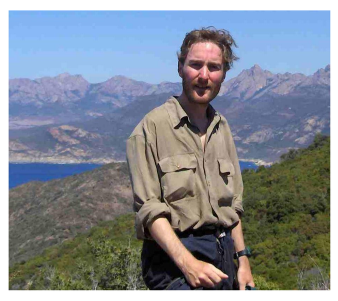
Université catholique de Louvain

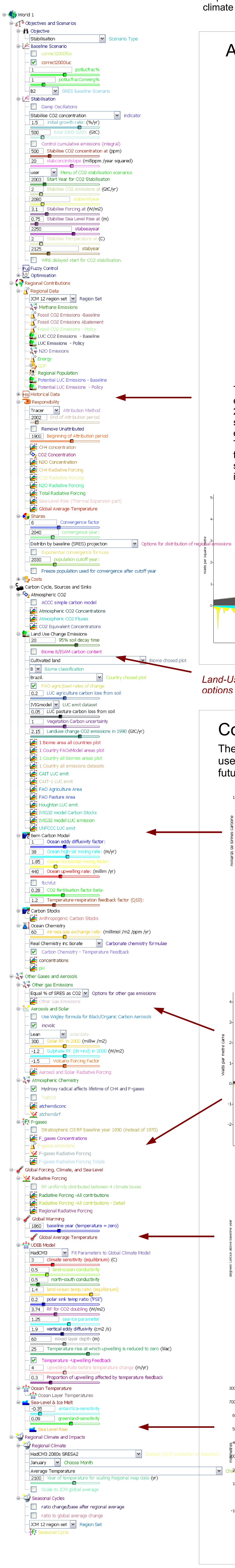
ASTR

MATCH
Modelling and assessment of contributions to climate change

Ben Matthews, *matthews@climate.be*
Institut d'Astronomie et de Géophysique,
UCL Louvain-la-Neuve, Belgium
Interactive Model: **www.climate.be/jcm**
With help from Jean Pascal vanYpersele, Christiano Pires de Campos



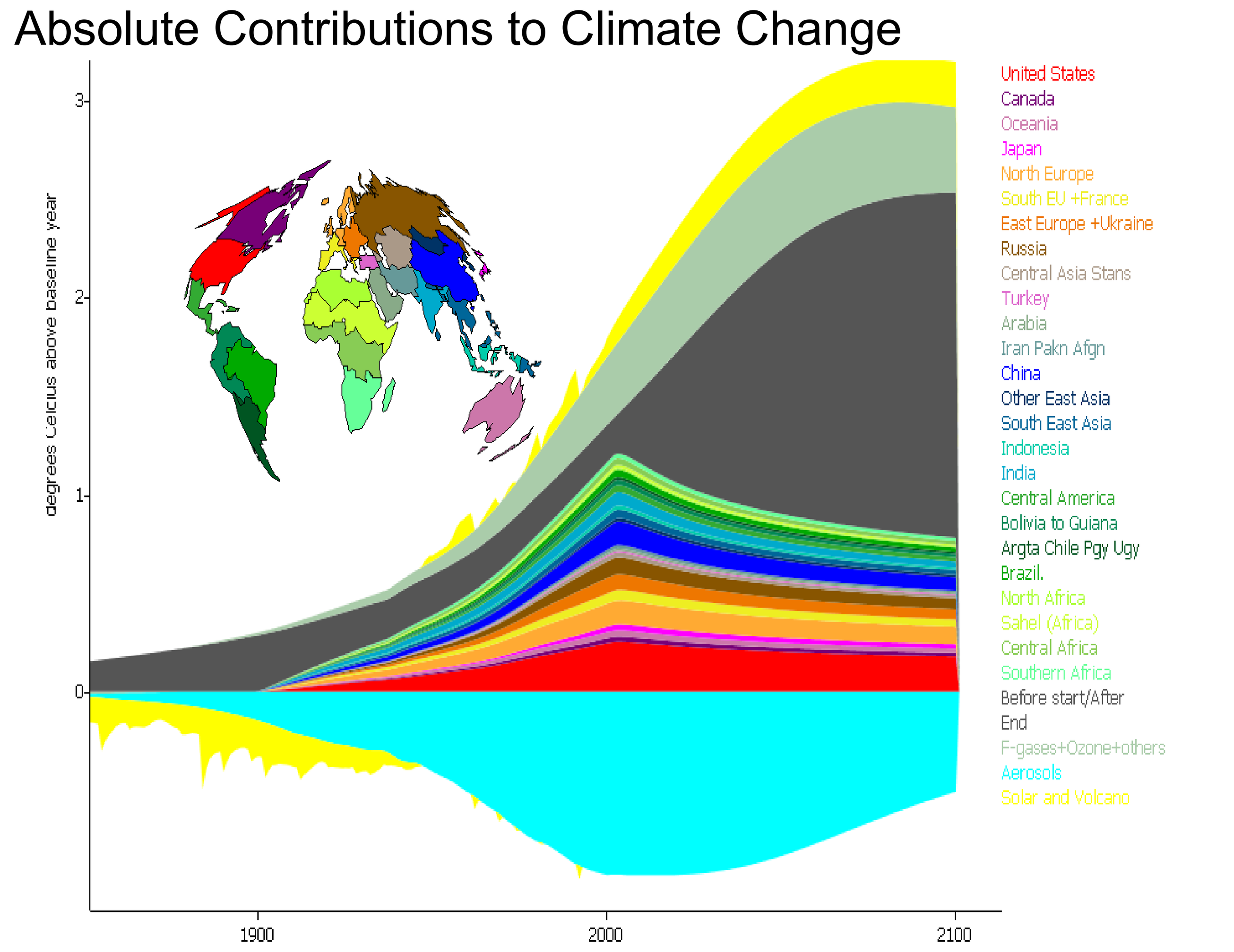
The column below shows JCM5 "tree" of adjustable parameters and curve sets



