Annex

I. INTRODUCTION

A. Mandate

1. The Subsidiary Body for Scientific and Technological Advice (SBSTA), at its fourteenth session, took note of the progress report on the review of the scientific and methodological aspects of the proposal by Brazil contained in document FCCC/SBSTA/2001/INF.2, including the conclusions of an expert meeting on the scientific and methodological aspects of the proposal, held in Bonn from 28 to 30 May 2001. It encouraged Parties to pursue and support the research effort on the scientific and methodological aspects of the proposal by Brazil, as recommended in document FCCC/SBSTA/2001/INF.2, and to communicate such activities to the secretariat. The SBSTA requested the secretariat to continue to coordinate the review of this proposal, to facilitate the dissemination of scientific and methodological information on this proposal, to organize an expert meeting to share information on the development of the scientific and methodological aspects of the proposal by Brazil, to broaden participation and to build scientific understanding of this subject before its seventeenth session, and to prepare a report for that session. To this end, the SBSTA requested all Parties, especially those not included in Annex I to the Convention, to nominate additional experts to the UNFCCC roster of experts. The SBSTA decided to consider this matter further at its seventeenth session (FCCC/SBSTA/2001/2, para. 32).

B. Scope of the note

2. This document contains information about the process used by the secretariat to respond to the above mandate and preliminary analysis undertaken by experts to explore the scientific and methodological aspects of the proposal by Brazil. It describes the results of an expert meeting held at Bracknell, United Kingdom of Great Britain and Northern Ireland, from 25 to 27 September 2002, including a proposal for future work. Additional background information can be found in document FCCC/SBSTA/2001/INF.2.

> This report contains preliminary results from simple climate models. The results have not been peer reviewed. They are presented for illustrative purposes to help the reader to understand the concepts presented in this paper. No definitive conclusions should be drawn, since models vary in their complexity and the data sets are limited.

C. Possible action by the SBSTA

3. The SBSTA may wish to take note of the information contained in this document and to provide guidance on what additional aspects of the proposal by Brazil need further consideration and how these issues should be addressed. In particular, the SBSTA may consider whether it wishes to proceed with a phase III process to improve the robustness of the preliminary results and/or whether at a minimum further steps should be taken to compile and integrate emissions data. The SBSTA may also wish to give further guidance to Parties and the secretariat regarding how to broaden participation of developing countries and possible roles and contributions of other scientific groups, such as the Intergovernmental Panel on Climate Change (IPCC), the International Geosphere-Biosphere Programme (IGBP) and the World Climate Research Programme (WCRP).

II. SUMMARY

4. The information presented in this report is based on analyses from 16 different research groups. All groups were provided with information necessary to build a very simple climate model to calculate global-average temperature change and sea level rise from historical emissions and to prepare attribution calculations. This information was partially based on the calculations initially presented by Brazil.

During the expert meeting, several experts presented example calculations using this simple approach, while other groups provided results using more complex climate models.

5. Preliminary calculations indicate that the effects of greenhouse gases, such as CO_2, CH_4 and N_2O, can be attributed to regional sources. The choice of methods, starting and end dates for attribution calculations, gases and indicators influence an attribution calculation. In some cases these are policy choices. Nevertheless, the results provide useful insights into the scientific and methodological aspects of the attribution calculations.

6. It is possible to assemble a more robust simple climate model and attribution tool using the scientific information in the IPCC Third Assessment Report (TAR) and the recent scientific literature. Such a tool would be capable of providing better attribution calculations. Such a model should include all greenhouse gases, tropospheric ozone, including its precursors, both natural and anthropogenic aerosols (black carbon, organic carbon and sulphate), represent the important non-linearities in the climate system and undergo more extensive validation and sensitivity studies. A proposed approach (phase III) to build specifications for such an attribution tool is provided in section VI. Phase III would require financial resources for the participating groups and broadened participation by developing countries.

7. Data limitations may prevent an attribution calculation at the country level even with a more robust model. However, a regional resolution finer than the ones provided in this paper may be possible.

