Projections of the pace of warming following an abrupt increase in atmospheric carbon dioxide concentration

Supporting Online Material: Text

S1. Radiative Forcing Function

The radiative forcing function $F_{\text{IPCC}}$ is given by

$$F_{\text{IPCC}}(c) = 3.35(g(c) - g(c_0)), \quad (S1)$$

where $c$ is the atmospheric CO$_2$ concentration in ppmv and $F_{\text{IPCC}}$ has units W m$^{-2}$ [10]. The CMIP5 simulations assume $p_0 = 285$ ppmv. The function $g(c)$ is given by

$$g(c) = \log(1 + 1.2c + 0.005c^2 + 1.4 \times 10^{-6}c^3) \quad (S2)$$

As result, the change in radiative forcing due to the 4× increase is

$$F_{\text{IPCC}}(c_{4\times}) = 3.35(g(4 \times 285) - g(285)) = 8.5197 \text{ W m}^{-2}. \quad (S3)$$
## Supporting Online Material: Tables

**Table S1.** Estimates for the climate sensitivity parameter ($\lambda$), adjusted radiative forcing ($F_{4}\times$), and equilibrium temperature change ($T_{4}\times$). For each of these parameters, the leftmost column is the estimate, $Err$ is the standard error in the estimate, and the two right columns are the range of the 95% confidence interval for the parameter. The rightmost column presents best fits to the effective ocean vertical diffusivity ($\kappa_v$).