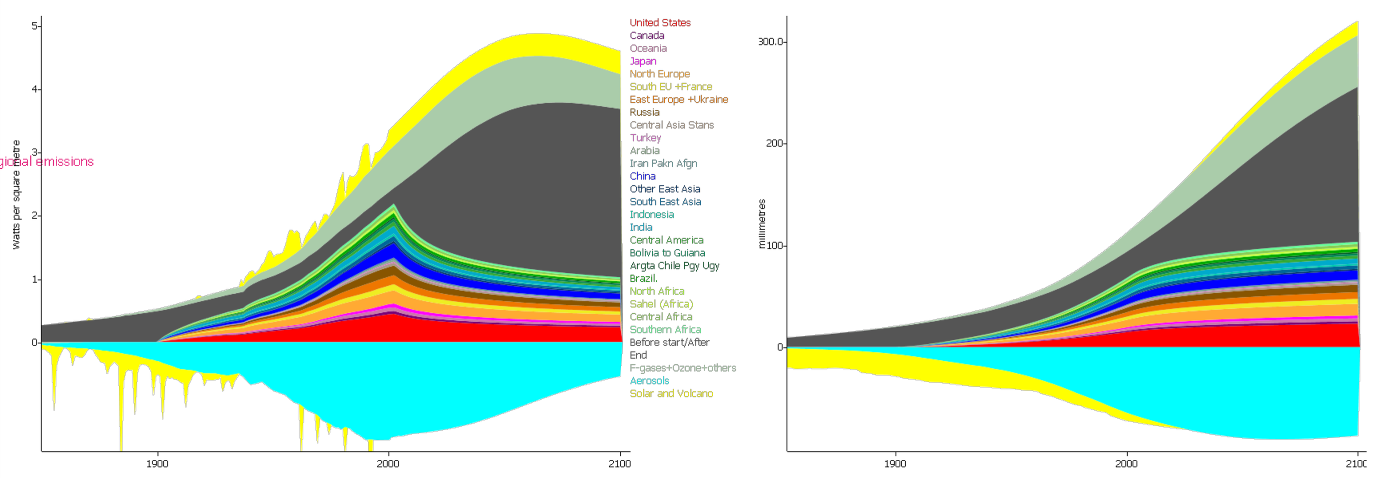
1. Attribution of Regional Contributions to Climate Change in Java Climate Model JCM5

This poster introduces some calculations made with Java Climate Model (JCM5) regarding regional contributions to climate change, as part of the international intercomparison process "ACCC", later evolving to "MATCH", set up in response to the request of the UNFCCC SBSTA for assessment of "Scientific and Methodological Issues" relating to the Brazilian Proposal. The latter proposed to apply the "polluter pays principle" to budren sharing in the global climate negotiations, and therefore required a relatively simple and transparent way of calculating the relative contribution of each country to global temperature rise.

