RESEARCH PLAN

Modelling and assessment of contributions to climate change (MATCH): Research plan for the further development of the scientific and methodological aspects of the proposal by Brazil for the calculation of contributions by source to climate change

Version 31 October[1]

Objective

To continue the work on the scientific and methodological aspects of the proposal by Brazil

Background

As part of the negotiations on the Kyoto Protocol, under the Framework Convention on Climate Change (UNFCCC) the delegation of Brazil made a proposal, in May 1997, which included a methodology to set differentiated emissions reduction targets for Parties according to the impact of their historic emissions on temperature rise (FCCC/AGBM/1997/MISC.1/Add.3). Documents can be found at www.unfccc.int. Whilst this aspect of the proposal was not utilised at the time, Parties nevertheless decided that the scientific and methodological aspects should be further explored.

As a result two expert meetings on the subject have been held under the auspices of the UNFCCC. The first expert meeting reviewed the scientific and methodological aspects of the proposal by Brazil (28 – 30 May 2001 in Bonn, Germany). Conclusions of that meeting can be found in document FCCC/SBSTA/2001/INF.2. The second expert meeting to assessed the preliminary results provided by the participating research institutions to provide new and comparable results on the issue of contributions to climate change (25 - 27 September 2002 in Bracknell, UK).

During this meeting a preliminary set of validation results and attribution results were presented and discussed. These demonstrated a widespread capability to deliver a potentially useful tool for use in attributing climate change using a variety of indicators. Nevertheless, it became clear during the discussions that developing the simplified tools from this exercise into robust tools for attribution at a finer resolution would be a major scientific undertaking that integrates the scientific findings of the IPCC Third Assessment Report (TAR) with new work that will reach beyond that of the TAR. The pathway to accomplish this, through a phase III process, was a major focus of the discussion. Conclusions of that meeting can be found in document FCCC/SBSTA/2002/INF.14.

At a meeting of the Subsidiary Body on Science and Technology (SBSTA 17, New Delhi, October/November 2002), the SBSTA agreed that work on the scientific and methodological aspects of the proposal by Brazil should be continued by the scientific community and that such work should be of a standard consistent with the practices of peer-reviewed published science. It invited the scientific community, including scientific and assessment programmes, such as the International

[1] This draft was developed by the support unit with input from UK DEFRA based on the outcomes of the three working groups of the expert meeting and comments on the draft report. The scientific coordination committee will further elaborate on the research plan.

Geosphere-Biosphere Programme, the World Climate Research Programme, the International Human Dimensions Programme on Global Environmental Change and the Intergovernmental Panel on Climate Change to provide information to Parties, and each other, on their interests in the work. The original text of the conclusions on the item "Scientific and methodological aspects of the proposal by Brazil" as adopted by the SBSTA can be found in document FCCC/SBSTA/2002/L.24.

At SBSTA 17, the governments of Brazil and the United Kingdom of Great Britain and Northern Ireland expressed their readiness to support a third expert meeting on the Brazilian proposal in 2003. The Government of Germany has also kindly offered to host the meeting.

At SBSTA18 (Bonn, 4 - 13 June 2003), positive responses from IGBP and WCRP were disseminated and the Governments of Brazil and of the UK informed all parties about the third expert meeting on the Proposal by Brazil to be held from 8 – 9 September 2003 in Berlin.

The 3rd meeting agreed to continue work on the scientific and methodological aspects of the proposal by Brazil and developed the work plans found below.

Aims of Phase III

- To develop a more robust attribution tool
- To study the sensitivity of the results to scientific uncertainties
- To study the sensitivity of the results to political and methodological choices
- To increase scientific participation, without the work becoming fragmented
- To increase political awareness of the methods, its advantages and disadvantages.

A scientific coordination committee guides the process. It consists presently of the following experts:

Name	**Affiliation**	**Expertise**
Xiaosu Dai	National Climate Center, China	Regional climate, impacts
Michel den Elzen	RIVM, Netherlands	Integrated models
Jan Fuglestvedt	CICERO Centre for Climate Research, Norway	Integrated models
Jason Lowe	Met Office, Hadley Centre for Climate Prediction and Research, UK	Global - regional climate
Joyce Penner	University of Michigan, USA	Aerosol - climate interactions
Michael Prather	University of California at Irvine, USA	Atmospheric chemistry / emission / climate
Cathy Trudinger	CSIRO Atmospheric Research, Australia	Methodology science, non-linear effects
Murari Lal	IIT, India	Global - regional climate and variability, sea level rise
Tbn	Tbn, Brazil	LULUCF?
Niklas Höhne	ECOFYS, Germany	Secretary

The process is supported by ECOFYS, Germany, as 'support unit' under contract by UK DEFRA. A process web site is under development.