8. Almost all models that were used to provide example calculations in this report are freely available. Some can be run under common operating systems without additional software, some can be run over the Internet, some can be implemented with commercial software and some are based on free software. It is possible with a relatively modest amount of resources to broaden participation and to build capacity in developing countries through ‘one-on-one’ visits and existing scientific agreements.

9. Any further work should include a wider segment of the scientific community and a peer review process.

III. BACKGROUND

10. In March 2002, the secretariat requested Parties to encourage research institutions active in the field of climate change modelling to participate in an information-sharing process. The objective of this process was to provide, as a first step, new and comparable results on the issue of contributions to climate change that could be discussed at the expert meeting. This process had two phases which were designed:

(a) To ensure the comparability of the models and

(b) To investigate the influence of different methodological choices.

The University of East Anglia in Norwich, United Kingdom, agreed to cooperate and assist the secretariat with this activity. It operates a web site that is linked to the web site of the UNFCCC secretariat with information on this activity, including the requirements and all results.[1] The secretariat provided information about this process to Parties at a side event organized during the sixteenth session of the SBSTA.

11. Phase I of the information-sharing process required researchers to build or apply an existing model capable of representing the historic path of concentrations, radiative forcing, temperature increase and sea level rise of a complex climate model. The Hadley Centre for Climate Prediction and Research

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[1] http://www.cru.uea.ac.uk/unfccc_assessment/

provided inputs (gas concentrations) for, and outputs (radiative forcing, temperature and sea level) of, their HadCM3 model to be used for validation.

12. In phase II, experts were encouraged to attribute changes in concentrations, radiative forcing, temperature change and sea level rise due to emissions in four different regions. The four regions of the IPCC Special Report on Emissions Scenarios (SRES) were chosen: members of the OECD in 1990 (OECD90), Eastern Europe and the former Soviet Union (REF), Africa and Latin America and the Middle East (ALM) and Asia (ASIA). Experts were encouraged to test the sensitivity of the results to different assumptions, such as emissions data sets and representations of the carbon cycle, as well as to different methodological choices (start date of emissions and indicators).

13. A reference case was defined as the contribution to temperature increase in 2000 attributed to the above-mentioned four regions using emissions of CO_2, CH_4 and N_2O from 1890 to 2000 from the EDGAR database.

14. In phase II, 13 groups submitted results:

(a) Centre for International Climate and Environmental Research (CICERO), Norway;

(b) Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia;

(c) Climate Change Advisory Team of the Danish Energy Agency (DEA-CCAT), Denmark;

(d) ECOFYS Energy and Environment, Germany;

(e) Hadley Centre, Meteorological Office, United Kingdom;

(f) Institute of Applied Energy (GRAPE), Japan;

(g) Université catholique de Louvain using the Java Climate Model (JCM), Switzerland/Belgium;

(h) Lawrence Berkeley National Laboratory (LBNL), United States of America;

(i) National Institute of Water and Atmospheric Research (NIWA), New Zealand;

(j) Research Institute of Innovative Technology for the Earth (RITE), Japan;

(k) National Institute of Public Health and the Environment (RIVM), the Netherlands;

(l) University of Illinois at Urbana Champaign using the Integrated Science Assessment Model (ISAM), United States of America;

(m) University of Illinois at Urbana Champaign (UIUC), Climate Research Group (CRG), United States of America.

15. The aim of the expert meeting held from 25 to 27 September 2002 was to enable experts to share their preliminary results, to explore options for broadening the participation of scientists from developing countries and to identify future work. Forty experts attended the meeting, including experts from the following developing countries: Argentina, Brazil, China, Kenya, India, Malaysia, Thailand. Experts from Chile, South Africa, Uganda, the United Republic of Tanzania, Venezuela and the Russian Federation were also invited, but unable to attend.