Absolute Contributions to Climate Change

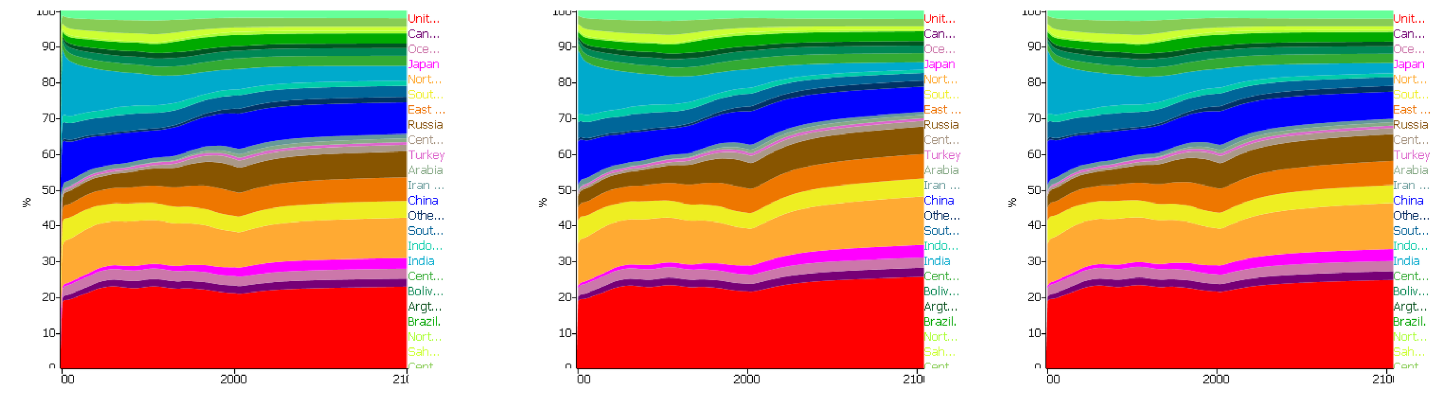


The plot above shows the absolute contributions to temperature rise (°C > 1850), due to emissions from CO2, CH4 and N2O from 25 regions (colors as on map) between 1900 and 2002. Forcing from other gases (O3, F-gases etc., in grey) and from aerosols (in cyan), and from solar variability and volcanos is also included but not attributed regionally. The effect of emissions before 1900 and after 2002 is shown in dark grey.
The plots below attribute the effect of the same emissions as above, on radiative forcing (left) for which the decay after 2002 is rather more rapid, and on the thermal expansion component of sea-level rise (right), whose large inertia is evident. Thus the choice of time horizon and indicator makes a difference to the relative contributions.



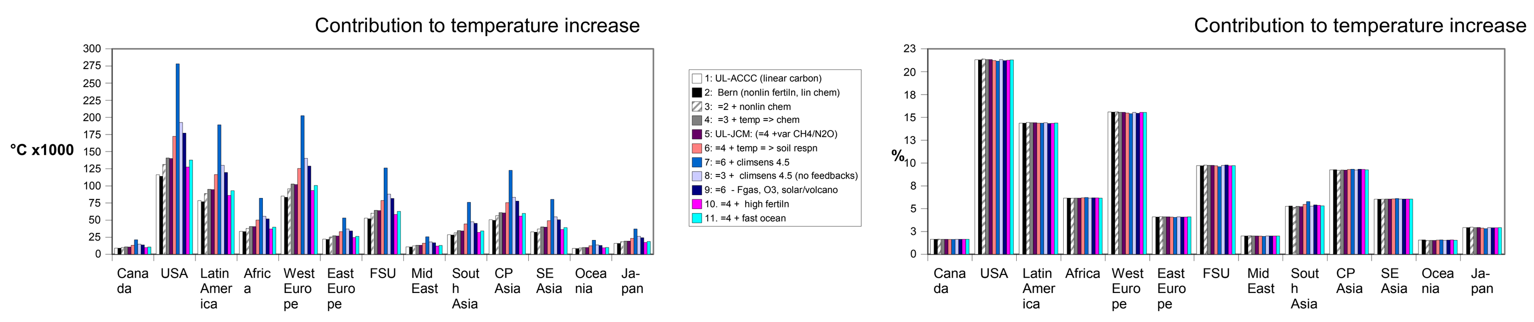
Land-Use-Change Emissions options (see second poster)