| Model       | $\lambda$ (W m$^{-2}$ K$^{-1}$) | $Err$ | 95% CI   | $F_{4}\times$ (W m$^{-2}$) | $Err$ | 95% CI   | $T_{4}\times$ (K) | 95% CI   | $10^{4} \times \kappa_v$ (m$^{-2}$ s$^{-1}$) |
|-------------|---------------------------------|-------|----------|-----------------------------|-------|----------|-------------------|----------|---------------------|
| BCC-CSM1.1  | 1.146                           | 0.027 | 1.093    | 1.198                       | 6.66  | 0.11     | 6.43              | 6.88     | 5.81                | 5.74                | 5.89    | 0.355               |
| BCC-CSM1.1(m)| 1.225                           | 0.041 | 1.144    | 1.306                       | 7.23  | 0.19     | 6.86              | 7.60     | 5.90                | 5.80                | 6.01    | 0.295               |
| CanESM2     | 1.029                           | 0.025 | 0.980    | 1.079                       | 7.63  | 0.13     | 7.37              | 7.90     | 7.41                | 7.31                | 7.53    | 0.338               |
| CSIRO-Mk3.6.0| 0.631                           | 0.037 | 0.558    | 0.703                       | 5.16  | 0.17     | 4.82              | 5.50     | 8.18                | 7.80                | 8.66    | 0.444               |
| FGOALS-g2   | 0.729                           | 0.018 | 0.694    | 0.764                       | 5.37  | 0.09     | 5.19              | 5.55     | 7.36                | 7.24                | 7.49    | 0.430               |
| FGOALS-s2   | 0.904                           | 0.042 | 0.822    | 0.987                       | 7.54  | 0.22     | 7.11              | 7.97     | 8.34                | 8.06                | 8.66    | 0.590               |
| GFDL-CM3    | 0.756                           | 0.027 | 0.703    | 0.808                       | 5.99  | 0.13     | 5.73              | 6.26     | 7.93                | 7.73                | 8.17    | 0.417               |
| GFDL-ESM2G  | 1.004                           | 0.039 | 0.927    | 1.081                       | 5.27  | 0.15     | 4.97              | 5.56     | 5.25                | 5.14                | 5.38    | 0.591               |
| GFDL-ESM2M  | 1.063                           | 0.033 | 0.998    | 1.127                       | 5.70  | 0.13     | 5.45              | 5.95     | 5.36                | 5.27                | 5.46    | 0.689               |
| INM-CM4     | 1.470                           | 0.045 | 1.380    | 1.560                       | 6.06  | 0.13     | 5.80              | 6.32     | 4.12                | 4.05                | 4.20    | 0.713               |
| IPSL-CM5A-LR| 0.785                           | 0.018 | 0.750    | 0.819                       | 6.37  | 0.10     | 6.18              | 6.57     | 8.12                | 8.01                | 8.25    | 0.464               |
| IPSL-CM5A-MR| 0.810                           | 0.023 | 0.765    | 0.854                       | 6.64  | 0.12     | 6.41              | 6.88     | 8.21                | 8.04                | 8.39    | 0.418               |
| IPSL-CM5B-LR| 1.040                           | 0.051 | 0.939    | 1.142                       | 5.40  | 0.20     | 5.02              | 5.79     | 5.19                | 5.06                | 5.36    | 0.332               |
| MIROC5      | 1.546                           | 0.050 | 1.447    | 1.646                       | 8.38  | 0.20     | 7.99              | 8.77     | 5.42                | 5.32                | 5.53    | 0.692               |
| MIROC-ESM   | 0.917                           | 0.025 | 0.867    | 0.967                       | 8.55  | 0.15     | 8.26              | 8.85     | 9.33                | 9.14                | 9.53    | 0.571               |
| MPI-ESM-LR  | 1.127                           | 0.035 | 1.057    | 1.197                       | 8.20  | 0.19     | 7.83              | 8.57     | 7.28                | 7.15                | 7.42    | 0.395               |
| MPI-ESM-MR  | 1.184                           | 0.037 | 1.111    | 1.257                       | 8.19  | 0.19     | 7.82              | 8.56     | 6.92                | 6.80                | 7.05    | 0.382               |
| MPI-ESM-P   | 1.242                           | 0.038 | 1.167    | 1.318                       | 8.59  | 0.20     | 8.20              | 8.97     | 6.91                | 6.80                | 7.04    | 0.391               |
| MRI-CGCM3   | 1.263                           | 0.034 | 1.195    | 1.331                       | 6.57  | 0.14     | 6.30              | 6.83     | 5.20                | 5.12                | 5.28    | 0.362               |
| NorESM1-M   | 1.097                           | 0.041 | 1.016    | 1.178                       | 6.31  | 0.15     | 6.01              | 6.61     | 5.75                | 5.60                | 5.92    | 0.747               |
| **Median**  | **1.051**                       | **0.036** | **0.989** | **1.134**                      | **6.60** | **0.15** | **6.35**              | **6.85**     | **6.92**                | **6.80**                | **7.04**    | **0.424**               |
| **Minimum** | **0.631**                       | **0.018** | **0.558** | **0.703**                      | **5.16** | **0.09** | **4.82**              | **5.50**     | **4.12**                | **4.05**                | **4.20**    | **0.295**               |
| **Maximum** | **1.546**                       | **0.051** | **1.447** | **1.646**                      | **8.59** | **0.22** | **8.26**              | **8.97**     | **9.33**                | **9.14**                | **9.53**    | **0.747**               |
| **Mean**    | **1.048**                       | **0.034** | **0.981** | **1.116**                      | **6.79** | **0.15** | **6.49**              | **7.09**     | **6.70**                | **6.56**                | **6.86**    | **0.481**               |
| **Standard deviation** | **0.241** | **0.010** | **0.230** | **0.254**                      | **1.17** | **0.04** | **1.14**              | **1.21**     | **1.41**                | **1.37**                | **1.47**    | **0.143**               |
Table S2. Cumulative amount of climate change realized at 10 years, at 100 years, and at equilibrium (100% of temperature change). These data are plotted in Figure 3.