16. The Government of the United Kingdom of Great Britain and Northern Ireland kindly hosted the expert meeting. It was held at the premises of the Meteorological Office, London Road, Bracknell. Financial support for the participation of developing country experts was provided by the governments of Australia, the Netherlands and Switzerland.

17. The agenda of the expert meeting is contained in the annex to this document. On the first day, the participating experts presented their preliminary results and latest scientific findings. A brief summary of the presentations is contained in section IV of this report. On the second and third days, two groups were formed. One group focused on the scientific aspects, that is, how to represent the climate system in a model for the purpose of calculating attributions to climate change and which historical data sets should be used. Their conclusions are contained in section VII. The other group focused on methodological aspects that need to be considered when calculating attributions to climate change. These results are included in section V. In addition, experts discussed ways to broaden the participation, especially by developing country experts. These conclusions are included in section VI of the report.

IV. SYNOPSIS OF PRELIMINARY ANALYSIS

18. Results from phase I were collected by the University of East Anglia and made available on the project web site. In phase II, 13 groups submitted results, details of which can be found on the project web-site. The presentations by the individual experts at the meeting are summarized below. Those presentations are also available on the project web site, as well as a summary presentation for phases I and II and the presentations on model and data validation.

19. The CICERO modelling group took into account the emissions not only of CO_2, CH_4 and N_2O, but also of other greenhouse gases (GHGs); consequently the total radiative forcing has a large number of components. The submission from CSIRO includes a discussion of model validation parameterizations and a comparison of a number of different methods of attribution. The DEA-CCAT modelling group provided extensive documentation of a more complex model, including a powerful numerical method and corresponding MathCAD worksheets, which can be downloaded by interested users. ECOFYS followed the default implementation described in the terms of reference of this modelling exercise and in addition contributed a discussion of various aspects of attribution indicators. The developers of the integrated assessment model GRAPE used their 10-year step climate module, which includes several gases not covered by the Kyoto Protocol. The UIUC applied a reduced form of the original ISAM model for future emission scenario analysis, including non-GHG cycles and an alternative climate model to generate results for this exercise. The JCM is a relatively complex model. The submission included not only modelling results, but also a Java model interface, allowing any remote user to vary parameters and observe changes in real time via the Internet. LBNL submitted a 10-year step version of the default implementation of the simple climate model, as well as a spreadsheet interface for the sensitivity analysis. With minor adjustments NIWA also implemented the default version and suggested a method for attributing aerosol emissions to regional sources. The simple climate model submitted by RITE is based on the MAGICC model and is also being used in the integrated assessment model DNE21. RIVM obtained their results from a model based on IMAGE calculations. They provided detailed sensitivity analysis as well. Another group of modellers at UIUC used an alternative GHG cycle model. They discussed a method of attributing aerosol emissions to regional sources. The Hadley Centre used the specifications of the simple model as well, including a linear approximation to the temperature response of their coupled model HadCM3.

20. Further, Michael Prather (University of California, Irvine) presented information on the completeness of the assessment and model validation. Joyce Penner (University of Michigan) covered the uncertainty of aerosol emissions. Silvia Muylert presented the work of the Federal University of Rio de Janeiro on historical contributions to global warming.

21. Common issues raised by different groups included the quality and continuity of emission data and fine tuning of GHG lifetimes. In particular, it was noted by several experts that historical emission data and future emission scenario data do not always match in the overlap period. Moreover, some modellers did not agree with the notion of a constant lifetime of methane in the atmosphere and suggested alternative approaches. More generally, it was noted by some participants that a representation

of the climate system in a simple model, i.e. neglecting classes of relevant gases as well as chemical and other feedbacks, was unrealistic and could entail hidden biases.

22. Most of the groups submitted results from the attribution calculations for more than one indicator, and some of the characteristics of these indicators were highlighted in individual submissions. For the reference case a comparison of the results from all groups is possible and can be found in figure 1. The relative contribution to temperature change in 2000 is shown using emissions of CO_2, CH_4 and N_2O attributed between 1890 and 2000 as provided in the EDGAR database.