Research Plan

Work will be undertaken in two streams:

A. Collecting and improving knowledge and data on the climate system: Latest scientific information on the climate system will be collected and overarching research questions regarding climate change science will by addressed
B. Calculating contributions to climate change: Attribution methods will be further developed and assessed and models will be used or built to assess contributions to climate change

Stream A. Collecting and reviewing knowledge and data on the climate system

In order to calculate contributions to climate change accurately and scientifically credible, latest scientific information on the climate system and emission data needs to be collected to be integrated into the models used in stream B. Due to the large number of issues, the ad-hoc group will have to rely on results and outcomes of other scientific process. If necessary information is not available, efforts will be made to generate this information.

The major scientific research questions were identified as follows:

1. How accurately can we reconstruct and understand the history of greenhouse gases (GHG), aerosols, and their precursors? This involves geographic emissions, atmospheric composition models, and observed abundances over the period 1750 to present. Sub-questions include:

> (1a). How well can we quantify the uncertainties in emissions at global, regional, and -- where possible -- national scales?
>
> (1b). What is the quantitative role of biogeochemical feedbacks and changes in natural emissions to these historical changes in atmospheric composition?
>
> (1c). How well can we reconstruct past LULUCF, and what uncertainty does this add to the history of atmospheric composition?

2. Can we improve our understanding of the current direct and indirect effects of aerosols on regional and global climate? Can we quantify the historical role (relative to GHG and natural forcing) of aerosols in the observed climate change?

3. How do we combine the effects GHG, aerosols, and LUCF to replicate past climate change (global and regional) within the range of variability/predictability, and be assured that no significant attributable anthropogenic forcings are missing?

4. Can we anticipate how feedbacks in biogeochemical cycles over the coming century(ies) will compare with the direct anthropogenic emissions in changing the climate?

Concrete further work to be done from now to December 2005
(to be developed)

Stream B. Calculating contributions to climate change[2]

B.1 Question to be addressed by June 2004 (including an expert workshop in April 2004):

1. How robustly can the models used in phase II be used to attribute anthropogenic climate change to regional emissions of well-mixed greenhouse gases, and what effect have uncertainties in emissions, climate models, and methodological choices on this attribution?

Most of this work has already been done, but there remain gaps in analysing how well different choices can be combined, and hence investigating what the total range of uncertainties (made up of scientific uncertainties and differences arising from a range of methodological choices) is.

Work under phase II has identified a range of possible impact indicators of climate change such as radiative forcing, global mean temperature change, sea-level rise and a range of possible attribution methods, and the results different models give for different choices of either climate indicator or attribution method. However some combinations of climate indicator, attribution methods and time frames may not be meaningful or produce counterintuitive results, and the summary report should clearly outline what combinations do make sense, and to what extent models give consistent answers across this range of combined choices. Furthermore, the influence of uncertainties in emissions on uncertainties in the attribution, for a given choice of timeline, climate indicator, and attribution method, has also not been widely tested by models to date. Also models have generally not incorporated all possible radiative forcing agents, e.g. emissions of CFCs and other well-mixed greenhouse gases that are controlled by the Montreal Protocol, and some climate system representations and key feedbacks could be improved (e.g. carbon cycle, energy balance of the climate system). Many of those questions have been tackled by individual modelling groups, but there are a number of gaps in combining those different options and testing their effect on the resulting attribution.

The key outcome to be reported by June 2004 would be the cross-correlation and dependencies between uncertainties, that is, the influence of different methodological choices (time frames, climate indicators, attribution methods), emission uncertainties, and the differences in model representation of the climate system, on the relative attribution to the four regions used in the model studies under phase II (OECD90, REF, ASIA, ALM).

