## Appendix A Model description of ACCC: global concentrations, temperature and sea level rise[1]

*Concentrations*

Concentration ( $\rho$ , in ppmv) is defined as perturbation from a pre-industrial ('background') concentration ( $\rho_{pi}$ ) caused by anthropogenic emissions. $\rho$ is calculated from the integral of $\dot{\rho}$ (change of $\rho$ in time)

$$\rho(t) = \int_{t_0}^{t} \dot{\rho}(t')dt'$$ , with $t_0$ emission start date and $t$ evaluation date. (A1)

The total global concentration including 'background' is defined as $\rho_{total}(t) = \rho(t) + \rho_{pi}$ (A2)

*$CO_2$* – $\rho_{pi} = 278$ ppmv; $C_{CO_2} = 0.471$ ppmv/GtC (conversion factor for emissions to concentrations); $\dot{\rho}$ is defined as a summation of the time derivative of carbon content in *S+1* independent carbon pools:

$$\dot{\rho}(t) = \sum_{s=0}^{S} \dot{\rho}_s(t) \text{, with } \dot{\rho}_0(t) = f_0 \cdot C_{CO_2} \cdot E_{CO_2}(t) \text{ and } \dot{\rho}_s(t) = f_s \cdot C_{CO_2} \cdot E_{CO_2}(t) - \rho_s(t)/\tau_s \quad \text{(A3a)}$$

where $E_{CO_2}(t)$ the total anthropogenic emissions (emissions from fossil fuel combustion, industrial sources and land use changes) (GtC). Combining eq. (A1) and (A3a) gives the alternative expression of $\rho$ by the convolution integral

$$\rho(t) = C_{CO_2} \int_{t_0}^{t} R(t-t') \cdot E(t')dt' \text{, with } R(t) = f_0 + \sum_{s=1}^{3} f_s e^{-t/\tau_s} \quad \text{(A3b)}$$

The coefficients $f_s$ (-) and $\tau_s$ (years) are calculated by fitting the impulse response function with the Bern C-cycle of Joos et al.(1996; 1999), which is used for the carbon cycle model calculations in the IPCC-TAR, i.e. $f_0 = 0.152$, $f_1 = 0.253$, $f_2 = 0.279$, $f_3 = 0.316$, $\tau_1 = 171.0$, $\tau_2 = 18.0$ and $\tau_3 = 2.57$.

*non-$CO_2$* – The change in concentration in time of non-$CO_2$ gas *g* ($CH_4$, $N_2O$, HFCs, PFCs, or $SF_6$) is defined by a single-lifetime expression:

$$\dot{\rho}_g(t) = C_g \cdot E_g(t) - \rho_g(t)/\tau_g \quad \text{(A4)}$$

$\rho_g$ and $E_g$ are the concentration and emissions expressed in ppbv and $MtCH_4$ for $CH_4$, in ppbv and MtN for $N_2O$ and in pptv and Mt for the other gases, and $\tau_g$ is the atmospheric lifetime. For $CH_4$, HCFCs and HFCs, fixed lifetimes taken from the IPCC-TAR are used.

*Radiative Forcing*

The global radiative forcing $F_{total}(t)$ ($Wm^{-2}$) is calculated as the linear sum of forcing $F_g(t)$ ($Wm^{-2}$) by all gases *g* plus a contribution by aerosol forcing direct and indirect radiative forcing from aerosols as

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[1] See also: http://unfccc.int/program/mis/brazil/.