| Model                   | % of Equilibrium Temperature Change | Amount of Temperature Change (K) |
|-------------------------|-------------------------------------|----------------------------------|
|                         | 0 to 10 yr                          | 0 to 100 yr                      |
|                         |                                     | 0 to 10 yr                       | 0 to 100 yr | Total |
| BCC-CSM1.1              | 54.7                                | 79.2                             | 3.18        | 4.60  | 5.81  |
| BCC-CSM1.1(m)           | 55.7                                | 86.0                             | 3.29        | 5.07  | 5.90  |
| CanESM2                 | 54.3                                | 77.4                             | 4.03        | 5.74  | 7.41  |
| CSIRO-Mk3.6.0           | 37.8                                | 60.4                             | 3.09        | 4.94  | 8.18  |
| FGOALS-g2               | 43.4                                | 67.3                             | 3.20        | 4.95  | 7.36  |
| FGOALS-s2               | 51.8                                | 67.3                             | 4.32        | 5.61  | 8.34  |
| GFDL-CM3                | 41.2                                | 67.6                             | 3.27        | 5.36  | 7.93  |
| GFDL-ESM2G              | 56.5                                | 69.1                             | 2.96        | 3.62  | 5.25  |
| GFDL-ESM2M              | 55.4                                | 70.0                             | 2.97        | 3.75  | 5.36  |
| INM-CM4                 | 59.4                                | 73.0                             | 2.45        | 3.01  | 4.12  |
| IPSL-CM5A-LR            | 44.0                                | 69.7                             | 3.58        | 5.67  | 8.12  |
| IPSL-CM5A-MR            | 44.8                                | 69.8                             | 3.68        | 5.73  | 8.21  |
| IPSL-CM5B-LR            | 53.1                                | 79.4                             | 2.76        | 4.12  | 5.19  |
| MIROC5                  | 56.7                                | 75.7                             | 3.07        | 4.10  | 5.42  |
| MIROC-ESM               | 45.5                                | 65.4                             | 4.25        | 6.10  | 9.33  |
| MPI-ESM-LR              | 53.3                                | 78.4                             | 3.88        | 5.70  | 7.28  |
| MPI-ESM-MR              | 55.6                                | 77.9                             | 3.84        | 5.39  | 6.92  |
| MPI-ESM-P               | 60.8                                | 79.2                             | 4.21        | 5.48  | 6.91  |
| MRI-CGCM3               | 55.5                                | 80.6                             | 2.89        | 4.19  | 5.20  |
| NorESM1-M               | 51.7                                | 69.7                             | 2.97        | 4.01  | 5.75  |
| **Median**              | **53.8**                            | **71.5**                         | **3.23**    | **5.01** | **6.92** |
| **Minimum**             | **37.8**                            | **60.4**                         | **2.45**    | **3.01** | **4.12** |
| **Maximum**             | **60.8**                            | **86.0**                         | **4.32**    | **6.10** | **9.33** |
| **Mean**                | **51.6**                            | **73.2**                         | **3.39**    | **4.86** | **6.70** |
| **Standard deviation**  | 6.4                                 | 6.5                              | 0.54        | 0.87  | 1.41  |
Table S3. Fit parameters for single exponential curves \(I-exp\) described by equation (4) in the main text.

| Model               | \(\tau_0\) (yr) |
|---------------------|-----------------|
| BCC-CSM1.1          | 38.8            |
| BCC-CSM1.1(m)       | 30.7            |
| CanESM2             | 42.7            |
| CSIRO-Mk3.6.0       | 83.0            |
| FGOALS-g2           | 92.6            |
| FGOALS-s2           | 69.3            |
| GFDL-CM3            | 67.6            |
| GFDL-ESM2G          | 85.4            |
| GFDL-ESM2M          | 87.5            |
| INM-CM4             | 44.4            |
| IPSL-CM5A-LR        | 89.2            |
| IPSL-CM5A-MR        | 61.1            |
| IPSL-CM5B-LR        | 43.0            |
| MIROC5              | 40.9            |
| MIROC-ESM           | 66.1            |
| MPI-ESM-LR          | 42.6            |
| MPI-ESM-MR          | 39.0            |
| MPI-ESM-P           | 37.2            |
| MRI-CGCM3           | 33.6            |
| NorESM1-M           | 63.3            |

Median 52.8
Minimum 30.7
Maximum 92.6

Mean 57.9
Standard deviation 21.0
Table S4. Fit parameters for two-exponential curves (2-exp) described by equation (5) in the main text.