23. Several groups have made their models publicly available for downloading and/or provided extensive documentation of the methodology used.

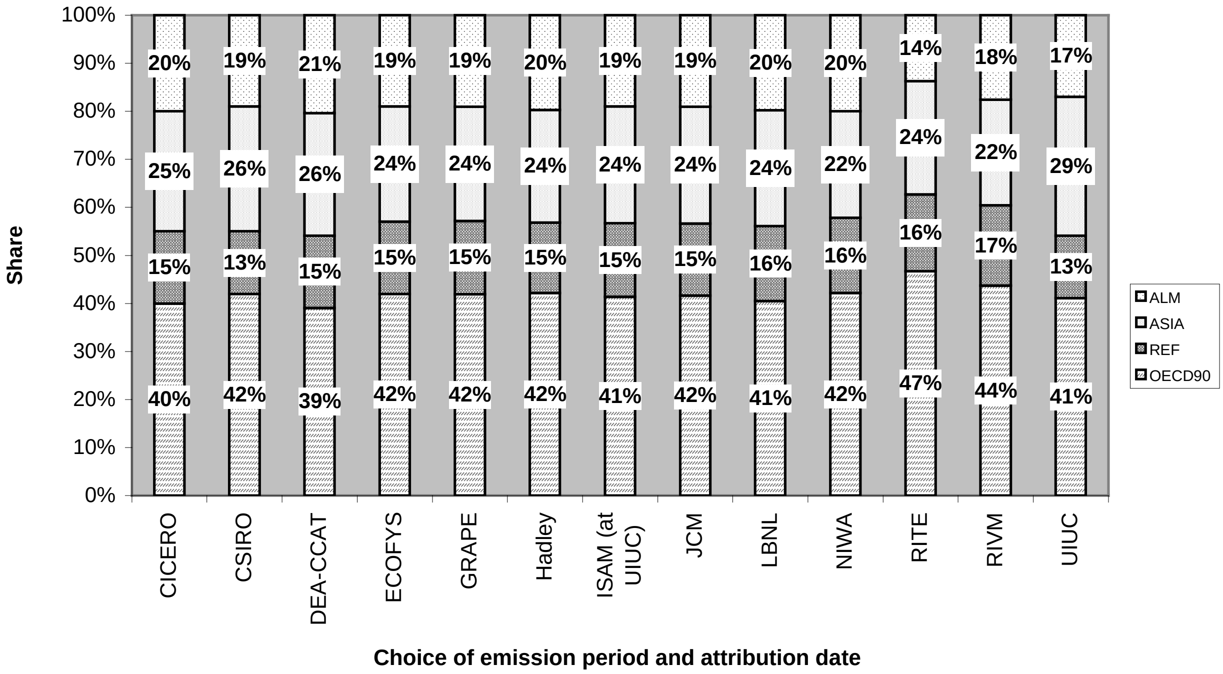

Figure 1. Comparison of reference case calculations: relative contribution to temperature change in 2000 with emissions of CO_2, CH_4 and N_2O attributed between 1890 and 2000 as provided in the EDGAR database.

V. METHODOLOGICAL ISSUES

A. Indicators for attribution to climate change and their characteristics

24. The Brazilian proposal (FCCC/AGBM/1997/MISC.1/Add.3) suggested that the global-mean surface temperature increase could be used as an indicator for contributions to climate change. The participants attending the meeting in Bonn, held from 28 to 30 May 2001, concluded that other indicators along the cause-effect chain from emissions to climate change could also be calculated and attributed to different sources of emissions. They noted that different indicators will result in different attributions (FCCC/SBSTA/2001/INF.2, para. 23).

25. At this meeting, experts did not select a preferred indicator, but identified several possible indicators and assessed their characteristics. The characteristics are listed in the following paragraphs.

26. **Closeness to impacts:** An ideal indicator would closely resemble the impacts of climate change. It would be further down the cause-effect chain. The experts felt that it should be an indicator of the

'damage potential', a measure of the unrealized potential for climate-change-induced environmental damage.

