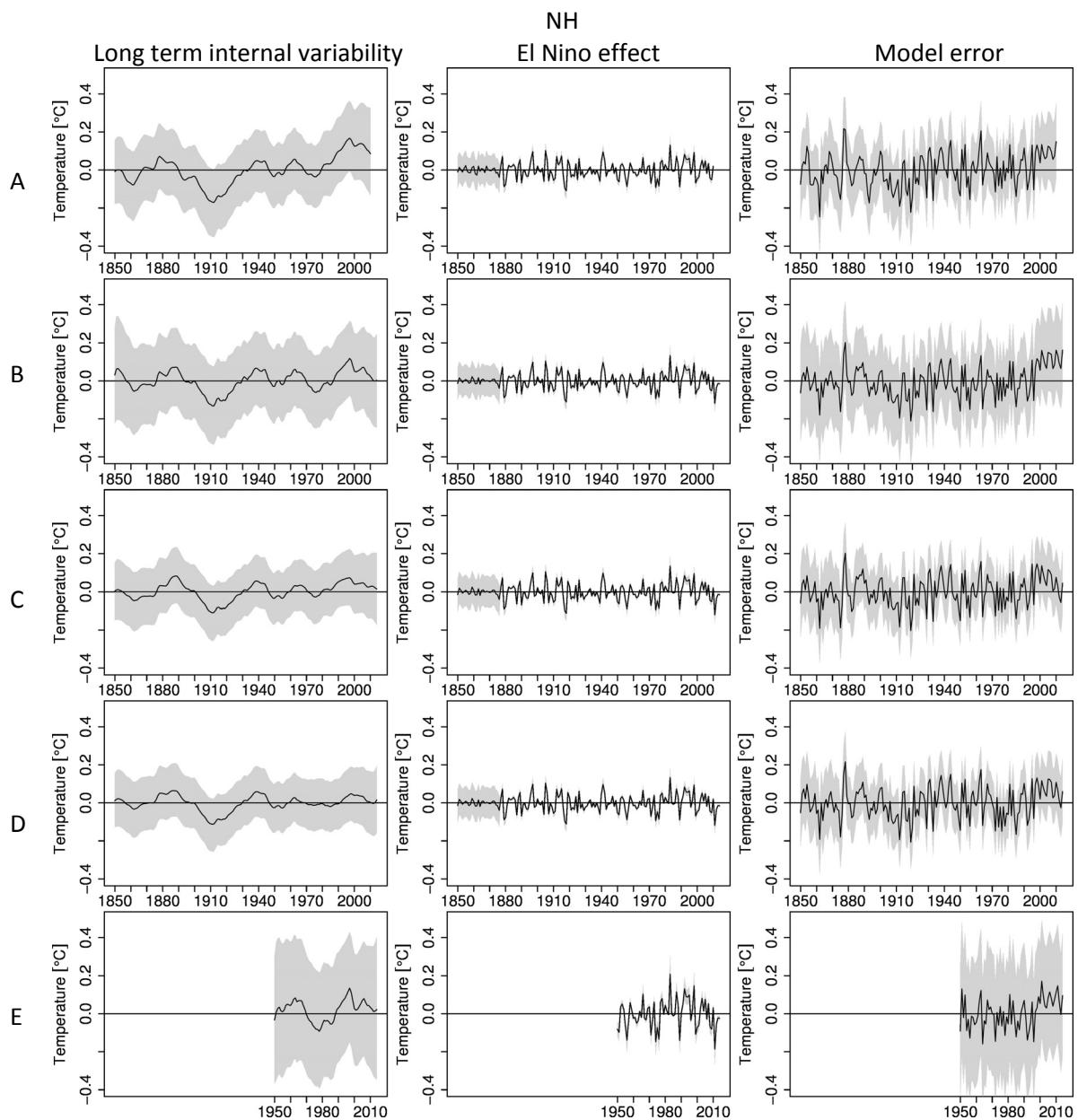
**Figure S2.** Posterior distributions for the  $ECS_{inf}$  (a) and TCR (b) for the five main analyses in this work. The IPCC AR5 likely (>66% probability) range for ECS (a) and TCR (b) is indicated by vertical dashed lines.



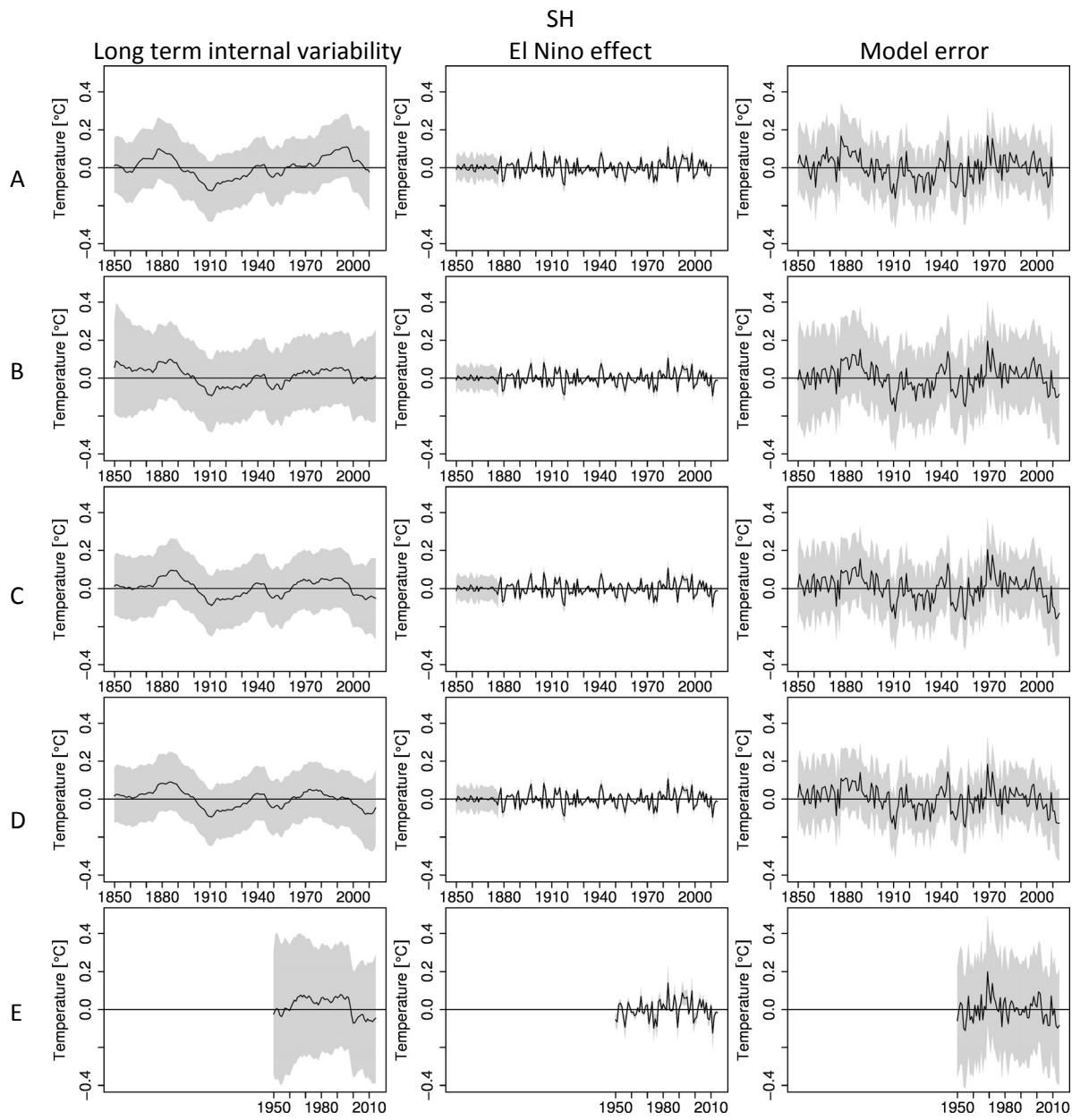
**Figure S3** Observed and fitted (posterior mean) values for GMST. The shaded areas show the 90% C.I. for fitted values. In a) the fitted values are the sum of the output from the deterministic SCM including model error and short- and long-term internal variability. In b) the fitted values are the sum of the output from the deterministic SCM and short- and long-term internal natural variability excluding the term for model error. In c) the fitted values are as presented in Fig. 2 i.e. the sum of the output from the deterministic SCM and the short-term internal variability excluding the terms for long-term internal variability and model error.