| Model                  | $\theta_0$ | $\theta_1$ | $\tau_0$ (yr) | $\tau_1$ (yr) |
|------------------------|------------|------------|----------------|----------------|
| BCC-CSM1.1             | 0.566      | 0.434      | 3.15           | 130.1          |
| BCC-CSM1.1(m)          | 0.587      | 0.413      | 3.00           | 109.2          |
| CanESM2                | 0.577      | 0.423      | 3.52           | 160.8          |
| CSIRO-Mk3.6.0          | 0.386      | 0.614      | 3.38           | 191.9          |
| FGOALS-g2              | 0.482      | 0.518      | 4.54           | 245.9          |
| FGOALS-s2              | 0.525      | 0.475      | 3.53           | 287.6          |
| GFDL-CM3               | 0.446      | 0.554      | 3.71           | 174.0          |
| GFDL-ESM2G             | 0.560      | 0.440      | 2.39           | 291.9          |
| GFDL-ESM2M             | 0.542      | 0.458      | 2.85           | 272.2          |
| INM-CM4                | 0.668      | 0.332      | 3.50           | 462.9          |
| IPSL-CM5A-LR           | 0.569      | 0.431      | 7.38           | 363.0          |
| IPSL-CM5A-MR           | 0.529      | 0.471      | 5.36           | 237.4          |
| IPSL-CM5B-LR           | 0.567      | 0.433      | 3.05           | 149.7          |
| MIROC5                 | 0.631      | 0.369      | 2.59           | 232.1          |
| MIROC-ESM              | 0.541      | 0.459      | 4.92           | 290.1          |
| MPI-ESM-LR             | 0.571      | 0.429      | 3.05           | 153.8          |
| MPI-ESM-MR             | 0.590      | 0.410      | 3.07           | 151.2          |
| MPI-ESM-P              | 0.588      | 0.412      | 2.66           | 141.8          |
| MRI-CGCM3              | 0.602      | 0.398      | 3.67           | 132.1          |
| NorESM1-M              | 0.499      | 0.501      | 3.12           | 201.6          |

**Median**

| $\theta_0$ | $\theta_1$ | $\tau_0$ (yr) | $\tau_1$ (yr) |
|------------|------------|----------------|----------------|
| 0.566      | 0.434      | 3.27           | 196.8          |

**Minimum**

| $\theta_0$ | $\theta_1$ | $\tau_0$ (yr) | $\tau_1$ (yr) |
|------------|------------|----------------|----------------|
| 0.386      | 0.332      | 2.39           | 109.2          |

**Maximum**

| $\theta_0$ | $\theta_1$ | $\tau_0$ (yr) | $\tau_1$ (yr) |
|------------|------------|----------------|----------------|
| 0.668      | 0.614      | 7.38           | 462.9          |

**Mean**

| $\theta_0$ | $\theta_1$ | $\tau_0$ (yr) | $\tau_1$ (yr) |
|------------|------------|----------------|----------------|
| 0.551      | 0.449      | 3.62           | 219.0          |

**Standard deviation**

| $\theta_0$ | $\theta_1$ | $\tau_0$ (yr) | $\tau_1$ (yr) |
|------------|------------|----------------|----------------|
| 0.063      | 0.063      | 1.16           | 89.7           |
Table S5. Fit parameters for three-exponential curves (3-exp) described by equation (6) in the main text.

| Model                  | \( \theta_0 \) | \( \theta_1 \) | \( \theta_2 \) | \( \tau_0 \) (yr) | \( \tau_1 \) (yr) | \( \tau_2 \) (yr) |
|------------------------|----------------|----------------|----------------|----------------|----------------|----------------|
| BCC-CSM1.1             | 0.235          | 0.352          | 0.412          | 0.691          | 6.19           | 140.7          |
| BCC-CSM1.1(m)          | 0.303          | 0.334          | 0.363          | 0.596          | 8.63           | 130.2          |
| CanESM2                | 0.458          | 0.245          | 0.298          | 2.130          | 26.98          | 322.3          |
| CSIRO-Mk3.6.0          | 0.197          | 0.212          | 0.591          | 0.801          | 8.83           | 208.0          |
| FGOALS-g2              | 0.333          | 0.227          | 0.440          | 1.611          | 27.56          | 322.2          |
| FGOALS-s2              | 0.079          | 0.453          | 0.468          | 0.194          | 4.71           | 297.7          |
| GFDL-CM3               | 0.181          | 0.284          | 0.535          | 0.745          | 7.22           | 185.7          |
| GFDL-ESM2G             | 0.130          | 0.432          | 0.438          | 0.295          | 3.17           | 294.6          |
| GFDL-ESM2M             | 0.160          | 0.385          | 0.455          | 0.372          | 4.13           | 275.6          |
| INM-CM4                | 0.197          | 0.481          | 0.322          | 0.322          | 5.31           | 543.1          |
| IPSL-CM5A-LR           | 0.216          | 0.394          | 0.390          | 0.000          | 16.23          | 461.3          |
| IPSL-CM5A-MR           | 0.185          | 0.379          | 0.436          | 0.442          | 10.27          | 294.5          |
| IPSL-CM5B-LR           | 0.292          | 0.316          | 0.393          | 0.482          | 8.81           | 176.3          |
| MIROC5                 | 0.259          | 0.384          | 0.356          | 0.639          | 4.71           | 253.7          |
| MIROC-ESM              | 0.204          | 0.364          | 0.432          | 0.690          | 9.34           | 348.8          |
| MPI-ESM-LR             | 0.278          | 0.315          | 0.407          | 0.904          | 6.70           | 169.0          |
| MPI-ESM-MR             | 0.230          | 0.380          | 0.390          | 0.406          | 5.83           | 165.0          |
| MPI-ESM-P              | 0.302          | 0.317          | 0.380          | 0.577          | 7.07           | 162.1          |
| MRI-CGCM3              | 0.305          | 0.356          | 0.339          | 0.679          | 10.55          | 170.0          |
| NorESM1-M              | 0.223          | 0.297          | 0.480          | 0.515          | 6.88           | 221.6          |