Relative Contributions / Attribution Method



These three plots show the relative (%) regional contributions to global warming due to emissions from CO2 (fossil+landuse), CH4 and N2O between 1900 and 2000 (the timescale continues to 2100 following a scenario stabilising CO2 at 500ppm, but emissions beyond 2000 are not attributed). Colours are as on the map (left). Three different methods were used for attributing over non-linear cause-effect relationships. The left plot was calculated using the JCM default "tracer" method, the centre plot using the "timeslice" and the right using the "marginal" method (for more explanation see MATCH paper#1 and papers of Enting and Trudinger). The difference in 2000 is very small, but is more apparent after 2000, the timeslice method giving relatively more weight to earlier CO2 emissions rather than later ones. Note the contributions of developing regions generally contain a higher proportion of methane, and hence fall off more rapidly after attribution stops in 2000.

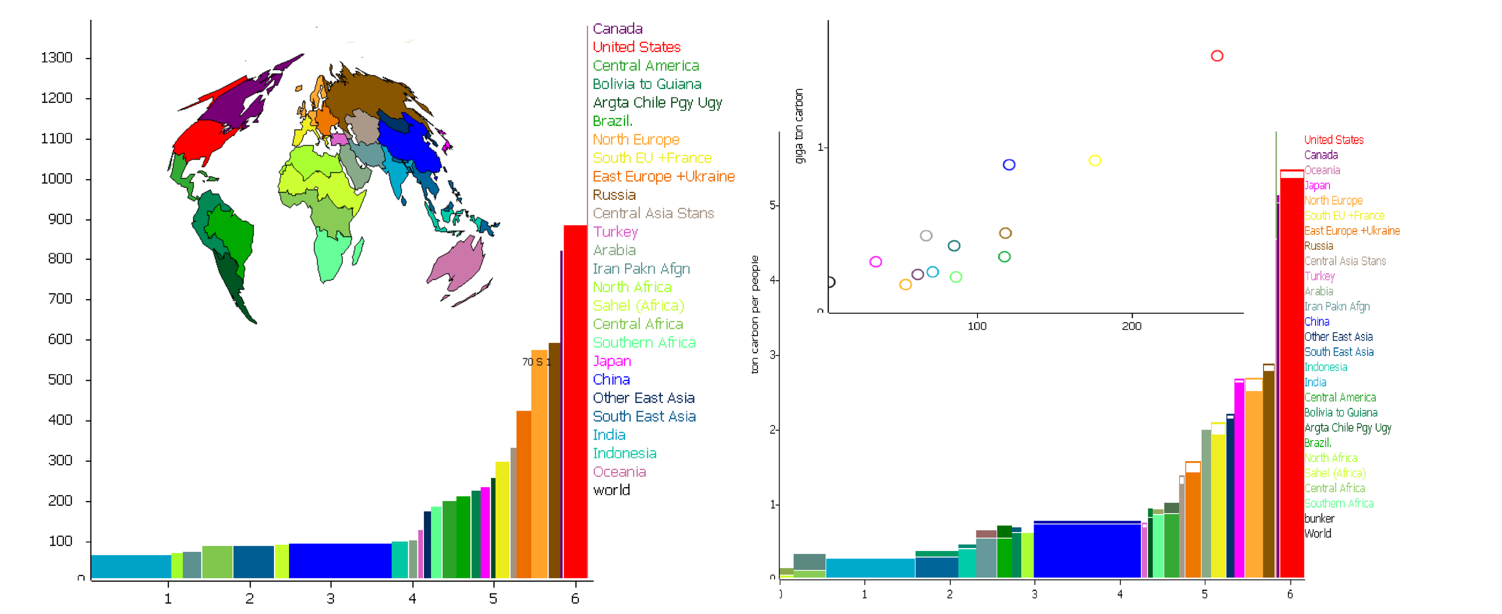
Effect of Carbon Cycle Variants, Absolute vs Relative contributions



The plots show the absolute (left) and relative (right) attributed temperature change in 2100 due to emissions of CO2, CH4 and N2O prior to 2000 (unattributed emissions follow SRES A2 thereafter). Each group compares 11 variants of carbon cycle parameters, including some temperature feedbacks on ocean chemistry and soil respiration. It is evident that this makes a big difference to absolute contributions, but little difference to relative contributions. These two plots were prepared for JCM contribution to MATCH paper #1, 2005, "Analysing countries' contribution to climate change: scientific and policy-related choices" (although only the relative one included, due to focus of that paper).

