Project no. GOCE-CT-2003-505539

Project acronym: ENSEMBLES

Project title: ENSEMBLE-based Predictions of Climate Changes and their Impacts

Instrument: Integrated Project

Thematic Priority: Global Change and Ecosystems

Milestone M2A.3.3
Specification of the forcings for the 21st century simulations in stream 2

Due date of deliverable: 31. May 2007
Actual submission date: 14. June 2007

Start date of project: 1 September 2004 Duration: 60 Months

Organisation name of lead contractor for this deliverable: FUB

Revision: final version

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the Consortium (including the Commission Services)	

1. Abstract

In the following, the set of forcings to be used for the second stream 21st century simulations are described. This includes gaseous components (including ozone), aerosols, and land use changes.

The greenhouse gas (GHG) and aerosol data are produced using the IMAGE model and are available as emission data and as concentrations, for 3 stabilization scenarios (475 ppm, 550 ppm, 650 ppm CO_2-equivalent), based on the SRES A1B scenario. They include the major GHG and air pollutants from energy, industry and land use (change). They are available as vertical integrated values either in gridded format, aggregated for 19 regions of the world, or globally aggregated, from 1970 to 2100 in time steps of 5 years.

Ozone data, derived from the Oslo-CTM2 model are available with a horizontal resolution of T21 and vertical resolution of L60 with an upper bound at 0.1 hPa. The data are available for the SRES scenarios A1B, A2, and B1 for the year 2100 as monthly files. Ozone data for the 475 ppm stabilization scenario will be provided until end of September 2007.

The land use data will be available on a 0.5°x0.5° grid, based on IMAGE scenarios until 2100 for the scenario A1B.

The data are available through the ENSEMBES member web-page.

2. Introduction

During the first 30 months of the project, a first stream of simulations for future climate is conducted with all contributing models. These model runs have contributed to the IPCC AR4 (besides one model, EGMAM, which could not deliver the runs in time). Analyses of the simulations can be found in the IPCC AR4. The availability of coordinated runs, using the same forcings lead to a much improved assessment of future climate and the associated uncertainties due to the different models used.

In the next step, a coordinated effort towards a new quality of simulations is planned (cf. Hibbard et al., 2007). To this purpose, all models are improved (inclusion or improvement of aerosol treatment, inclusion of carbon cycle models, inclusion of variable vegetation cover etc.) and the second stream simulations are agreed. Since most models have now reached a level of complexity prohibiting a multitude of runs, a central scenario was agreed to be the common target.

All partners are requested to run at least one realization of the A1B scenario and the GHG and aerosol forcings as in stream one, but with additional land use / land cover change (without stabilisation, i.e. without any specific mitigation action). The land-use / land-cover data will be available through the ENSEMBLES web page.

To demonstrate the effect of significant mitigation actions, an emission reduction scenario is requested from all partners, based on the SRES A1B scenario. Since a 550 ppm CO_2-equivalent stabilization scenario would be very close to the B1 scenario and it would be very interesting to analyse a scenario with an overshoot, it was agreed to aim for a CO_2 stabilisation at 450 ppm. Stabilization scenarios at 450, 550, and 650 ppm CO_2-equivalent starting from the B2 scenario have been presented by RIVM (van Vuuren et al., 2007a). However, according to RIVM, a 450 ppm CO_2-equivalent stabilization scenario can not be obtained with the same policy options as used for the scenarios starting from the B2 scenario when starting from the A1b scenario. With policy measures available, only 475 ppm could be obtained. The stabilization could only be reached beyond 2100, since there is an overshoot to about 530 ppm, already reduced again to about 490-500 ppm by 2100. A further reduction of CO_2-equivalent concentrations could be obtained by reducing deforestation, but it remains questionable if this is a realistic policy option, since it could well be pronounced, but most probably could neither be enforced, nor controlled. Thus, we propose to keep the deforestation as defined in A1b and as used in the stream one simulations to ensure consistency of the runs. The resulting changes could then be attributed to the GHG emissions and are not mixed up with differences due to a different land use policy. Thus it is proposed to take the 475 ppm instead of the 450 ppm CO_2-equivalent scenario. In terms of radiative forcing we expect only minor changes when using 475 ppm instead of 450 ppm. This should be expressed in terms of the resulting probability to exceed the 2°C target, to make our results relevant for the debate on mitigation in particular from the EU's perspective. Further stabilisation scenarios (550 ppm and 650 ppm) are defined and will be run with the models or at the institutions that can afford more than one realisation.