27. **Understandable:** The indicator should be understandable to scientists as well as the public. In addition, it should be clear how the indicator can be attributed to different sources of emissions.

28. **Certainty:** The calculation of the attribution using the indicator should be reliable. The data necessary to calculate the indicator need to be available as well as robust calculation methods. Each step further down the cause-effect chain (i.e. from emissions to concentrations or to radiative forcing and so on) introduces additional uncertainty, due to an additional step in the calculation. The way in which the indicator accounts for early emissions also influences the certainty (see backward discounting).

29. **Backward discounting:** Some indicators give less 'weight' to emissions that occurred a long time ago. For example, the concentration of methane today is not influenced by emissions of methane 100 years ago. Because of the short lifetime of methane in the atmosphere, these emissions have decayed almost completely by now. The experts noted that it is uncertain whether such 'backward discounting' reflects the influence of emissions with respect to damages. In addition, 'backward discounting' also affects the certainty of the indicator, since information that dates further back is usually more uncertain.

30. While experts agreed that an ideal indicator should be close to impacts, understandable and certain, they could not recommend whether and how much backward discounting is appropriate.

31. There is a 'trade-off' among indicators. On the one hand, the indicator should be as close as possible to the actual impacts of climate change, i.e. damages, as possible. It should therefore be further down the cause-effect chain. On the other hand, it should be calculated with certainty and therefore be at the beginning of the cause-effect chain.

32. Table 1 lists the indicators and their characteristics as assessed by the experts. The number of circles is a relative marker, indicating whether the indicator meets the characteristic more or less than for other indicators. A description of each indicator, of which some are shown in figure 2, follows.

33. **Cumulative emissions:** The sum of annual emissions from a source between a start and an end date (indicator A). This indicator can only be applied for one greenhouse gas at a time. Effects of several gases cannot be compared.[2]

34. **Concentrations:** The effect of all emissions between a start and an end date on concentrations of the greenhouse gases in the atmosphere at the end date (indicator B). This indicator can only be applied for one greenhouse gas at a time. Effects of several gases cannot be compared.

35. **Integrated past concentrations:** Integrating the increased concentrations due to emissions from a start date to an end date (indicator C). This indicator was used in the calculations that accompanied the original Brazilian proposal.[3] It can be seen as a first proxy for the temperature increase. This indicator can also only be applied for one greenhouse gas at a time. Effects of several gases cannot be compared.

36. **Radiative forcing (due to increased concentrations)**: the radiative forcing due to the increased concentrations at the end date (indicator D). The effects of different gases can be combined with this indicator.

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[2] Aggregating cumulative emissions for several gases using global warming potentials was also mentioned at the meeting.

[3] A later version of the calculations provided by the Brazilian delegation calculates temperature increase, rate of temperature increase and sea level rise.

37. **Integrated past radiative forcing:** Integrating the radiative forcing due to increased concentrations from a start date to an end date (indicator E). This indicator is very similar to 'integrated past concentrations' (indicator C). It can be used to combine the effects of all gases.

38. **Integrated future radiative forcing:** The radiative forcing due to the concentrations integrated from when emissions end to a future date (indicator F). It applies the concept of global warming potentials (GWPs) to concentrations (instead of applying it to pulse emissions), taking explicitly into account the unrealized effects that will occur in the future after the gases have been emitted.

39. **Temperature increase**: The increase in global-average surface temperature due to emissions (indicator G). The calculation takes into account the effect of emissions between a start and an end date on concentrations and on radiative forcing.

40. **Rate of temperature change**: The rate of temperature change calculated as the derivative of the temperature increase.

41. **Sea level rise:** The processes of thermal expansion of water and melting of ice. Because sea levels increase very slowly (in the order of thousands of years), the effects seen today may be small compared to those that will occur in the future, even if emissions stop.

