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## 1 Introductory note

First we should mention that the International Energy Analysis group at LBNL is not a climate modelling group. We are primarily interested in economic aspects of future energy scenarios, and we use the Bern model for  $CO_2$  concentration calculations.

Currently we are developing a simple model for energy supply scenarios with which we can study long term implications of burden sharing prescriptions that are being discussed. Our participation in this exercise can be seen as a test on whether the simple climate model can be implemented easily and used by a more general audience.

In implementing the simple climate model we followed carefully the instructions and used default values given in the Terms of Reference. Our simple model runs in 10-year intervals, which is why for this exercise we have also approximated annual values by 10-year averages.

## 2 Methodology

- **Emissions:** Historic emission data for  $CO_2$  and  $CH_4$  were taken from CDIAC. There we found global emission data for  $CO_2$  from fossil fuel consumption from 1760 to 1999, as well as  $CO_2$  emissions from land use change for the period 1850 to 1990. For  $CH_4$ , CDIAC data are available from 1860 to 1990. For periods earlier than 1860 we assumed  $CH_4$  emissions to be proportional to contemporary  $CO_2$ , with a proportionality factor that we calculated from the 1860 values. Historic emission data for  $N_2O$  were found in the EDGAR-HYDE 1.4 database

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for the period 1890-1995, and we interpolated data for earlier periods linearly, assuming zero N<sub>2</sub>O emissions in 1760.

For the period 2000-2100 the SRES A2 marker scenario provides emission data for CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O. We also use SRES data for emissions of the three gases during the decade 1990-2000, though we notice that already in 1990 SRES data on CO<sub>2</sub> are slightly lower than the ones reported by CDIAC. This discontinuity in the data can clearly be identified in the concentration graph. Comments on how to make the time series consistent would be welcome.

- **Concentrations:** For calculating concentration levels for CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O from the corresponding emissions we have solely used the approximations recommended on the project website. The CO<sub>2</sub> concentration is approximated by a sum of exponentially decaying functions

$$\Delta\rho_{CO_2}(t) = C_{CO_2} \int_{-\infty}^t E_{CO_2}(t') \cdot \left[ f_{CO_2,0} + \sum_{k=1}^3 f_{CO_2,k} \cdot e^{\left(\frac{t-t'}{\tau_{CO_2,k}}\right)} \right] dt' \quad (1)$$

and we have also used the default values for the constants  $C_{CO_2} = 0.47$  ppmv/GtC,  $f_{CO_2,0} = 0.152$ ,  $f_{CO_2,1} = 0.253$ ,  $f_{CO_2,2} = 0.279$ ,  $f_{CO_2,3} = 0.316$ ,  $\tau_{CO_2,1} = 171.0$  years,  $\tau_{CO_2,2} = 18.0$  years,  $\tau_{CO_2,3} = 2.57$  years.

For CH<sub>4</sub> a single decay constant  $\tau_{CH_4} = 8.4$  years is used, and for N<sub>2</sub>O the decay constant  $\tau_{N_2O} = 120$  years, as previously used in the Brazilian Proposal and in IMAGE. Thus

$$\Delta\rho_{CH_4}(t) = C_{CH_4} \int_{-\infty}^t E_{CH_4}(t') e^{-\frac{t-t'}{\tau_{CH_4}}} dt', \quad (2)$$

$$\Delta\rho_{N_2O}(t) = C_{N_2O} \int_{-\infty}^t E_{N_2O}(t') e^{-\frac{t-t'}{\tau_{N_2O}}} dt'. \quad (3)$$

The mass-to-concentration factors for CH<sub>4</sub> and N<sub>2</sub>O are related by  $C_{CO_2}[\text{ppm/GtC}] = 16/12 \cdot C_{CH_4}[\text{ppb/MtCH}_4] = 28/12 \cdot C_{N_2O}[\text{ppb/MtN}]$ .

- **Radiative forcing:** For the calculation of the additional radiative forcing from the concentration level of the gases CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O

we have used, in accordance with the Terms of Reference, the simplified expressions in Table 6.2 of TAR (p. 358)<sup>2</sup>:

CO <sub>2</sub>	$\Delta F = \alpha(g(C) - g(C_0))$	$\alpha = 3.35$
CH <sub>4</sub>	$\Delta F = \beta(\sqrt{M} - \sqrt{M_0}) - (f(M, N_0) - f(M_0, N_0))$	$\beta = 0.036$
N <sub>2</sub> O	$\Delta F = \gamma(\sqrt{N} - \sqrt{N_0}) - (f(M_0, N) - f(M_0, N_0))$	$\gamma = 0.12$

where

$$g(C) = \ln(1 + 1.2C + 0.005C^2 + 1.4 \cdot 10^{-6}C^3)$$

describes the logarithmic saturation of the absorption bands of CO<sub>2</sub>, and the function

$$f(M, N) = 0.47 \ln(1 + 2.01 \cdot 10^{-5}(MN)^{0.75} + 5.31 \cdot 10^{-15}M(MN)^{1.52})$$

takes also into account the band overlap between CH<sub>4</sub> and N<sub>2</sub>O. Here  $C$  is the CO<sub>2</sub> concentration in units of ppm,  $M$  is the CH<sub>4</sub> concentration in ppb and  $N$  is the N<sub>2</sub>O concentration in ppb. The subscript 0 denotes the unperturbed concentrations, and we have used the values  $C_0 = 280$ ,  $M_0 = 700$  and  $N_0 = 275$ .

Radiative forcing from aerosols is implemented by using default values for direct and indirect forcing provided by HadCM3 for the period 1860 to 2100. These data can also be found on the project web site.

- **Temperature increase:** Temperature increases are calculated with the help of the response function

$$R(t) = \frac{a_1}{\tau_1} e^{-\frac{t}{\tau_1}} + \frac{a_2}{\tau_2} e^{-\frac{t}{\tau_2}} \quad (4)$$

with parameters  $a_1 = 0.59557$ ,  $a_2 = 1 - a_1 = 0.40443$ ,  $\tau_1 = 8.4007$  and  $\tau_2 = 409.54$ , as given on the project website.

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<sup>2</sup>Thus, for CO<sub>2</sub> we follow the WMO approach.

The change in the transient global mean surface temperature is then

$$\Delta T(t) = T_f \int_0^t F(t')R(t-t')dt' \quad (5)$$

where  $T_f = 7.3583$ .

- **Sea level rise:** The response function of the corresponding sea level rise takes the same functional form as in (4), but the values of the fitting parameters are  $a_1 = 0.96677$ ,  $a_2 = 1 - a_1 = 0.03323$ ,  $\tau_1 = 1700.2$  and  $\tau_2 = 33.788$ . Then the sea level rise is calculated from

$$\Delta S(t) = S_f \int_0^t F(t')R(t-t')dt' \quad (6)$$

where  $S_f = 4.7395$ .

### 3 Results and concerns

Attached are the data tables and graphs showing the results of the concentration calculation for the three gases, the total radiative forcing (including direct and indirect radiation forcing from aerosols), the temperature increase, as well as the implied sea level rise.

There are two issues that need to be addressed:

1. As mentioned above, the emission time series for CO<sub>2</sub> shows a discontinuity between 1990 and 2000 where historic emission data and A2 projections are being merged.
2. We were not able to reproduce CH<sub>4</sub> and N<sub>2</sub>O concentration levels of the A2 scenario (see TAR, p.810), given the corresponding emissions. The values we find are consistently lower.

Helpful comments on these matters would be welcome.