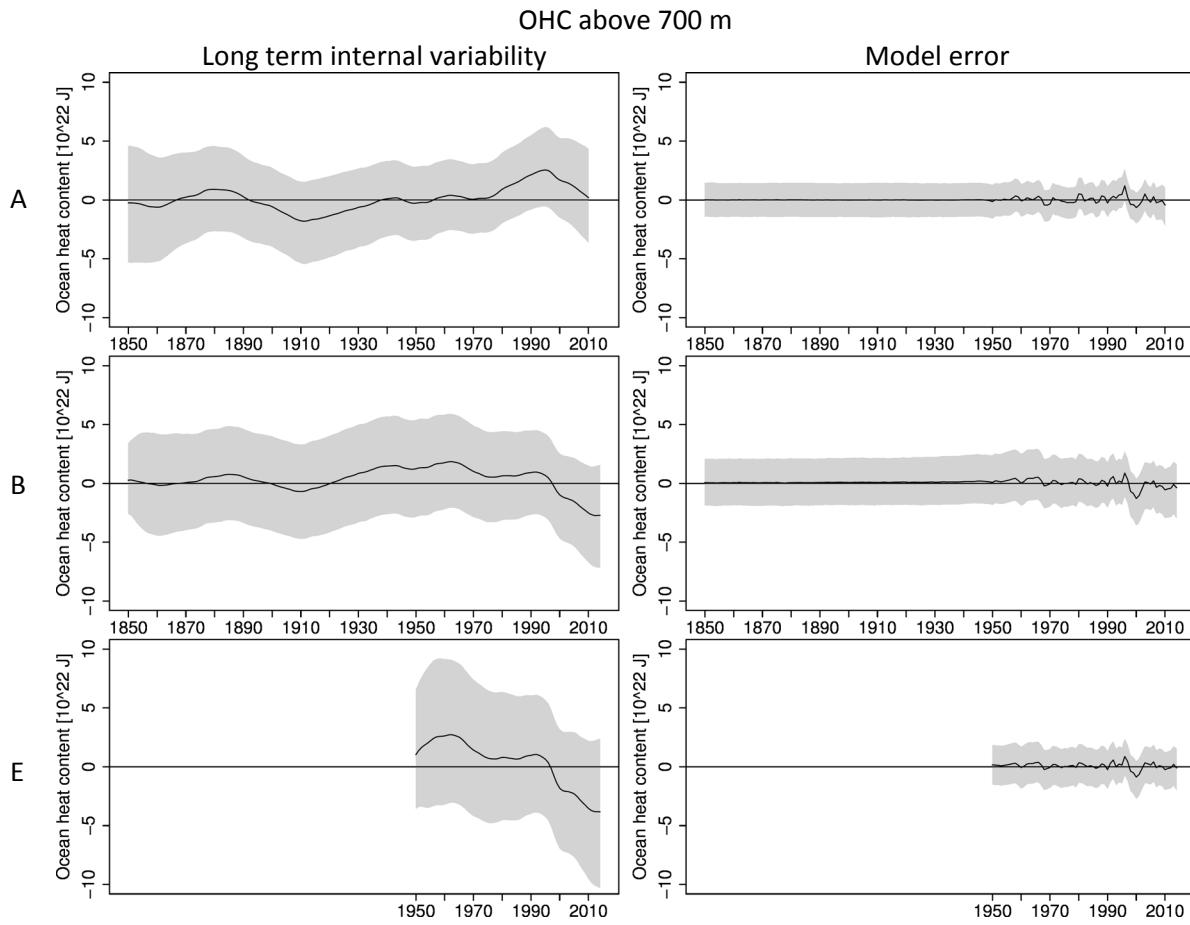
**Figure S4.** Posterior distribution of time series **(a)** and prior (dotted) and posterior (solid) probability density function (PDF) in 2010 **(b)** for total forcing. The shaded areas in **(a)** represent the 90% C.I.



**Figure S5a** For all main cases (A-E) posterior estimates of the long-term internal variability term (left column), the ENSO term (middle column) and the model errors (right column) for the northern hemispheric temperature.



**Figure S5b** Same as Fig. S4a but for southern hemispheric temperature.



**Figure S5c** Same as Fig. S4a but for the long-term internal variability term (left column) and the model errors (right column) for the OHC above 700m for case A, B, and E.