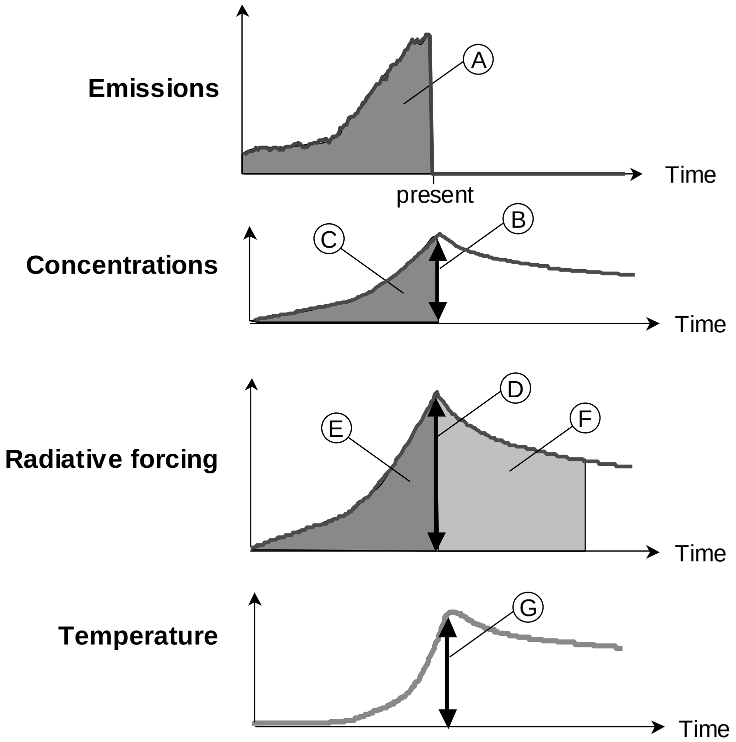

Figure 2. Indicators for attribution to climate change (adapted from ECOFYS)

Table 1. Indicators for attribution to climate change and their characteristics

	Figure 2	**Close to impacts**	**Understandable**	**Certain**	**Backward discounting**
Cumulative emissions	A	-	●●●●	●●●[4]	-
Concentrations	B	●	●●●●	●●◖	●●●
Integrated concentrations	C	●◖	-	●●◖	●●
Radiative forcing (due to increased concentrations)	D	●●	●●	●●	●●●
Integrated past radiative forcing	E	●●●	-	●●	●●
Integrated future radiative forcing	F	●●●◖	-	●●	●●●
Temperature	G	●●●●	●●●●	●◖	●●
Rate of temperature change	-	●●●●	●●[5]	●	**?**
Sea level rise	-	●●●●	●●●●	◖	●

42. The indicators from concentrations onwards in the above list do not include the effects of the emissions that will occur after the emission. Greenhouse gases stay in the atmosphere after they have been emitted for a period of time, depending on their particular removal processes. In that period, the gases contribute to increased concentrations, radiative forcing, increased temperatures and sea level rise. The temperature and sea level may rise after the attributed emissions have stopped. To account for these effects, an evaluation of the indicator can be made at a point in time after the emissions have stopped (see section on evaluation date).

43. The temperature can be used as an indicator, evaluated at the point in time after emissions have stopped where the global temperature is reaching a peak. However, the peak of the temperature resulting from individual sources alone might occur at a different time.

44. It is possible to combine various indicators into composite indicators in order to resemble more closely actual damages. This was not explored at the expert meeting.

45. The experts only considered indicators evaluated at the global scale. Conceptually, regional indicators also could be defined, but such calculation would be extremely complex and more uncertain.

46. Figure 3 provides an illustrative example of different indicators as submitted for the expert meeting. It can be observed that different indicators lead to different relative attributions.

4 The certainty depends on the certainty of the emissions.

5 While the indicator 'rate of temperature change' is well understandable, the attribution of positive and negative contributions to the rate of temperature change is more abstract.