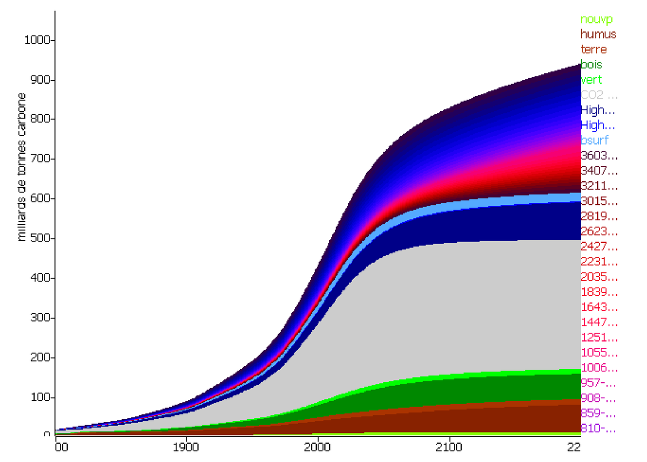
Attributed Warming per capita, compared to current emissions

The histogram below left shows attributed warming per capita including CO2, CH4 and N2O from 1890 to 2002 (y-axis: °C per capita $x10^{12}$, x-axis: population $x10^{9}$, areas °C, colors as map).
For comparison, the histogram below right shows CO2 emissions per capita in 2002 (y-axis : GtC) , the main part of each bar showing fossil emissions and the top part land-use-change (shown white in case where net land-use sink is subtracted from fossil emissions).
The scatterplot (insert right) plots current fossil emissions (Y) against attributed temperature (X)
Note: it is debatable, whether current population is an appropriate divisor for responsibility accumulated over a long time

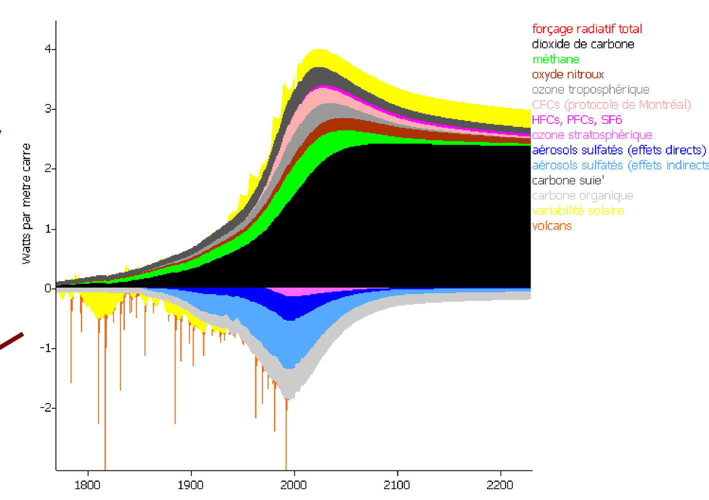


Core Science of JCM5: Carbon, Forcing, Climate

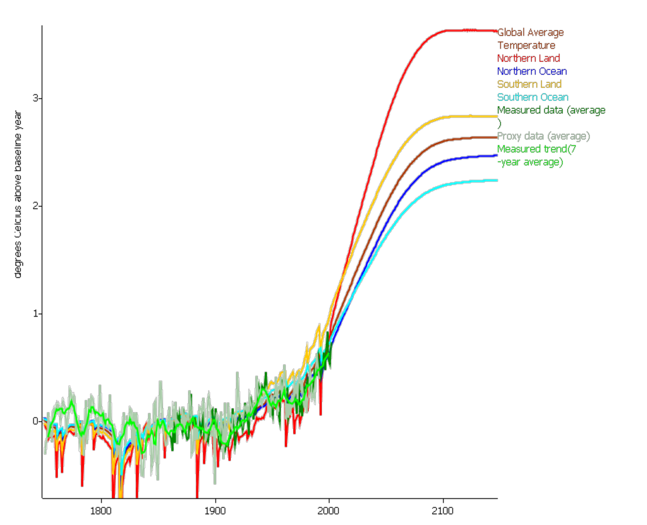
The core science of JCM5 has been derived principally from formulae and simple models used by IPCC-TAR. The plots below illustrate some components, showing both history and future (a scenario stabilising CO2 concentration at 500ppm is followed beyond 2002).