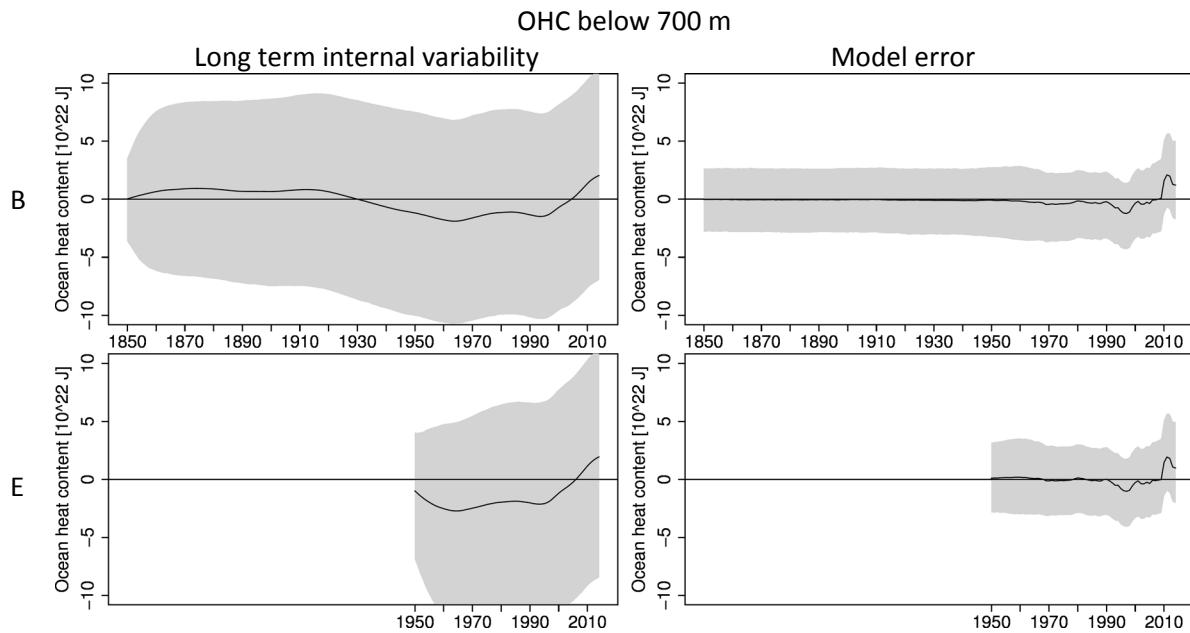


Figure S5d Same as Fig. S4c but for OHC below 700m for case B and E.

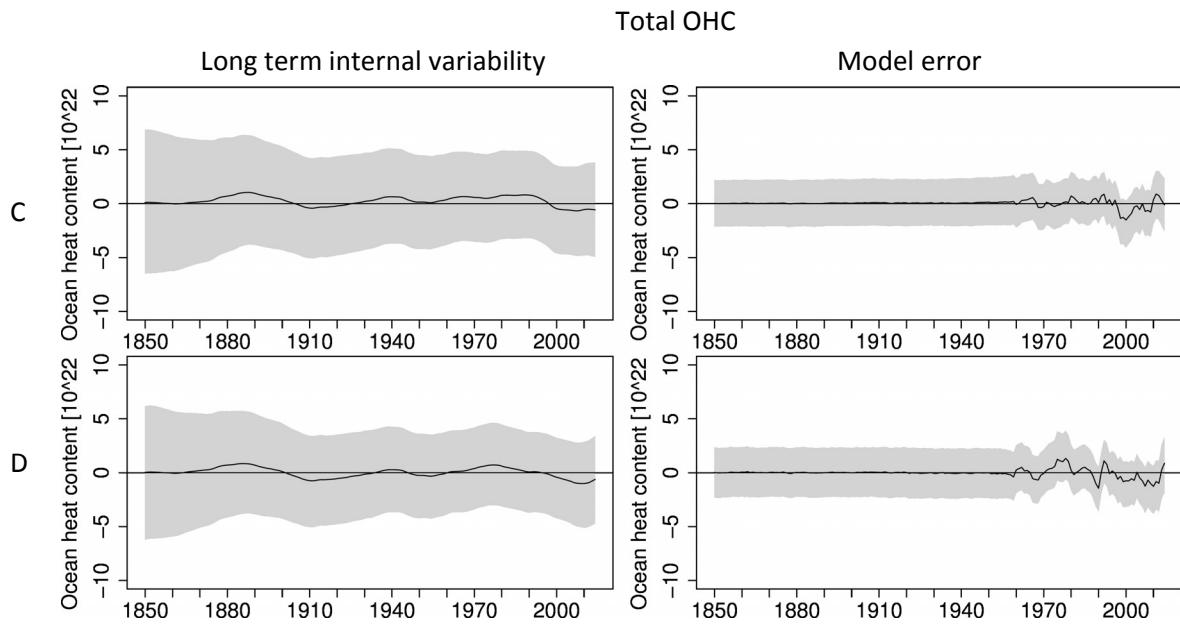
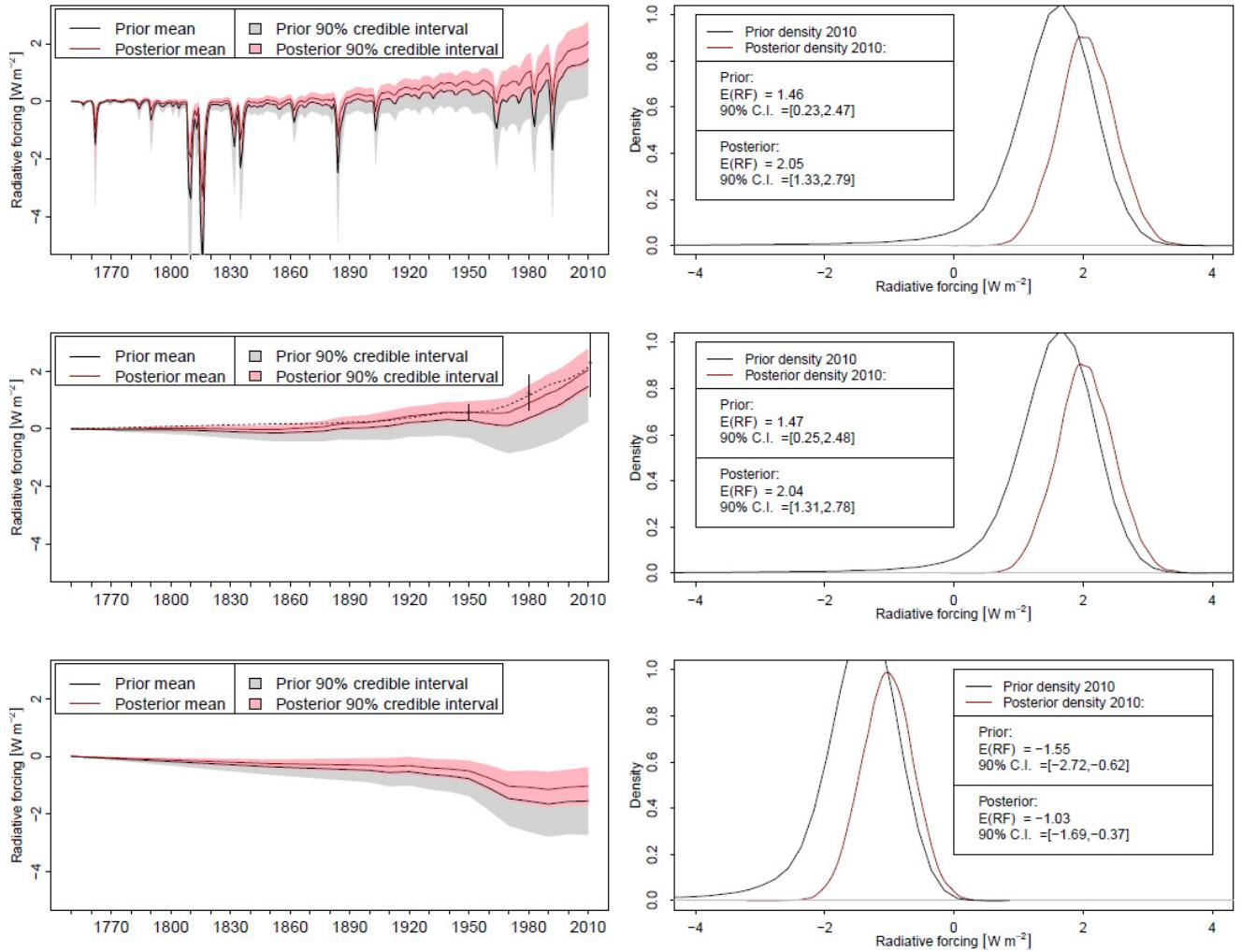