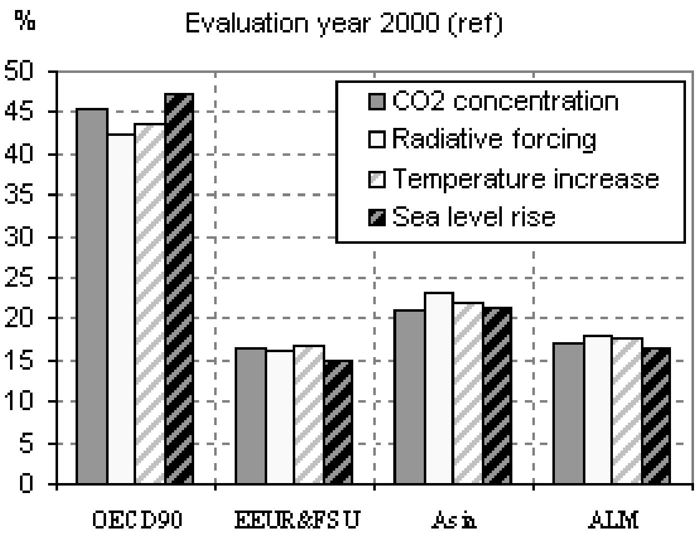

Figure 3. Illustrative results from RIVM for different indicators attributed to four global regions in relative terms. Attribution period: 1890-2000, evaluation date 2000, source of CO_2 emissions: CDIAC, source of CH_4 and N_2O emissions (included for all indicators but concentration): EDGAR

B. Non-linearities and feedbacks

47. Several processes in the climate system are non-linear and include feedbacks. As a consequence, the sum of the effects of emissions from individual regions is not equal to the effect of all emissions together. This is illustrated schematically in figure 4. Two sources, A and B, together have a given effect (figure 4, right). However, assigning a particular effect to the sources A and B is difficult. As can be seen from figure 4 (left and middle), the attribution results are different, if the individual effects of A and of B are considered compared to the effect of A and B taken together.

48. Some non-linearities occur, for example, in the carbon cycle, the atmospheric chemistry, the relationship between concentration of CO_2 and radiative forcing, the relationship between radiative forcing and temperature increase and the relation between temperature increase and sea level rise. Feedback processes will lead to non-linearities when the feedback is strong. Even when the feedbacks behave linearly, they introduce the same methodological problems as non-linearities. The experts felt that at this stage it is difficult to determine the relative significance of the non-linearities and feedbacks for the attribution calculation.

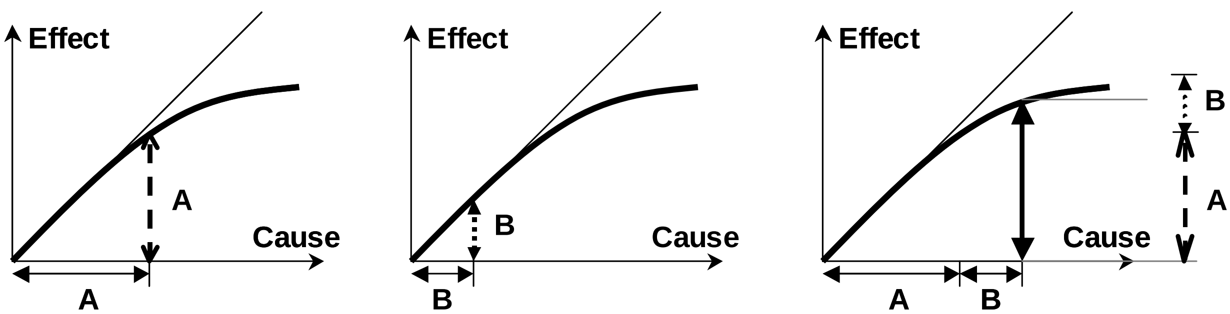

Figure 4. Schematic diagram of a non-linear relationship between a cause and an effect

49. The original Brazilian proposal[6] and some participating experts used simplified linearized models. The representation of the climate system is less realistic, yet the attribution is simple, because emissions at each point in time are considered as having the same effect. However, the attribution results of such models could be misleading. In general, on short time scales, linearized models are more reliable than on longer time scales.