provided by the Hadley Center. The contribution to global radiative forcing by each GHG *g* is calculated using the following functional dependencies (Ramaswamy et al., 2001):

$$F_{CO_2}(t) = 5.325 \log(\rho_{total}(t) / \rho_{pi}) \quad \text{(A5)}$$

$$F_{CH_4}(t) = 0.036 \left[ \sqrt{\rho_{CH_4,total}(t)} - \sqrt{\rho_{CH_4,pi}} \right] - f\left(\rho_{CH_4,total}(t), \rho_{N_2O,pi}\right) + f\left(\rho_{CH_4,pi}, \rho_{N_2O,pi}\right) \quad \text{(A6)}$$

$$F_{N_2O}(t) = 0.12 \left[ \sqrt{\rho_{N_2O,total}(t)} - \sqrt{\rho_{N_2O,pi}} \right] - f\left(\rho_{CH_4,pi}, \rho_{N_2O,total}(t)\right) + f\left(\rho_{CH_4,pi}, \rho_{N_2O,pi}\right) \quad \text{(A6)}$$

with the overlap forcing of $CH_4$ and $N_2O$ defined by

$$f(\rho_{CH_4}, \rho_{N_2O}) = 0.47 \ln\left[1 + 2.01 \cdot 10^{-5} \left(\rho_{CH_4} \rho_{N_2O}\right)^{0.75} + 5.31 \cdot 10^{-15} \rho_{CH_4} \left(\rho_{CH_4} \rho_{N_2O}\right)^{1.52}\right] \quad \text{(A8)}$$

For the other gases radiative forcing is given by

$$F_g(t) = \alpha_g \left(\rho_{g,total}(t) - \rho_{g,pi}\right) = \alpha_g \rho_g(t) \quad \text{(A9)}$$

The values of $\alpha_g$ are given in Ramaswamy et al. (2001). The forcings of aerosols and of chlorinated and brominated halocarbons are used in the calculation of global radiative forcing, and thus global mean temperature increase, but not in the attribution of responsibility calculations.

*Temperature Change and Sea Level Rise*

Both global mean surface-air temperature (T) and ocean heat content (SLR) are calculated by impulse response functions of radiative forcing, mathematically equivalent to a model consisting of two independent (parallel) box models:

$$\dot{T}(t) = \sum_{s=1}^{2} \dot{T}_s(t) = \sum_{s=1}^{2} \left[ \frac{T_{eq}}{F_{eq}} \frac{a_s^T}{\tau_s^T} F_{total}(t) - T_s(t) / \tau_s^T \right] \quad \text{(A10)}$$

$T(t) = \int_{t_0}^{t} \dot{T}(t')dt'$, which, with (A10), is equivalent to $T(t) = \frac{T_{eq}}{F_{eq}} \int_{t_0}^{t} R^T(t-t') F_{total}(t)dt'$ (A11)

with $R^T(t) = \sum_{s=1}^{2} \frac{a_s^T}{\tau_s^T} e^{-t/\tau_s^T}$ (A12)

$$S\dot{L}R(t) = \sum_{s=1}^{2} S\dot{L}R_s(t) = \sum_{s=1}^{2} \left[ \frac{SLR_{eq}}{F_{eq}} \frac{a_s^{SLR}}{\tau_s^{SLR}} F_{total}(t) - SLR_s(t) / \tau_s^{SLR} \right] \quad \text{(A13)}$$

$SLR(t) = \int_{t_0}^{t} S\dot{L}R(t')dt'$, which, with (A13), is equivalent to

$$SLR(t) = \frac{SLR_{eq}}{F_{eq}} \int_{t_0}^{t} R^{SLR}(t-t') F_{total}(t)dt' \quad \text{(A14)}$$

with $R^{SLR}(t) = \sum_{s=1}^{2} \frac{a_s^{SLR}}{\tau_s^{SLR}} e^{-t/\tau_s^{SLR}}$ (A15)

The default parameters for using eq. (A10)-(A15) in ACCC are given in Table A.1.