Figure S5e Same as Fig. S4c but for total OHC for case C and D.



**Figure S6a.** For Case A the prior and posterior distribution of the RF time series and PDF of RF in 2010 for total RF (upper panel), anthropogenic RF (middle panel) and total aerosol effect (lower panel). Red color for the posterior distributions and black lines and grey shadings for the prior distribution.

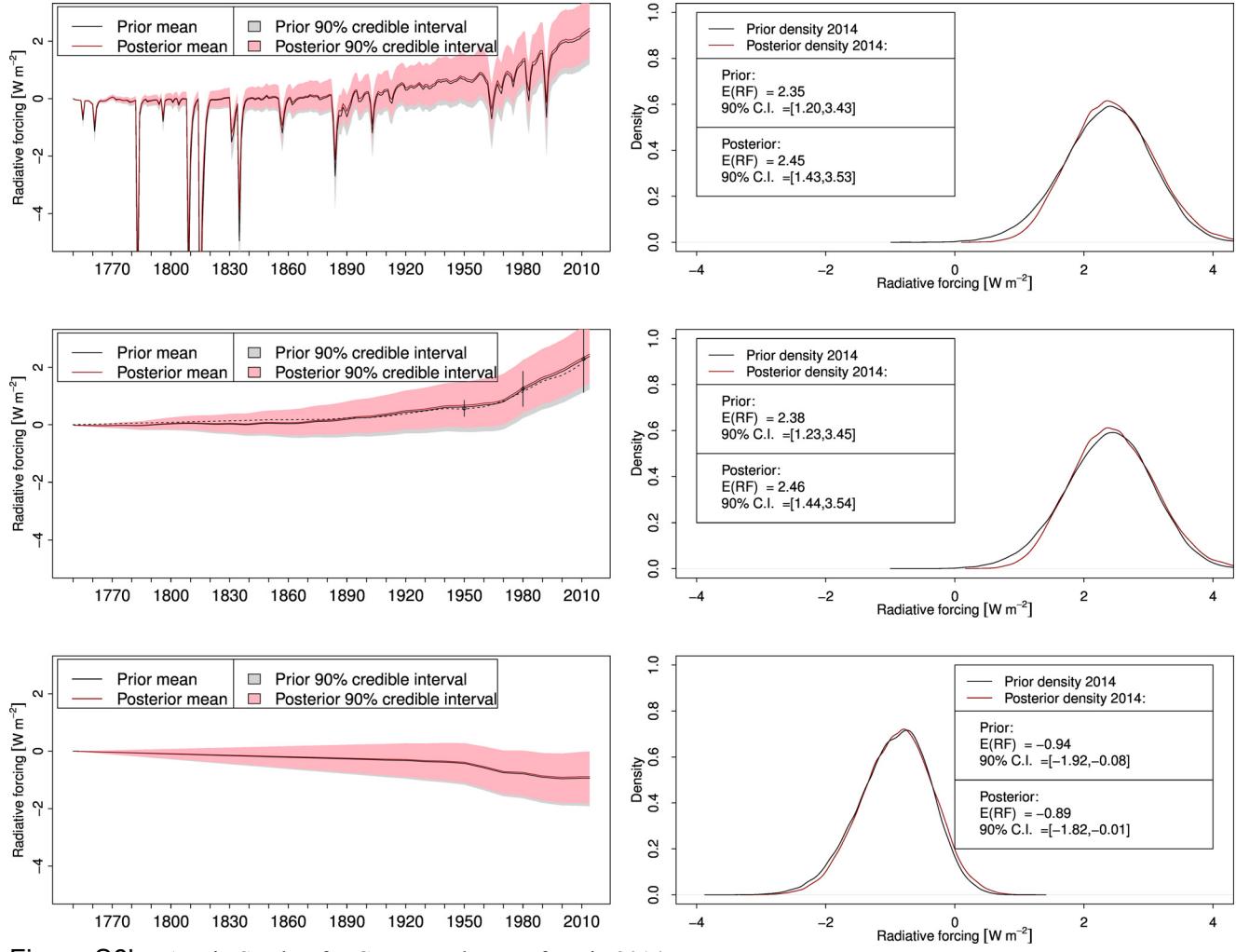


Figure S6b. As Fig S7a but for Case B and PDF of RF in 2014.