| Median                 | 0.226          | 0.354          | 0.409          | 0.586          | 7.15           | 237.7          |
| Minimum                | 0.079          | 0.212          | 0.298          | 0.000          | 3.17           | 130.2          |
| Maximum                | 0.458          | 0.481          | 0.591          | 2.130          | 27.56          | 543.1          |

| Mean                   | 0.238          | 0.345          | 0.416          | 0.655          | 9.46           | 257.1          |
| Standard deviation     | 0.083          | 0.071          | 0.070          | 0.476          | 6.74           | 108.3          |
Table S6. Ranking of equations by goodness of fit to the abrupt4xCO2 simulations according to the corrected Akaike information criterion (AICc). Labels 1-exp, 2-exp, and 3-exp refer to equations (4), (5), and (6), respectively, in the main text. Label 1-D refers to the model described by equations (8), (9), and (10). By definition, ΔAICc for the best-fit equation is zero.

| Model                | Best-fit Equation | 2nd-best fit Equation | ΔAICc | 3rd-best fit Equation | ΔAICc | 4th-best fit Equation | ΔAICc |
|----------------------|-------------------|-----------------------|-------|------------------------|-------|------------------------|-------|
| BCC-CSM1.1           | 3-exp             | 2-exp                 | 82.3  | 1-D                    | 115   | 1-exp                  | 738.4 |
| BCC-CSM1.1(m)        | 3-exp             | 1-D                   | 7.3   | 2-exp                  | 77.52 | 1-exp                  | 587.2 |
| CanESM2              | 3-exp             | 1-D                   | 82.3  | 2-exp                  | 119.02| 1-exp                  | 729.6 |
| CSIRO-Mk3.6.0        | 3-exp             | 2-exp                 | 48.9  | 1-D                    | 103   | 1-exp                  | 616.5 |
| FGOALS-g2            | 3-exp             | 1-D                   | 239.0 | 2-exp                  | 308.00| 1-exp                  | 1331.4|
| FGOALS-s2            | 3-exp             | 2-exp                 | 15.3  | 1-D                    | 287   | 1-exp                  | 679.5 |
| GFDL-CM3             | 3-exp             | 2-exp                 | 60.9  | 1-D                    | 103   | 1-exp                  | 709.4 |
| GFDL-ESM2G           | 3-exp             | 2-exp                 | 9.6   | 1-D                    | 415   | 1-exp                  | 1210.7|
| GFDL-ESM2M           | 3-exp             | 2-exp                 | 30.8  | 1-D                    | 456   | 1-exp                  | 1286.1|
| INM-CM4              | 3-exp             | 2-exp                 | 72.7  | 1-D                    | 372   | 1-exp                  | 740.0 |
| IPSL-CM5A-LR         | 3-exp             | 1-D                   | 213.9 | 2-exp                  | 226.12| 1-exp                  | 1198.7|
| IPSL-CM5A-MR         | 3-exp             | 2-exp                 | 137.1 | 1-D                    | 181   | 1-exp                  | 707.4 |
| IPSL-CM5B-LR         | 3-exp             | 1-D                   | 38.1  | 2-exp                  | 82.74 | 1-exp                  | 627.2 |
| MIROC5               | 3-exp             | 2-exp                 | 13.4  | 1-D                    | 148   | 1-exp                  | 553.9 |
| MIROC-ESM            | 3-exp             | 2-exp                 | 190.0 | 2-exp                  | 390   | 1-exp                  | 872.0 |
| MPI-ESM-LR           | 3-exp             | 2-exp                 | 50.9  | 1-D                    | 107   | 1-exp                  | 660.4 |
| MPI-ESM-MR           | 3-exp             | 2-exp                 | 71.4  | 2-exp                  | 96    | 1-exp                  | 661.8 |
| MPI-ESM-P            | 3-exp             | 2-exp                 | 63.4  | 1-D                    | 68    | 1-exp                  | 617.1 |
| MRI-CGCM3            | 3-exp             | 1-D                   | 15.8  | 2-exp                  | 128.37| 1-exp                  | 646.6 |
| NorESM1-M            | 3-exp             | 2-exp                 | 77.9  | 1-D                    | 209   | 1-exp                  | 706.0 |
Table S7. Ranking of equations by goodness of fit to the 1pctCO2 simulations according to the corrected Akaike information criterion (AICc). Labels 1-exp, 2-exp, and 3-exp refer to equations (4), (5), and (6), respectively, in the main text. Label 1-D refers to the model described by equations (8), (9), and (10). By definition, ΔAICc for the best-fit equation is zero. Models FGOALS-g2, GFDL-ESM2G, and GFDL-ESM2M are not included on this table because the CO2 concentrations in their submitted simulations apparently did not continue rising at 1% per year.