Concrete further work to be done between now and April 2004:

a) Emission uncertainties (as soon as possible - from Group A) Develop estimates of emission uncertainties for the four regions used in phase II, based on the EDGAR database. Because of time constraints, those uncertainty estimates cannot be thorough, but should rather represent upper-limit working hypotheses that can be used to test their effect on uncertainties in attribution. A fuller description of uncertainties can only be developed over the course of a year or more.

b) Attribution methods Determine a minimum range of attribution methods to be used for further testing by all models used in the inter-comparison. A range of questions needs to be addressed before a final recommendation can be provided:

[2] Some experts strongly recommended prioritization of the work to increase the feasibility.

- What are the implications of applying the attribution methods at different steps in the cause-effect chain? For example, an important question is the sensitivity of calculations of attribution of temperature change to applying particular methods, in particular normalization, only to temperature outcomes (i.e., at the end of the cause-effect chain), versus applying them to each step in the chain separately (i.e., first attributing concentrations, then radiative forcing, then temperature change).
- Do non-CO_2 gases introduce new methodological issues? The development of the inventory was done using the carbon cycle as an example. Considering other gases, with different types of relationships, could have different implications for particular methods. The case of SO_2, which has an effect opposite in sign to the greenhouse gases, is a case in point.
- Do negative emissions (e.g., sequestration) introduce any methodological difficulties?
- What are the implications of performing attribution calculations for many gases at the same time? For example, what methodological choices are introduced when the carbon cycle is affected by temperature change, which itself is affected by methane concentrations, and methane concentrations are affected by the emissions of multiple gases?
- What methodological approaches exist for multiple causation? For example, the net CO_2 fertilization flux typically depends on both the atmospheric CO_2 content, as well as the carbon content of photosynthetic reservoirs. Some methods (e.g., generalized marginal) treat this issue implicitly, others (e.g., flux-based) treat it explicitly. The implications of different approaches remain to be clarified.
- What are the implications of normalizing the results of methods that, when applied to all units of cause, do not add to global total effect?
- Are the normalization conventions well-defined in the presence of complex feedback-loops in the climate and biogeophysical cycles?
- What can be learned from experience in other scientific disciplines, for example, in attributing the health impacts caused by a mixture of environmental and lifestyle effects.

c) Cross-check methodological choices (by April 2004) Determine if any combinations of climate indicator, attribution method and time frame need to be ruled out because of resulting methodological inconsistencies or non-sensical results for those specific combinations.

d) Test effect of emission uncertainties (by April 2004) Test the effect of emission uncertainties (including land-use change emissions) in the four regions on attribution for a range of time frames, climate indicators and attribution methods (including uncertainties in future emissions, based on all SRES emission scenarios).

e) Test methodological choices against hypothetical emission scenarios (by April 2004) Test the robustness and differences of combined choices of climate indicator and attribution method with hypothetical emission scenarios. A set of test cases could include (relative to constant or exponentially increasing total world emissions), for a single region: linear increase; linear decrease; constant fraction; sharp increase followed by sharp decrease; constant fraction with sharp decrease just before the end date.

f) Test effect of all well-mixed greenhouse gases (by April 2004) Test the degree to which the inclusion of other well-mixed greenhouse gases not included in models to date (mainly gases controlled by the Montreal Protocol), including their attribution to the four regions, affects the attribution calculations made in the absence of those gases.

g) Test effect of key feedback mechanisms (by April 2004) Test the degree to which a more detailed representation of feedbacks in the climate system (for example, carbon cycle, reaction of the climate system to radiative forcing) affects the attribution calculations made to date under phase II.

h) Describe model realism (by April 2004) Demonstrate the extent to which the simple climate models used to date are able to represent observed compositions of the atmosphere and climate changes (mostly covered in phase I) and whether tuning of those models to match observations would affect absolute and relative attribution calculations.

It would be the task of the Scientific Coordination Group, with the help of the secretariat, to solicit and collect relevant work as listed above from the scientific community, ensuring that key gaps as listed above are filled as well as possible. Groups should also be encouraged to submit their results in a consistent format, which allows easy compilation by the Secretariat. The expert workshop in April 2004 would discuss the findings of this "closing the gaps" work, and decide on ways of presenting and summarising the findings for policymakers at SBSTA 20 in June 2004.