The economic and social scenarios are developed by RT7 and simulated to obtain greenhouse gas (GHG) emissions and concentrations providing the input to the climate models. There may be small differences between the global mean GHG concentrations in the data sets for stream two compared to stream one, due to differences in the derivation methods. However, it is suggested to use the new data sets for stream two to ensure self-consistency of the runs.

In the following, three data sets will be introduced that are available as forcing data for the stream two simulations. In section three, simulated GHG and aerosol emissions and concentrations are described. In section four, a detailed ozone data set is introduced, and in section five the land use / land cover change data set for the stream two simulations is described.

3. Major greenhouse gases and aerosols

RIVM (Detlef van Vuuren) provided:

FAIR-SiMCaP simulations:

Annual mean anthropogenic **emission** data (fossil CO_2, deforestation CO_2, CH_4, N_2O, NOx, VOCs, CO, three groups of SO_2, CF_4, C_2F_6, HFC-125, HFC-134A, HFC-143A, HFC-227EA, HFC-245CA, and SF_6), from 1990 – 2040, decadal from 2040 – 2400.

Annual mean **concentrations** (CO_2, CH_4, N_2O) 1765 – 2400, concentrations separated in low, middle and high levels for CO_2 and CH_4 from 1990 – 2400

Annual mean **radiative forcing** inventories (CO_2, CH_4, N_2O, total Halogens, tropospheric and stratospheric O_3, direct and indirect SO_4, bioaerosols, total aerosols, fossil fuel organic (FOC) and black carbon (FBC), CH_4-O_3, and the substances defined in the Montreal, and Kyoto protocols) from 1770 – 2400.

The **emission** data (CH_4, total Cl, CO, CO_2, Halogens, total HFC, N_2O, NOx, total PFC, SOx, NMVOC) are additionally available separated according to their emission source in 5 groups: energy, industry, agriculture / land use, natural, and total, and for 19 regions of the world, namely:

1. Canada
2. USA
3. Central America
4. South America
5. Northern Africa
6. Western Africa
7. Eastern Africa
8. Southern Africa
9. OECD Europe
10. Eastern Europe
11. Former USSR
12. Middle East
13. South Asia
14. East Asia
15. South East Asia
16. Oceania
17. Japan
18. Greenland
19. Other

and globally:

20. World

every five years 1970 – 2100.

Historic annual CFC-12 values are derived from the reconstructed histories of the annual mean atmospheric mole fractions for the halocarbons CFC-11, CFC-12, CFC-113 and Carbon Tetrachloride (http://gaslab.ucsd.edu/pub/cfchist/) described in Walker et al., 2000.

Annual values for the equivalent CFC-11 concentration (all halogenated species except CFC-12) is derived from the radiative forcing computed from the annual concentrations of all the halogenated species except CFC-12 specified in Houghton et al., 2001.

Concentrations are at 5-yearly resolution are taken from UNEP/WMO, 1998.

The CF_4 preindustrial concentration is taken from Harnish et al., 1996. The annual values of CF_4 and C_2F_6 have been derived using the aluminium production data given in Weston, 1996.

Concentrations are derived at annual resolution using cubic spline interpolation. The resulting series have been edited to suppress small oscillations around zero that can be generated by the cubic spline interpolation.

The computations of the radiative forcing are made within the Excel spreadsheet GHGs_1850-2000.xls using the values of the radiative forcing for each gas given in table 1-6 of WMO/UNEP, 2002.