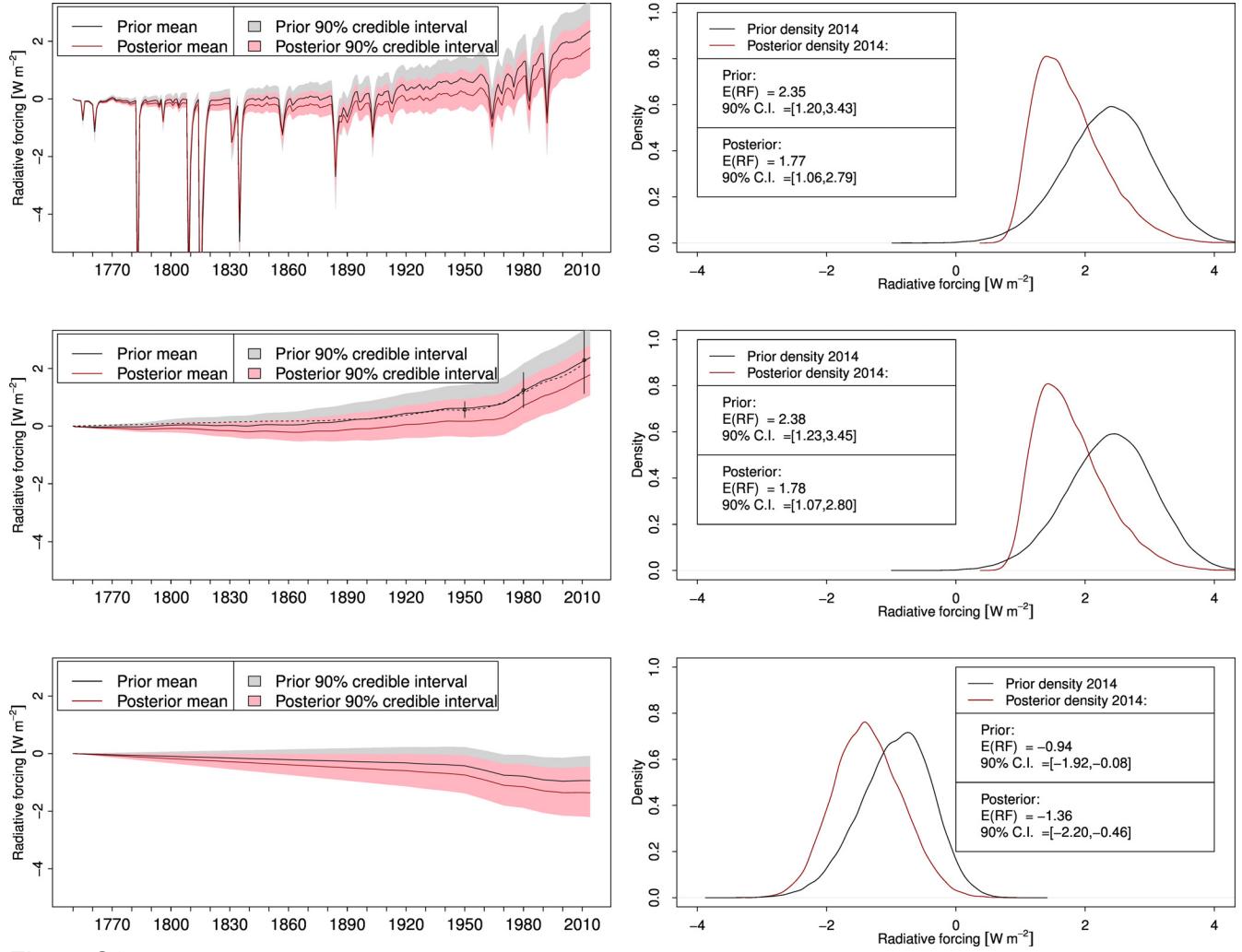


Figure S6c. As Fig S7b but for Case C.