| Model                | Best-fit Equation | 2nd-best fit Equation | 3rd-best fit Equation | 4th-best fit Equation |
|----------------------|-------------------|-----------------------|-----------------------|-----------------------|
| BCC-CSM1.1           | 1-D               | 3-exp 22.50           | 2-exp 29.50           | 1-exp 309.77          |
| BCC-CSM1.1(m)        | 1-D               | 3-exp 14.10           | 2-exp 17.12           | 1-exp 117.88          |
| CanESM2              | 3-exp             | 2-exp 7.38            | 1-D 13.67             | 1-exp 294.73          |
| CSIRO-Mk3.6.0        | 2-exp             | 1-D 10.07             | 3-exp 12.08           | 1-exp 235.05          |
| FGOALS-s2            | 2-exp             | 3-exp 4.00            | 1-D 77.46             | 1-exp 331.44          |
| GFDL-CM3             | 3-exp             | 1-D 2.22              | 2-exp 4.29            | 1-exp 379.14          |
| INM-CM4              | 3-exp             | 2-exp 5.07            | 1-D 51.90             | 1-exp 275.47          |
| IPSL-CM5A-LR         | 2-exp             | 1-D 95.64             | 3-exp 622.55          | 1-exp 579.48          |
| IPSL-CM5A-MR         | 1-D               | 2-exp 38.54           | 3-exp 55.21           | 1-exp 368.33          |
| IPSL-CM5B-LR         | 2-exp             | 1-D 2.53              | 3-exp 7.92            | 1-exp 243.50          |
| MIROC5               | 1-D               | 1-exp 19.85           | 3-exp 41.06           | 2-exp 35.63           |
| MIROC-ESM            | 1-D               | 2-exp 73.33           | 3-exp 8.75            | 1-exp 206.47          |
| MPI-ESM-LR           | 1-D               | 2-exp 8.75            | 3-exp 14.92           | 1-exp 192.12          |
| MPI-ESM-MR           | 2-exp             | 3-exp 9.82            | 1-D 10.43             | 1-exp 240.14          |
| MPI-ESM-P            | 2-exp             | 1-D 4.70              | 3-exp 9.61            | 1-exp 133.22          |
| MRI-CGCM3            | 1-D               | 3-exp 11.56           | 2-exp 23.50           | 1-exp 177.00          |
| NorESM1-M            | 1-D               | 2-exp 44.50           | 3-exp 54.33           | 1-exp 349.76          |
Table S8. Root-mean-square error (K) of prediction in annual mean temperature values in the 1pctCO2 simulations based on fits to the abrupt4xCO2 simulations. Labels 1-exp, 2-exp, and 3-exp refer to equations (4), (5), and (6), respectively, in the main text. Models FGOALS-g2, GFDL-ESM2G, and GFDL-ESM2M are not included on this table because the CO₂ concentrations in their submitted simulations apparently did not continue rising at 1% per year. Mean RMS error for the 3-exp fit with IPSL-CM5A-LR removed is 0.16 K.