The total radiative forcing of all CFCs besides CFC-12 is then converted back into the concentration of CFC-11 (called CFC-11*) that would give the same radiative forcing as the sum of the radiative forcing of all the halogenated species.

The annual CFC-12 global concentration values computed from the northern hemisphere and southern hemisphere concentrations given in the file http://gaslab.ucsd.edu/pub/cfchist/cfc12atmhist98.m have been used up to 1990, and completed by zero values from 1900 to 1930

The series represent annual mean (that is central values) for the year in question. Thus, 0.49 is added to the year before writing the series. In this way a rounding of the year when writing it in integer form rounds the year to the correct integer.

If needed, the data can be provided in more aggregated formats, and can also be provided harmonised to 2000 emission inventories by RIVM. The emission data can also be provided as gridded data, using the downscaling technique described in van Vuuren et al., 2007b.

The data are available as Excel or ascii-files and can be obtained from the RT2 web-page.

4. Ozone data

UiO (Bjoerg Rognerud) provided monthly mean global gridded 3-dimensional ozone fields (horizontal resolution T21, vertical resolution L60, upper bound at 0.1hPa) obtained with the model Oslo-CTM2. The data are available for the years 1850, 1900, 1950, 1980, 2000, and 2100 for the three SRES scenarios A1B, A2, and B1 in NetCDF format. The data can be obtained from a server at UiO, linked at the ENSEMBLES RT2A web-page. A stabilisation scenario at 475ppmv is planned, emission data relevant for ozone chemistry for this scenario are provided by RIVM (see section 3). Ozone data for the stabilization scenario will be available by end of September 2007.

5. Land use / land cover change data

IPSL/LSCE (Nathalie de Noblet-Ducoudré) has provided a global land use / land cover change data set with 0.5°x0.5° resolution from 1700 to 2100. Historical reconstructions for cropland (in percentage of each grid cell yearly from 1700 to 1992, Ramankutty and Foley, 1999; in the following RF99) and pasture (in absence or presence, i.e. 0% or 100% per grid cell 1700 to 1990, every 50 years from 1700 till 1950, and every 20 years afterwards; Klein Goldewijk, 2001; in the following K01) are used. For the historical maps (1700 till 1990), *if only crops* are found in a given grid-cell then the *extent provided by RF99* is kept. *If only pasture* is found then *its extent is set to 100%* and no other vegetation type can share the cell. *If both crops and pasture* co-exist within the same grid-cell, then *the extent covered with pasture* is restricted to the part of the grid-cell not covered with crops (*100%-crop extent*). If the crop extent in RF99 exceeds 50%, then the extents of both crop and pasture are set to 50%. These analyses are done for the specific years provided in the K01 dataset. *A linear interpolation is then carried out for the pasture extent, to extrapolate yearly values* at each grid-cell.

Extrapolation of the data set for the A1b scenario is obtained using the IMAGE2.2 scenarios, producing maps of absence or presence of either cropland or pasture per grid cell (http://www.mnp.nl/image/image_products/; The-IMAGE-Project, 1998; in the following FUTU98). A*n anomaly procedure is used to ensure consistency between past and future changes*. Every 10 years, starting year 2000, the changes predicted in FUTU between the specific decade under consideration and the previous one are examined. The IMAGE scenarios only provide presence or absence of a given vegetation type, *the increase in either crop or pasture is then always done at the expense of natural vegetation* that disappears completely from the grid cell (i.e. crop + pasture extent = 100%). If no change is found, then the extent of crop and/or pasture of the decade is set equal to the extent of the previous decade (i.e. the one derived from the historical databases for 1990 for year 2000). If *either* crop *or* pasture increases, then its spatial extent is either increased to the amount needed for the sum (crop+pasture) to be equal to 100%, or unchanged. Conversely, if a decrease *in either crop or pasture* extent is found, then *its spatial extent is set to zero*, and natural vegetation can occupy the part of the cell that just became vacant. If they *both increase*, then their extent is increased by 50% of the part of the grid-cell that was natural the previous decade.

