Supplementary Data:
Maximum warming occurs about one decade after a carbon dioxide emission

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Supplementary Methods:
S1. Thermal Inertia model fit and determination

The free parameters in the 2-box model related to thermal inertia are (Held *et al* 2010): 1) land/ocean-mixed-layer effective heat capacity, 2) thermocline/deep-ocean effective heat capacity, and 3) exchange rate between surface and deep reservoirs. We estimated these physically-based parameters using the best fit coefficients fitting these models to the CMIP5 *abrupt4xCO2* results as determined by *(Caldeira and Myhrvold 2013)*, taking into consideration the climate-sensitivity parameter for each model using equations found in (Held *et al* 2010).

The one free parameter in the one-dimensional ocean model is the effective ocean vertical diffusivity (Caldeira and Myhrvold 2013). For the one-dimensional ocean model, effective vertical diffusivity was reported by *(Caldeira and Myhrvold 2013)*. The coefficients and model type used for each of the CMIP5 models are shown in Table 1 of the main text.

S1.1. One-dimensional slab diffusion model:

The model of the temporal temperature response in a one-dimensional slab diffusion model is as follows:

$$T(t)= \mathrm{delT4x} * (1 - e^{t / tau})*\mathrm{Erfc}[(t/tau)^{(1/2)}]$$

Where:

$$tau = \kappa * (\rho * f_{ocean} * c_p / \lambda)^2/(365.25*86400.)$$

We take delT4x (equilibrium temperature change in response to CO_2-quadrupling), κ (thermal diffusivity) and λ (the climate sensitivity parameter) are from *(Caldeira and Myhrvold 2013)*. κ for each model are in Table S4.

S1.2. Two-box model:

According to (Geoffroy *et al* 2012):

$$T(t) = (F / \lambda) (1 - a_f * e^{-t/\tau_f} - a_s * e^{-t/\tau_s})$$

where:

$$a_f + a_s = 1$$
$$(a_f / \tau_f) + (a_s / \tau_s) = \lambda / C$$
$$\tau_f * a_f + \tau_s * a_s = (C + C0) / \lambda$$
$$\tau_f * a_s + \tau_s * a_f = C0/ \gamma$$

We take a_f and a_s (fit scaling parameters for a fast and slow response), τ_f and τ_s (time scales for a fast and slow response), F (forcing) and λ are from *(Caldeira and Myhrvold 2013)*. C (land/ocean-mixed layer effective heat capacity), C0 (thermocline/ deep-ocean effective heat capacity) and γ (effective exchange rate) derived for each model are in Table S4.

S1.3. Forcing adjustment scaling factor:
The forcing response to and abrupt4xCO2 scenario is extended to epsilon changes around 389 ppm using a scaling factor based on Table 6.2 in the IPCC TAR WG1 (Ramaswamy *et al* 2001):

$$g(C)= \ln(1 + 1.2\ C + .005\ C^2 + 1.4*10^{-6}\ C^3)$$

$$\Delta F= 3.35\ (G(C) - G(C_0))$$

where C is atmospheric carbon dioxide concentration relative to a reference concentration, C_0. This yields a scaling factor of 8.13×10^{-4} CO2-quadrupling effect/GtC.

S2. Curve fits to temperature

The functional forms of the convoluted responses we use in our analysis are somewhat cumbersome, but the responses in the first 100 years are well approximated using a three exponential fit:

$$\Delta T(t) = -(a_1 + a_2 + a_3) + a_1 e^{-t/\tau_1} + a_2 e^{-t/\tau_2} + a_3 e^{-t/\tau_3}$$

Table 1 in the main text presents coefficients for a 3-exponential fit of the combined carbon-climate response curves presented in Figure 1 and the associated RMS. The curves are fit to the median or percentile temperature response among the 6,000 models in each year; thus the curves don't represent the behavior of any one model.

Supplementary References

Caldeira K and Myhrvold N P 2013 Projections of the pace of warming following an abrupt increase in atmospheric carbon dioxide concentration *Environ. Res. Lett.* **8** 034039

Geoffroy O, Saint-Martin D, Olivié D J L, Voldoire A, Bellon G and Tytéca S 2012 Transient Climate Response in a Two-Layer Energy-Balance Model. Part I: Analytical Solution and Parameter Calibration Using CMIP5 AOGCM Experiments *J. Clim.* **26** 1841–57

Held I M, Winton M, Takahashi K, Delworth T, Zeng F and Vallis G K 2010 Probing the Fast and Slow Components of Global Warming by Returning Abruptly to Preindustrial Forcing *J. Clim.* **23** 2418–27

Ramaswamy V, Boucher O, Haigh J, Hauglustine D, Haywood J, Myhre G, Nakajima T, Shi G Y and Solomon S 2001 Radiative forcing of climate *Clim. Change* 349–416

Table S1. CO2 pulse response function multi-model analysis (IRF-MIP) models

Model
ACC2
Bern2.5D-LPJ
Bern3D-LPJ
CLIMBER2-LPJ
DCESS
GENIE
HADGEM2-ES
LOVECLIM1.1
MAGICC6
MESMO 1.0
MPI-ESM
NCAR CSM1.4
CSM1.4
TOTEM2
UVic 2.9

Table S2. CMIP5 Models included in analysis.