| Model                  | 1-exp | 2-exp | 3-exp | 1-D  |
|------------------------|-------|-------|-------|------|
| BCC-CSM1.1             | 0.27  | 0.10  | 0.10  | 0.09 |
| BCC-CSM1.1(m)          | 0.49  | 0.34  | 0.34  | 0.32 |
| CanESM2                | 0.45  | 0.16  | 0.16  | 0.17 |
| CSIRO-Mk3.6.0          | 0.39  | 0.17  | 0.17  | 0.18 |
| FGOALS-s2              | 0.72  | 0.22  | 0.22  | 0.29 |
| GFDL-CM3               | 0.51  | 0.13  | 0.13  | 0.13 |
| INM-CM4                | 0.30  | 0.11  | 0.11  | 0.13 |
| IPSL-CM5A-LR           | 0.87  | 0.11  | 0.11  | 0.16 |
| IPSL-CM5A-MR           | 0.39  | 0.12  | 0.13  | 0.11 |
| IPSL-CM5B-LR           | 0.23  | 0.10  | 0.11  | 0.11 |
| MIROC5                 | 0.21  | 0.22  | 0.22  | 0.20 |
| MIROC-ESM              | 0.40  | 0.25  | 0.26  | 0.19 |
| MPI-ESM-LR             | 0.29  | 0.15  | 0.16  | 0.15 |
| MPI-ESM-MR             | 0.28  | 0.13  | 0.13  | 0.13 |
| MPI-ESM-P              | 0.26  | 0.16  | 0.17  | 0.17 |
| MRI-CGCM3              | 0.22  | 0.13  | 0.12  | 0.12 |
| NorESM1-M              | 0.31  | 0.10  | 0.11  | 0.09 |
| **Median**             | 0.31  | 0.13  | 0.16  | 0.15 |
| **Minimum**            | 0.21  | 0.10  | 0.10  | 0.09 |
| **Maximum**            | 0.87  | 0.34  | 1.00  | 0.32 |
| **Mean**               | 0.39  | 0.16  | 0.21  | 0.16 |
| **Standard deviation** | 0.18  | 0.06  | 0.21  | 0.06 |
| Modeling Center (or Group)                                                                 | Institute ID | Model Name                                                      |
|------------------------------------------------------------------------------------------|--------------|----------------------------------------------------------------|
| Commonwealth Scientific and Industrial Research, Organization (CSIRO) and Bureau of Meteorology, (BOM), Australia | CSIRO-BOM    | ACCESS1.0, ACCESS1.3                                           |
| Beijing Climate Center, China Meteorological, Administration                             | BCC          | BCC-CSM1.1, BCC-CSM1.1(m)                                      |
| Instituto Nacional de Pesquisas Espaciais (National Institute for Space Research)        | INPE         | BESM OA 2.3                                                    |
| College of Global Change and Earth System, Science, Beijing Normal University            | GCESS        | BNU-ESM                                                        |
| Canadian Centre for Climate Modeling and Analysis                                         | CCCMA        | CanESM2, CanCM4, CanAM4                                        |
| University of Miami – RSMAS                                                               | RSMAS        | RSMAS, CCSM4(RSMAS)                                            |
| National Center for Atmospheric Research                                                 | NCAR         | CCSM4                                                          |
| Community Earth System Model Contributors                                                | NSF-DOE-NCAR | CESM1(BGC), CESM1(CAM5), CESM1(CAM5.1,FV2), CESM1(FASTCHEM), CESM1(WACCM) |
| Center for Ocean-Land-Atmosphere Studies and National Centers for Environmental Prediction| COLA and NCEP| CFSv2-2011                                                     |
| Centro Euro-Mediterraneo per I Cambiamenti, Climatici                                     | CMCC         | CMCC-CESM, CMCC-CM, CMCC-CMS                                    |
| Centre National de Recherches Météorologiques / Centre Européen de Recherche et Formation, Avancée en Calcul Scientifique | CNRM-CERFACS | CNRM-CM5                                                       |
| Organization                                                                 | Code       | Model Name                                      |
|------------------------------------------------------------------------------|------------|------------------------------------------------|
| Commonwealth Scientific and Industrial Research, Organization in collaboration with Queensland, Climate Change Centre of Excellence | CSIRO-QCCCE | CSIRO-Mk3.6.0                                  |