The sum of crop and pasture define, per year and per grid-cell, the amount of natural vegetation cover that can exist. It is suggested to keep the natural vegetation as it is in the respective models. The recommended methodology for the use of the crop&pasture data in the second stream simulations is that each model keeps its vegetation map as used in stream 1 simulations, and change only the crop and pasture fraction as provided in this dataset. The data will soon be available via the RT2A web-page.

6. Other data

3-D sulfate (and other) aerosol concentrations for the A1B scenario are available from Oliver Boucher. For the 475 ppm scenario the model can be re-run to produce the necessary data. This will be done when the gridded emissions necessary for the calculation are available (from Detlef van Vuuren). For further scenarios (e.g. stabilization at 550 ppm or 650 ppm), it is not yet agreed who could provide the runs. This should be discussed when partners are able to realize the respective runs.

For the high top models (EGMAM, CNRM-CM2) extrapolation of the forcing fields to stratospheric levels will be necessary. This will be achieved by using the present-day vertical structure and distributing the future concentrations proportionally to the present-day distribution. The stratospheric extension will be the responsibility of the groups running the high top models.

For the atmospheric oxidants (OH and H_2O_2) it is suggested to use the same forcing data in stream two as was used in stream one, to ensure comparability of the respective runs.

Natural DMS (separately for ocean and land areas) are not in the data set. It is suggested to assume them as constant and use the present-day fields for the future projections.

For the natural forcing (solar and volcanic) it is suggested to use the same forcings as in stream one.

8. Conclusion

To maximise the consistency of the forcings used, it is proposed that all partners use temporal linear interpolation of the emissions which are available every five years.

The necessary forcing data for the A1b simulations in stream two will be available until end of August 2007. The forcing data for the mitigation scenario will become available until September 2007.

References:

Harnish J, R Borchers, P Fabian, HW Gaggeler, U Schotterer, 1996: Effect of natural tetrafluoromethane, Nature 384, 32

Hibbard, K.A., Meehl, G.A., Cox, P.M., and Friedlingstein, P., 2007: A strategy for Climate Change Stabilization Experiments, EOS, 88 (20)

Houghton et al., 2001: Climate Change 2001: The Scientific Basis:

- Annex II.2.10 (http://www.grida.no/climate/ipcc_tar/wg1/540.htm) for CFCs

- Annex II.2.4 (http://www.grida.no/climate/ipcc_tar/wg1/534.htm) for PFCs, SF6 and HFCs

Klein Goldewijk, K., 2001: Estimating global land use change over the past 300 years: The HYDE database. *Global Biogeochemical Cycles*, **15**, 417-433.

Ramankutty, N. and J.A. Foley, 1999: Estimating historical changes in land cover: North America croplands from 1850 to 1992. *Global Ecology and Biogeography*, **8**, 381-396.

UNEP/WMO, 1998: Scientific Assessment of Ozone Depletion: Chapter 11: Halocarbon scenarios for the future ozone layer and related consequences, Guus Velders (RIVM) and Sasha Madronich (NCAR), Version 5

van Vuuren, D.P.; M.G.J. den Elzen; P.L. Lucas; P. Eickhout; B.J. Strengers; B. van Ruijven, S. Wonink; R van Houdt, 2007a: Stabilizing greenhouse gas concentrations at low levels: an assessment of reduction strategies and costs. Climatic Change, 81, 119-159.

van Vuuren, D.P. et al., 2007b: Global Environmental Assessment

Walker, S. J., R. F. Weiss and P. K. Salameh, 2000: Reconstructed histories of the annual mean atmospheric mole fractions for the halocarbons CFC-11, CFC-12, CFC-113 and carbon tetrachloride. Journal of Geophysical Research, 105, C6, 14,285-14,296

Weston RE, 1996: Possible greenhouse effects of tetrafluoromethane and carbon dioxide emitted from aluminum production. Atmos Env 30, 2901-2910

WMO/UNEP, 2002: Scientific Assessment of Ozone Depletion: http://www.wmo.ch/web/arep/reports/o3_assess_rep_2002_front_page.html