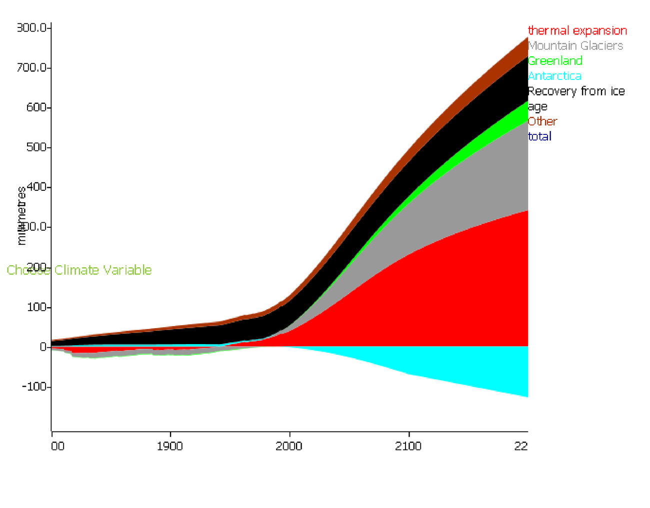
Bern Carbon Cycle:
The plot shows stocks of anthropogenic carbon: grey is atmospheric CO2, blues show different ocean layers, becoming red at greater depths, green shows land plants and brown soil / humus. JCM calculates individual fluxes in the Bern model (rather than a pulse response function), so many parameters are adjustable (see tree on left), including some climate-carbon feedbacks.



Other gases, Atmospheric Chemistry and Forcing:
JCM includes emissions of over 30 gases and aerosol precursors (including CH4 and N2O, CO NOX & VOC, and derived O3, all the CFCs and HFCs, BC / OC / SO4, etc.). Solar variability and volcano forcing are also included. The plot (left) shows the components of the radiative forcing from all these sources evolving over time. The stabilisation scenario assumes mitigation of all gases, so the relative contribution from short-lived gases decreases in the future. Although only CO2, CH4 and N2O are currently attributed to regions, all gases are included when calculating absolute forcing and temperature..

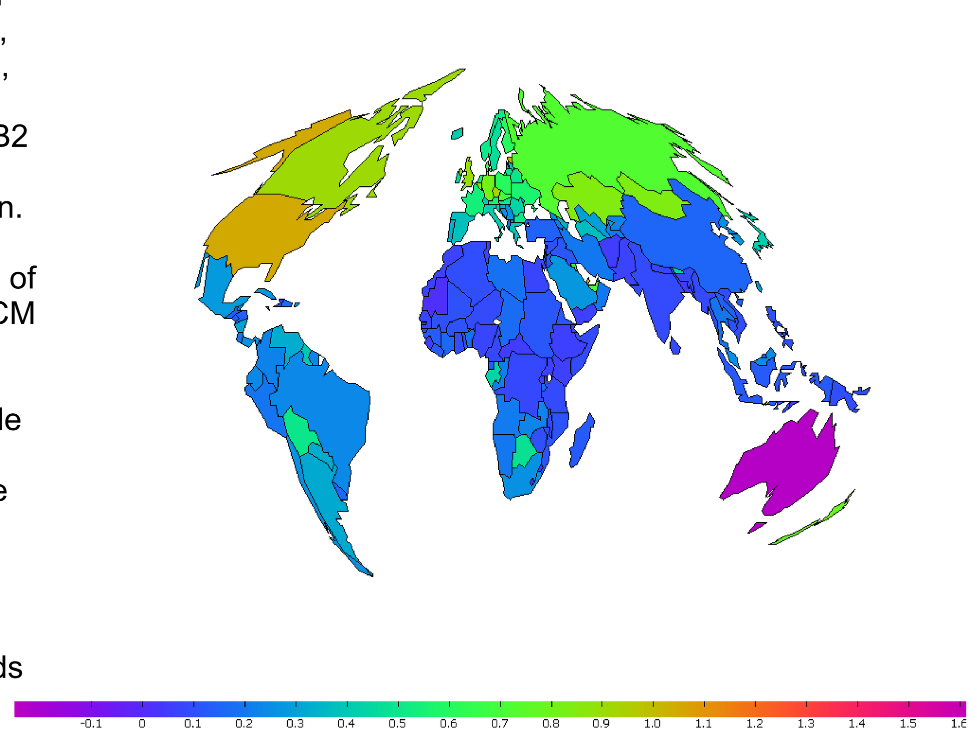


Upwelling-Diffusion Energy Balance Model:
JCM implements a java version of the UDEB climate model developed by Wigley and Raper, comprising 4 surface boxes and about 80 ocean layers. The parameters of this model (see tree on left) may be adjusted either individually or as a set in order to fit one of seven GCMs, as explained in IPCC-TAR (apx 9.1). In this plot, temperatures of the four surface boxes are shown (reds and blue), together with measured global average data from UEA-CRU (greens). For example, the northern land, being the least buffered by slow ocean heat uptake, reacts more dramatically to volcano and aerosol forcing.