*Table A.1. Parameter values for temperature calculations (left column) and for sea level rise (right column) calculations. These parameters were taken from a fit to a HadCM3 experiment, with $F_{eq}$ = 7.0 $Wm^{-2}$.*

| T | SLR |
|---|---|
| $T_{eq} = 7.3583$ K | $SLR_{eq} = 4.243E+10$ |
| $\tau_1^T = 8.4007$ years | $\tau_1^{SLR} = 870.28$ years |
| $a_1^T = 0.59557$ | $a_1^{SLR} = 0.951$ |
| $\tau_2^T = 409.54$ years | $\tau_2^{SLR} = 32.018$ years |
| $a_2^T = 0.40443$ | $a_2^{SLR} = 0.04898$ |

## Appendix B Model description of ACCC: contributions of emission regions

*Concentrations*

Calculations of concentration changes resulting from emissions are performed according to the equations in Appendix A for each emitting region separately. For example, the change in $CO_2$ concentration for ACCC for region *r* is expressed as in eq. (A3a):

$$\dot{\rho}^r(t) = \sum_{s=0}^{3} \dot{\rho}_s^r(t) \tag{B1}$$

with $\dot{\rho}_0^r(t) = f_0 \cdot C_{CO_2} \cdot E_{CO_2}^r(t)$ and

$$\dot{\rho}_s^r(t) = f_s \cdot C_{CO_2} \cdot E_{CO_2}^r(t) - \rho_s^r(t) / \tau_s \tag{B2}$$

with $E_{CO_2}^r(t)$ the time series of anthropogenic emissions (PgC) for region *r*.

The total global $CO_2$ concentration is then calculated for a total of *R* regions as

$$\rho^{total}(t) = \sum_{r=1}^{R} \sum_{s=0}^{S} \rho_s^r(t) + \rho_{pi} = \sum_{r=1}^{R} \sum_{s=0}^{S} \int_{t_0}^{t} \dot{\rho}_s^r(t')dt' + \rho_{pi} \tag{B3}$$

which equals $\rho(t)$ as calculated using eqs. (A2) and (A3b)

*Radiative Forcing*

In the default case, non-linearities in radiative forcing are not accounted for. The contribution of region *r* to total global forcing is calculated as:

$$F^r(t) = \sum_{g=1}^{G} F_g^{total}(t) \frac{\rho_g^r(t)}{\rho_g(t)} \tag{B3}$$

The summation is performed over all *G* GHGs.

*Temperature Change and Sea Level Rise*

As for concentrations, the same equations as applied globally in Appendix A are applied for each region individually, with global forcing replaced by attributed forcing from eq. (B3). For example, (A10) will become:

$$\dot{T}^r(t) = \sum_{s=1}^{2} \dot{T}_s^r(t) = \sum_{s=1}^{2} \left[ \frac{T_{eq}}{F_{eq}} \frac{a_s^T}{\tau_s^T} F^r(t) - T_s^r(t) / \tau_s^T \right] \quad \text{(B4)}$$

and the convolution integral in (B4):

$$T^r(t) = \frac{T_{eq}}{F_{eq}} \int_{t_0}^{t} R^T(t-t') F^r(t) dt' \quad \text{(B5)}$$

## Appendix C [m1]Hadley Centre climate model (HadCM3)

HadCM3 is a state-of-the-art three dimensional coupled ocean-atmosphere model, which, given realistic GHG concentrations and sulphate emissions can credibly simulate the observed surface warming of the 20th century (Stott et al., 2000). Two HadCM3 experiments were used in the ACCC study, a long stabilisation experiment and a simulation of the 20th and 21st centuries (Johns et al., 2003), with the 21st century concentrations derived from the SRES A2 scenario (Nakicenovic et al., 2000). In the stabilisation simulation the $CO_2$ concentration was increased from pre-industrial levels by a factor of four then held constant for around 900 years while HadCM3 simulated the resulting transient climate change. Impulse response functions were fitted to the surface air temperature, ocean heat uptake and the thermal expansion component of mean sea level rise in order to construct simple linear climate models. The second HadCM3 simulation provided a dataset against which the simple climate models could be tested.

[m1]I deleted Appendix A and B, and place this on the MATCH website.