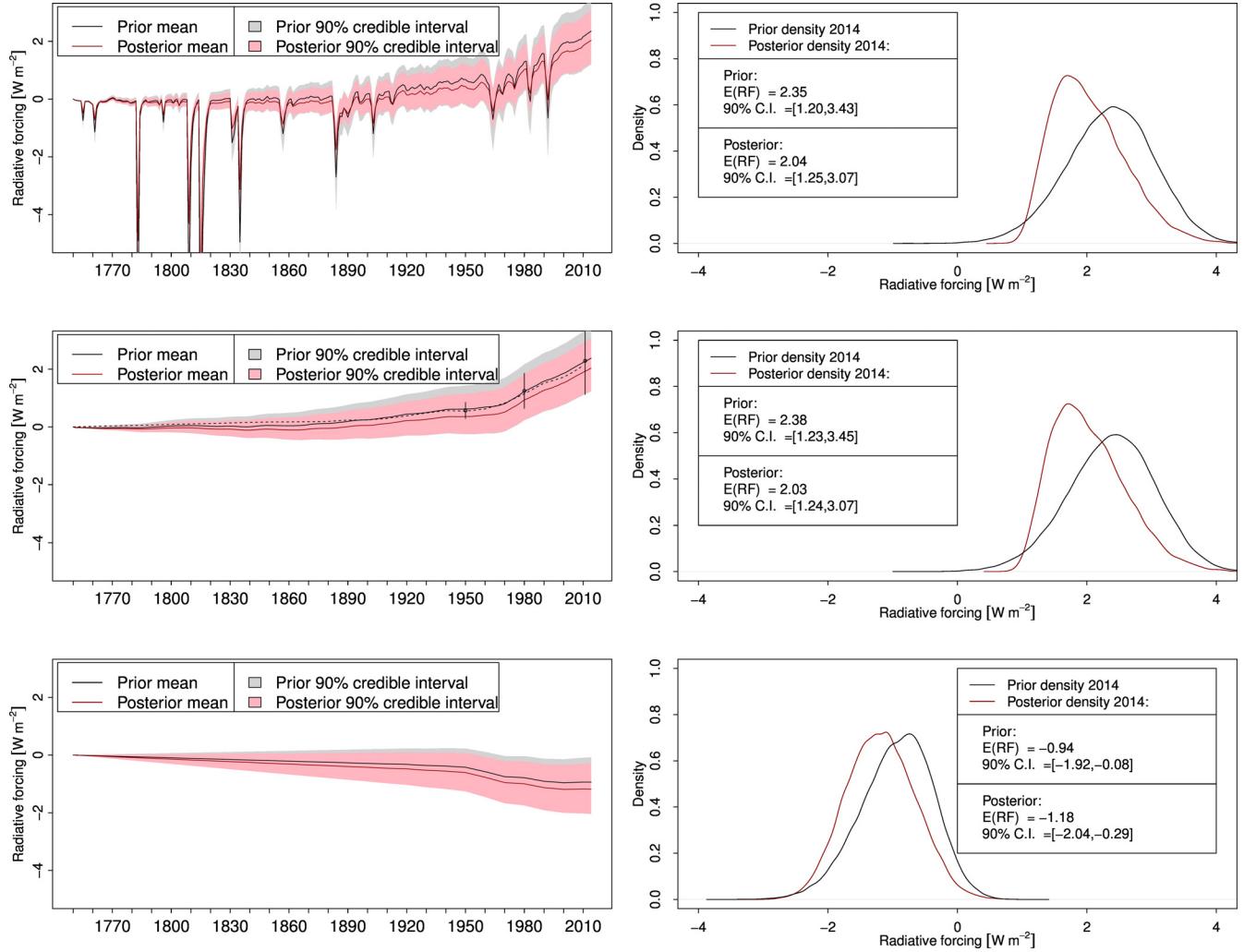


Figure S6d. As Fig S7b but for case D.

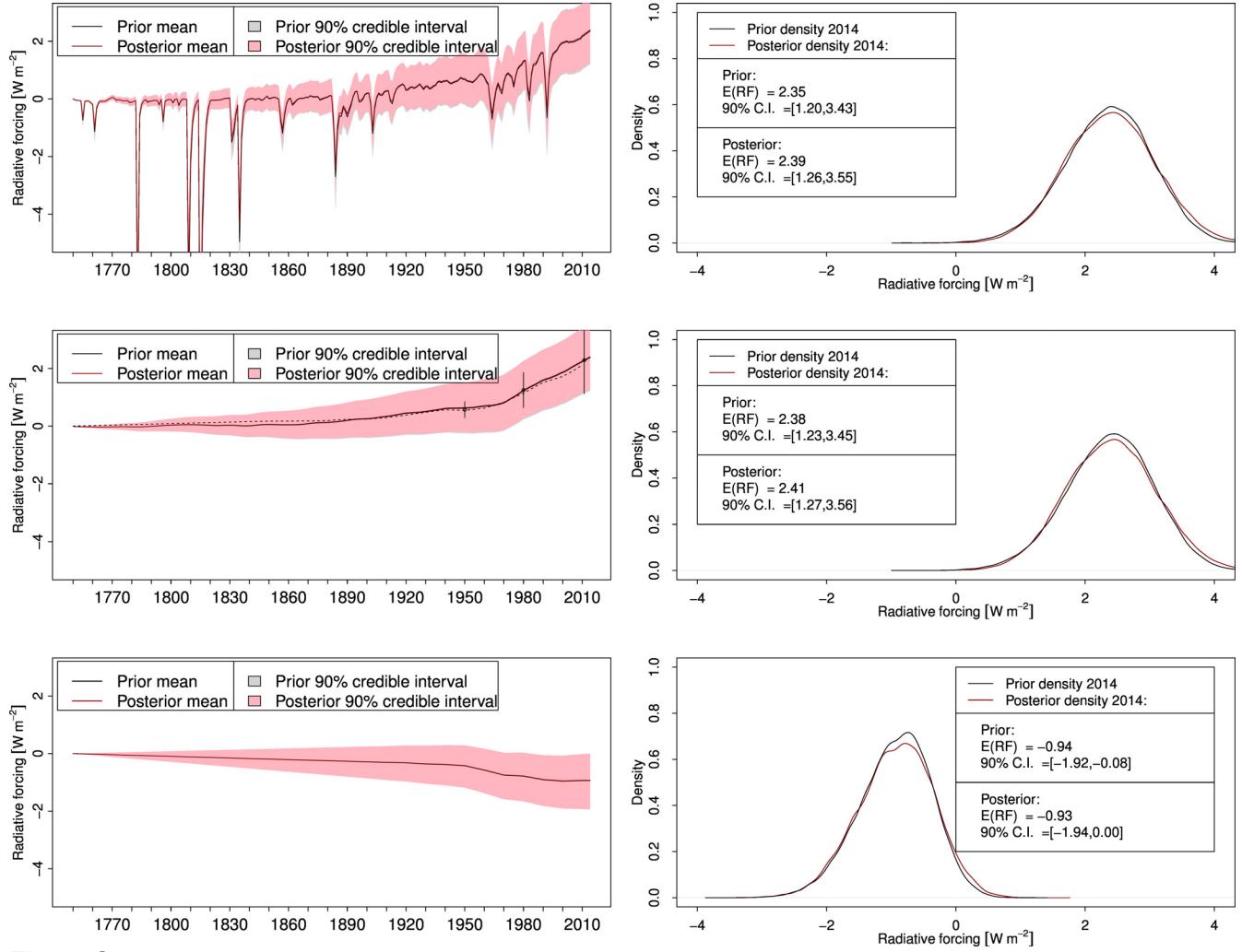


Figure S6e. As Fig S7b but for case E.