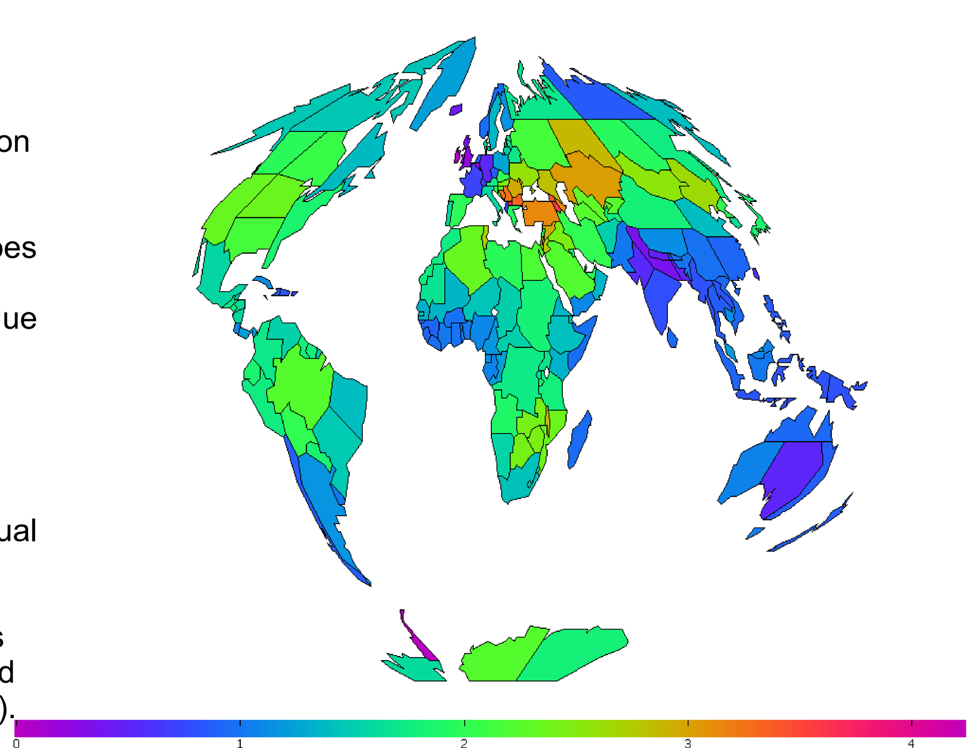
Sea Level Rise:
The plot shows contributions to sea-level rise. The thermal expansion (derived from UDEB model) is relatively predictable, but the ice-melt components are highly uncertain. Although JCM is consistent with IPCC-TAR, recent measurements suggest that ice is melting much faster than projected by such models.

Distribution of Cause and Effect of global warming



The top map shows the distribution of attributed warming per capita in 2025, attributing CO2 (Fossil and LandUse), CH4 and N2O from 1750 to 2025 (historical data 1750 to 2002, SRES B2 thereafter). Units are degrees C (relative to 1750) per billion population.

The lower map shows the distribution of warming predicted by HadleyCM3 GCM (data from IPCC-DDC) in July, averaged for the 30-year period centered on 2025, scaled to the simple model average for exactly the same scenario. Units are degrees C relative to 1960-90



This is only one snapshot to illustrate the different distributions. The distribution of climate impacts depends on many climate variables (e.g. preciptation, cloud-cover, winds etc.), large seasonal variations, changing frequency of extreme events, and socioeconomic factors influencing vulnerability. Further work is needed on assessing relative impacts.

Note that the attribution (top map) does not include aerosols, ozone, etc., however the distribution of warming due to these short-lived gases would be very different from that of well-mixed gases.

The top map also illustrates that JCM can calculate attribution for all individual nations, and for future as well as history. Note that some apparent anomalies inless developed countries are due to landuse change (calculated using IVIG model, see second poster).