| EC-EARTH consortium                                                          | EC-EARTH  | EC-EARTH                                       |
| LASG, Institute of Atmospheric Physics, Chinese, Academy of Sciences and CESS, Tsinghua University | LASG-CESS  | FGOALS-g2                                      |
| LASG, Institute of Atmospheric Physics, Chinese, Academy of Sciences          | LASG-IAP   | FGOALS-g1, FGOALS-s2                          |
| The First Institute of Oceanography, SOA, China                              | FIO        | FIO-ESM                                       |
| NASA Global Modeling and Assimilation Office                                 | NASA GMAO  | GEOS-5                                         |
| NOAA Geophysical Fluid Dynamics Laboratory                                    | NOAA GFDL  | GFDL-CM2.1, GFDL-CM3, GFDL-ESM2G, GFDL-ESM2M, GFDL-HIRAM-C180, GFDL-HIRAM-C360 |
| NASA Goddard Institute for Space Studies                                     | NASA GISS  | GISS-E2-H, GISS-E2-H-CC, GISS-E2-R, GISS-E2-R-CC, GISS-E2CS-H, GISS-E2CS-R |
| National Institute of Meteorological Research/Korea Meteorological Administration | NIMR/KMA   | HadGEM2-AO                                    |
| Met Office Hadley Centre (additional HadGEM2-ES realizations contributed by Instituto Nacional de Pesquisas Espaciais) | MOHC (additional realizations by INPE) | HadCM3, HadCM3Q, HadGEM2-CC, HadGEM2-ES, HadGEM2-A |
| Natural and Environmental Research Council/Met Office Hadley Centre           | undeclared | HiGEM1.2                                       |
| Institute for Numerical Mathematics                                          | INM        | INM-CM4                                       |
| Institute                                                                 | Model | Models                                                                 |
|--------------------------------------------------------------------------|-------|------------------------------------------------------------------------|
| Institut Pierre-Simon Laplace                                           | IPSL  | IPSL-CM5A-LR, IPSL-CM5A-MR, IPSL-CM5B-LR                               |
| Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies | MIROC | MIROC-ESM, MIROC-ESM-CHEM                                             |
| Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology | MIROC | MIROC4h, MIROC4m, MIROC5                                               |
| Max Planck Institute for Meteorology                                    | MPI-M | MPI-ESM-HR, MPI-ESM-MR, MPI-ESM-LR, MPI-ESM-P                         |
| Meteorological Research Institute                                       | MRI   | MRI-AGCM3.2H, MRI-AGCM3.2S, MRI-CGCM3, MRI-ESM1                        |
| Nonhydrostatic Icosahedral Atmospheric Model Group                     | NICAM | NICAM.09                                                               |
| Norwegian Climate Centre                                               | NCC   | NorESM1-M, NorESM1-ME                                                  |
Supporting Online Material: Figures

**Figure S1.** Linear fits to change in top-of-atmosphere energy balance as a function of change in global mean air temperatures near Earth’s surface. The intercept with the vertical axis is the estimate of the adjusted radiative forcing from a quadrupling of atmospheric CO₂ content (\(F_{4\times}\)), the intercept with the horizontal axis (\(\Delta T_{4\times}\)) is the estimate of equilibrium warming resulting from a this change in atmospheric CO₂ content, and the slope of the line is the estimate of the climate feedback parameter (\(\lambda\)).
Figure S2. Temperature results for CMIP5 models that have performed the *abrupt4xCO2* simulations (*black dots*). Also shown are 1-exp (*purple*), 2-exp (*brown*), 3-exp (*blue*), simple log (*green*), and 1-D (*θκ, red*) model fits to this data.
Figure S3. Temperature results for CMIP5 models that have performed the 1pctCO2 simulations (black dots). Also shown are predictions made by the 2-exp (brown), 3-exp (blue), simple log (green), and 1-D (θκ, red) models fit to this data.