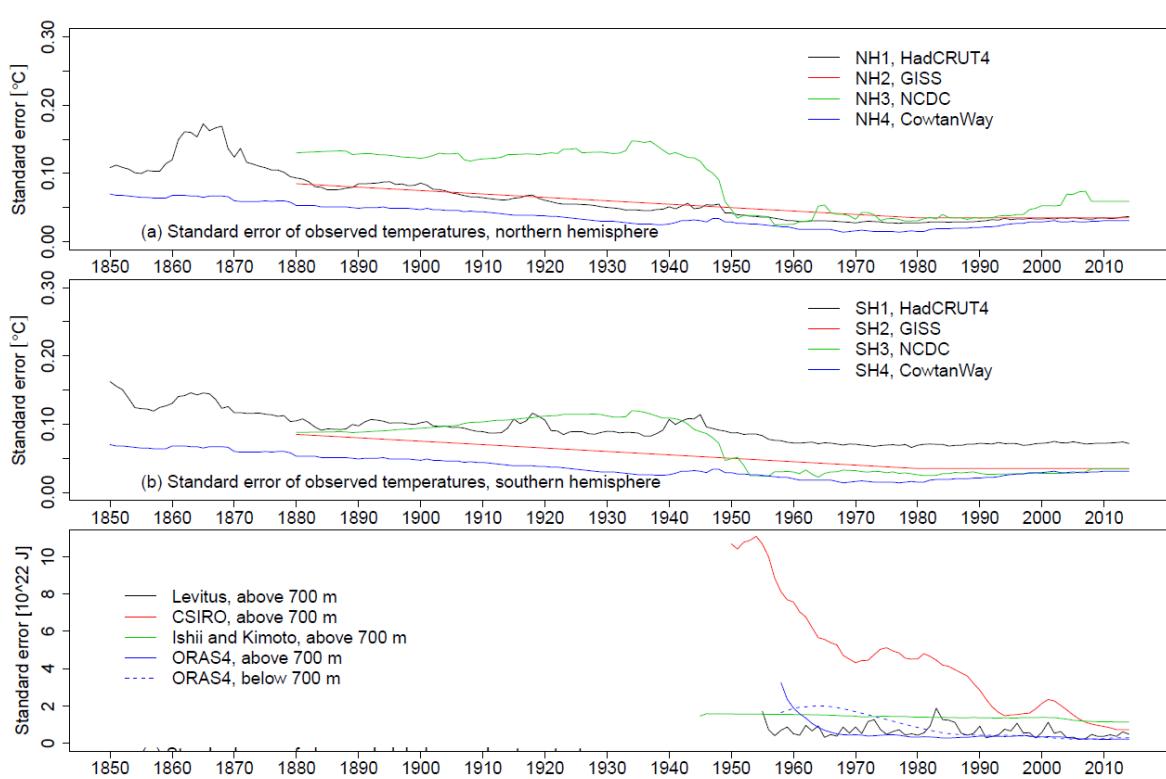


Figure S7a. Reported standard errors of annual hemispheric temperature and ocean heat content data.

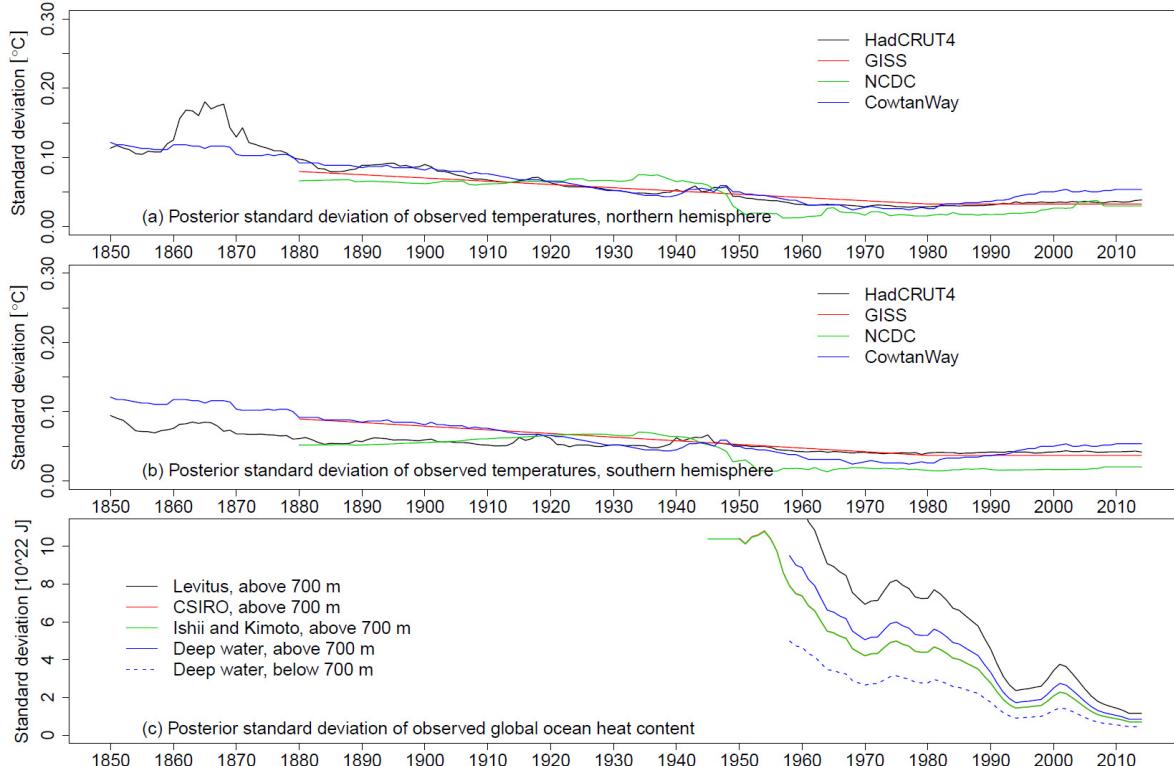
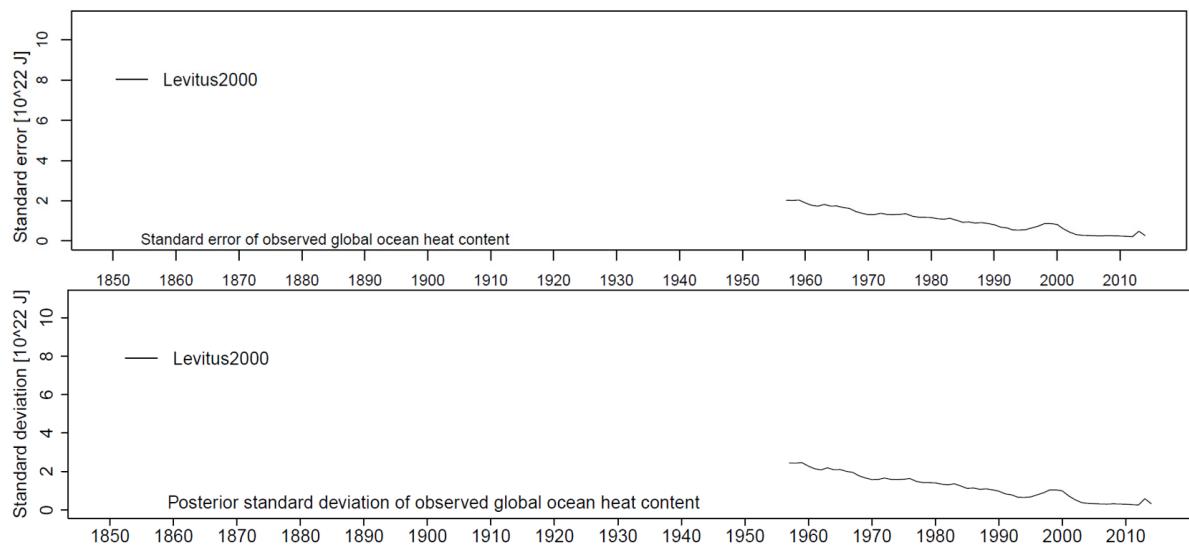
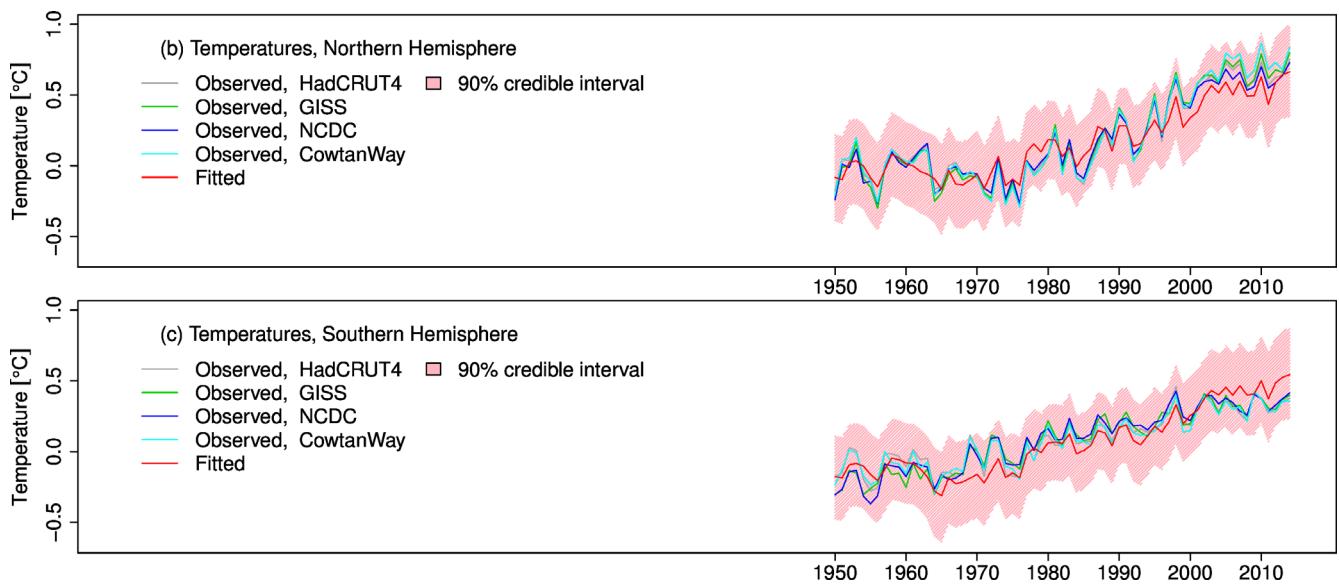