B.2 Question to be addressed by December 2004:

2. To what extent does a fuller representation of the climate system, and of other key non-attributed emissions that affect the climate, change the results of the attribution calculations based on emissions of well-mixed greenhouse gases?

Work under Question 1 will have presented attribution calculations based on regional emissions of well-mixed greenhouse gases, using climate models that offer a limited representation of the climate system, and not accounting for other climate-relevant emissions such as aerosols or tropospheric ozone. The next phase of the work programme would focus on the question whether a fuller representation of the climate system significantly changes the outcome of the attribution calculations for well-mixed greenhouse gases or the sensitivity of attribution methods. At this stage, aerosols and their precursors and ozone precursors would be included in the climate models, but their emissions are not used to attribute regional contributions to climate change. Attribution at this stage would still be done only on the basis of regional emissions of well-mixed greenhouse gases, for the four regions used to date (OECD90, REF, ASIA, ALM) or an increased number of regions. The question of whether and how emissions of aerosols and ozone precursors can be included in regional attribution will be addressed under question 3, which is discussed further below. The expert meeting scheduled for April 2004 could elaborate further the work items summarised below.

Concrete further work to be done between now and December 2004:

a) Aerosol emissions

- Incorporate regional (but not attributed) emissions of aerosols at an appropriate spatial scale represented by the models, using a wide range of emission scenarios and estimates, using proxy data where necessary. Use TAR parameterisation of climatic effects of aerosols.
- Evaluate the extent to which this non-attributed incorporation of aerosol emissions changes the results of the attribution calculations carried out for

Question 1, using a range of combinations of climate indicators, attribution methods, and time frames. (This means, attribution is still only calculated on the basis of emissions of well-mixed greenhouse gases, but the models used to do the attribution calculations have a fuller representation of key climate drivers.)

- Describe the relative magnitude of uncertainties introduced in the attribution calculations due to this non-attributed consideration of aerosol emissions, differences between models formulations, and aerosol emission uncertainties for past and potential future emissions based on SRES and other relevant proxy scenarios to 2100.

b) Tropospheric ozone

- Incorporate relevant ozone precursors and ozone chemistry as well as OH in climate models, using updated TAR parameterisation.
- Evaluate the extent to which incorporation of tropospheric ozone and its precursors (non-attributed) in climate models changes the results of attribution calculations for well-mixed greenhouse gases

c) Complex atmospheric chemistry feedbacks

- Include more complex feedback mechanisms in models, for example, variable CH4 lifetime, and evaluate the extent to which the incorporation of those mechanisms changes the result of attribution calculations for well-mixed greenhouse gases.

d) Solar and volcanic variability including uncertainties

- Incorporate natural climate drivers (solar variability and volcanic eruptions) and test the extent to which incorporation of those natural climate drivers affects the results of the attribution calculations for well-mixed greenhouse gases.

e) Summary: Evaluate improvements of model realism and overall effect on attribution calculations for well-mixed greenhouse gases

- Describe the extent to which the improvements to climate models described above improve the realism of model outputs (with regard to observed global average temperature trends).
- Describe the extent to which the improvements to climate models described above alter the results of attribution calculations for regional emissions of well-mixed greenhouse gases as described in Question 1, for a range of climate indicators, attribution methods, time frames, and taking into account uncertainties emissions and natural climate drivers.

B.3 Question to be addressed by July 2005:

3. To what extent can other anthropogenic emissions and processes be used to calculate regional contributions to climate change, and is it possible to achieve a finer regional resolution of the attribution calculations?

Work under Questions 1 and 2 will have presented attribution calculations based on four regions (OECD90, REF, ASIA, ALM), using more complex representations of the climate system and key climate drivers, but attributing regional contributions to global climate change only on the basis of regional emissions of well-mixed greenhouse gases. In the last phase of this methodological work before reporting back to

SBSTA23 in December 2005, work should focus on the question to what extent emissions other than well-mixed greenhouse gases, namely aerosols and ozone precursors, and possibly changes in albedo can be used to attribute total regional contributions to climate change, and how a finer regional resolution can be achieved.

It is more difficult to clearly state the methodological work to be done for this phase, and the points below are more an outline of key questions that should be explored by modelling groups. The scientific work required for this phase would clearly go beyond the science summarised in the TAR. The expert meeting scheduled for April 2004 could elaborate further the work items summarised below.