Modeling Institution	**Model**
Beijing Climate Center, China Meteorological Administration	BCC-CSM1.1
	BCC-CSM1.1(m)
Canadian Centre for Climate Modelling and Analysis	CanESM2
Commonwealth Scientific and Industrial Research Organisation in collaboration with the Queensland Climate Change Centre of Excellence	CSIRO-Mk3.6.0
LASG, Institute of Atmospheric Physics, Chinese Academy of Sciences; and CESS, Tsinghua University	FGOALS-g2
	FGOALS-s2
NOAA Geophysical Fluid Dynamics Laboratory	GFDL-CM3
	GFDL-ESM2G
	GFDL-ESM2M
Institute for Numerical Mathematics	INM-CM4
Institut Pierre-Simon Laplace	IPSL-CM5A-LR
	IPSL-CM5A-MR
	IPSL-CM5B-LR
Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology	MIROC5
	MIROC-ESM
Max Planck Institute for Meteorology (MPI-M)	MPI-ESM-LR
	MPI-ESM-MR
	MPI-ESM-P
	MRI-CGCM3
Norwegian Climate Centre	NorESM1-M

Table S3. Key quantitative results

Value/ Range		ΔT_{max} (mK / GtC)	Time to ΔT_{max} (years)	ΔT at year 100 as a fraction of ΔT_{max}
Median		2.2	10.1	0.8
Likely (> 66%)	Lo	1.8	7.6	0.7
	Hi	2.6	18.4	0.91
Very Likely (> 90%)	Lo	1.6	6.6	0.63
	Hi	2.6	18.4	0.91
Virtually Certain (> 99%)	Lo	1.5	5.4	0.56
	Hi	3.5	100.	1.

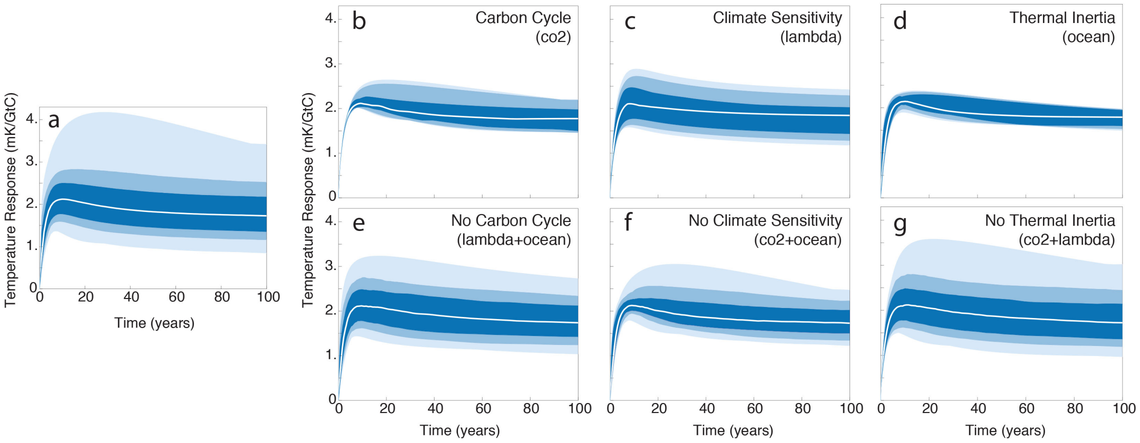

Fig. S1. Temperature increase from a CO_2 emission separating uncertainty in the carbon cycle, climate sensitivity and thermal inertia. Time series of the median (white), likely range (>66%, dark blue), very likely range (>90%, medium blue) and minimum-maximum response range (light blue) of the marginal warming, partitioned to display uncertainty associated with: (a) all 6000 convolution-function simulations (b) the carbon cycle alone (n=15), (c) climate sensitivity alone (n=20), (d) ocean thermal inertia alone (n=20), (e) climate sensitivity and thermal inertia together (n=400), (f) carbon cycle and thermal inertia together (n=300), and (g) carbon cycle and climate sensitivity together (n=300), for the first 100 years after an emission.