Figure S7b. Posterior standard deviation of annual hemispheric temperature and ocean heat content data for case B. Note that CSIRO and Ishii and Kimoto are almost identical in panel (c) and that the temporal profiles of the reported errors for CSIRO are used for all OHC700 (see Appendix A).



**Figure S8.** Reported standard error for Levitus2000 (upper panel) and posterior standard deviation (lower panel) for case D.



**Figure S9.** Observed and fitted (posterior mean) values for the hemispheric mean surface temperature series for case E (data from 1950). The shaded areas show the 90% C.I. for the sum of the output from the deterministic EBC/UDM and the term representing short-term internal natural variability (excluding the term for long-term internal natural variability and model error).

**Table S1.** Priors of ECS and the other parameters of the SCM.

Name	Unit	Range
Mixed layer depth	m	25-125
Vertical heat diffusivity	$\text{cm}^2 \text{ sec}^{-1}$	0.06 - 0.8*
Polar parameter	-	0.161-0.569
Vertical velocity, upwelling rate	$\text{m yr}^{-1}$	0.55-2.55
Air-sea heat exchange parameter	$\text{W} (\text{m}^2\text{K})^{-1}$	5-25
Oceanic inter hemispheric heat exchange coefficient	$\text{W} (\text{m}^2\text{K})^{-1}$	0-7
Climate sensitivity (ECS)	K	0-20

\* The vertical heat diffusivity is equal H times the vertical velocity, where H is the scale depth.

Range of H: 400-1000 meter. H is uniform, the vertical heat diffusivity is not.

**Table S2.** List of forcing components included in Forc\_Skeie14 and Forc\_AR5

Forcing components Forc_Skeie14	Forcing components Forc_AR5
Long-lived greenhouse gases (LLGHGs)	$\text{CO}_2$
Tropospheric $\text{O}_3$	GHG Other*
Stratospheric $\text{O}_3$	$\text{O}_3$ (Tropospheric)
Stratospheric $\text{H}_2\text{O}$ from $\text{CH}_4$	$\text{O}_3$ (Stratospheric)
Direct aerosol effects: Sulphate	Aerosol (Total)
Direct aerosol effects: BC fossil fuel and biofuel (FFBF)	LUC
Direct aerosol effects: OC FFBF + secondary organic aerosols	$\text{H}_2\text{O}$ (Stratospheric)
Direct aerosol effects: Biomass burning aerosols	BC Snow
Direct aerosol effects: Nitrate	Contrails
Cloud albedo effect	Solar irradiance
Cloud lifetime effect	Volcanoes
Semi-direct aerosol effect	
Snow albedo effect	
Land use change	
Volcanoes (3 separate series)	
Solar irradiance	