Concrete further issues to be addressed between April 2004 and July 2005:

a) Improve regional scale of calculations. To improve the regional resolution of attribution calculations (for phase II the four SRES regions), it was thought desirable to aim for attribution calculations for the regions of the EDGAR database. This raises the following specific questions and work items to be addressed before they can be incorporated in model calculations:

- (from Group A) A full description of emission uncertainties in the EDGAR database, including their correlations in time and between regions
- (from IPCC TGCIA) Downscaling of SRES emission projections to the EDGAR regions, including possible uncertainties and cross-correlations. Needs to include guidance on how to deal with boundary issues (boundaries between SRES and EDGAR regions, and boundaries in time from historic to projected emissions on regional scales)
- (from various groups) Regional aerosol and ozone precursor emissions, including proxies where necessary, and including uncertainties

b) Attribution including aerosol and ozone precursor emissions. The climatic effects of aerosols and ozone are not globally uniform because aerosols and ozone are not well-mixed in the atmosphere. In addition the dependence on the background atmosphere due to chemical non-linearity in the O3-OH chemistry can lead to very different chemical responses between various regions. This raises a number of questions

- If the climatic effect of aerosols and ozone is described in a global average way, can we account for the fact that emissions in different regions have different effects on the global average climate? (For example, short-lived greenhouse agents with intense local forcings, teleconnections and rainout processes for aerosol emissions, lower background pollution in the southern hemisphere)
- Does the climatic effect of aerosols and tropospheric ozone need to be described on a regional rather than global average basis? Are there consistent ways to describe regional climatic effects? How would the effect of an emission that leads to cooling in one region but warming in another region be described in terms of regional or global attribution? Are there climate indicators that could be used for both regional and global attribution?
- If regional climatic effects are to be considered in attribution calculations, how can model differences be reconciled?
- Are climate indicators and attribution methods used under questions 1 and 2 equally suited to attribution of the effects of aerosols and ozone? (For example, can we incorporate the important influence of aerosol emissions on regional rainfall patterns when the chosen climate indicator is global average temperature change?)

- Are methodological choices linked to time frames suited to attribution of the effects of aerosols and ozone, given the short lifetime of those substances? Does any combination of methodological choices that is reasonable for well-mixed greenhouse gases lead to counterintuitive or non-sensical results if aerosols and ozone are included in the attribution calculations?

c) Terrestrial biosphere dynamics. Emissions and absorptions from land-use and land-use change need to be more fully incorporated, including an attribution of carbon sinks, and feedbacks between climate and terrestrial carbon sources and sinks (for example, carbon changes in soils, change in forest cover and albedo effects, carbon fertilisation). This also raises the question of how the effect of feedbacks should be attributed. The comment was made that given the scientific and technical difficulties of “factoring-out” direct human-induced from indirect and natural influences on carbon sinks, it would be best to not treat indirect and natural components separately from direct human-induced changes. The IPCC is currently grappling with this question, and recent recommendations from an expert meeting suggest that it is not currently comprehensively possible to separate direct human-induced from indirect and natural changes.

d) Land-use and land-use change inventories. Closely linked with a more comprehensive treatment of the terrestrial biosphere and its feedback loops is the question of regional inventories of forest cover and other land-use and land- use change, and the uncertainties on regional scales for inventories dating back to 1900 or earlier. Substantially more work is required (see Group A) to provide robust inventory information and uncertainty estimates. Studies to date have shown that uncertainties in land-use change emissions are particularly relevant for early end dates of attribution studies.

Timing

The SBSTA requested the scientific community to report on progress in June 2004 and in November 2005. In order to prepare for the report in June 2004, the next expert meeting is planed for April 2004. The meeting will be prepared by the scientific coordination committee. The following Table provides an overview of the further work. It should be reviewed at the next expert meeting.

Table: Tentative work plan for the ad-hoc group

	2003				2004												2005											
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
UNFCCC meetings																												
Expert meetings														(Tentative)							(Tentative)							
A: Collecting and improving information on the climate system																												
B1: Complete assessment with existing simple models																												
B2: Use of fuller representation of the climate system for well mixed gases and four regions																												
B3: Contributions of other forcings and finer regional detail																												