50. Due to the non-linearities and the feedbacks:

(a) Emissions at different points in time will have different effects. For example, because of the non-linearity in the calculation of radiative forcing from concentrations, the additional radiative forcing due to additional CO_2 concentration is a quarter lower today (due to higher CO_2 concentrations) than it was at the beginning of industrialization (when the CO_2 concentration was lower).

(b) The effect of emissions of individual sources may depend on emissions of other sources. For example, the effect of CO_2 emissions today is different because emissions have occurred in the past.

51. Therefore, attributing effects to different sources is not straightforward (see figure 4) and a scientifically credible method for doing this needs to be laid out.

C. Methods of attribution

52. Several methods were proposed, before and at the expert meeting, to attribute the effects, when the sum of the effects of individual sources is not equal to the effect of the total of sources: the ‘marginal’, ‘proportional’, ‘residual’, ‘differential’ and ‘time slicing’ methods.

53. **Marginal method:** As shown in figure 5 (left), the tangent is taken at the point of the total source and applied for the individual sources. As a consequence, the proportion between source A and source B is the same as the proportion between effect A and effect B. But the sum of the attributed effects is not equal to the total effect. Effect A and effect B can be scaled so that their total is equal to the total effect (‘normalized marginal method’).

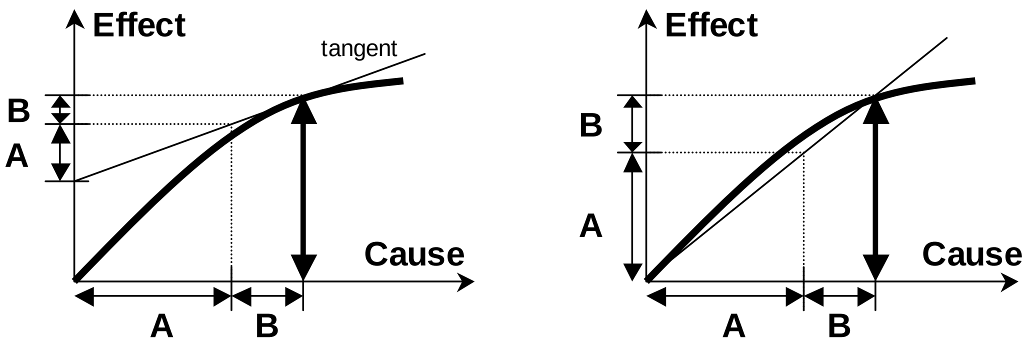

Figure 5. Attribution under the ‘marginal method’ (left) and the ‘proportional method’ (right).

54. **Proportional method:** Under the ‘proportional method’, the total effect is distributed proportionally between the sources. The proportion between source A and source B is the same as the proportion between effect A and effect B. The effect of A plus B is the total effect (see figure 5, right). The result is the same as that given by the ‘normalized marginal method’, but it can be obtained without calculating the tangent.

55. **Residual method:** A method that can be implemented most easily is the ‘residual method’. First the total effect of sources A and B is calculated, then the effect of all sources but source A. The

[6] The updated version of the calculations by the delegation of Brazil did include non-linear effects.

difference between these two effects is attributed to source A. Several groups have applied this method, because it is easy to implement in existing models. Experts noted, however, that the attribution results depend on the level of geographical resolution and the size of the groups. The sum of the attributed effects is not equal to the total effect. The individual effects can be scaled so that their total is equal to the total effect ('normalized residual method'). Since alternative methods exist which do not have these properties, experts recommended not to use this method.

56. **Other methods:** Other methods have been proposed to attribute non-linear effects. The preceding methods give the same "weight" to different causes, independent of their origin. The 'differential method' and the 'time slicing method' were both proposed by Enting.[7] They trace the origin of the cause and treat it accordingly. Experts noted that the differential method may produce, under certain circumstances, paradoxical results and recommended not to use this method. Regarding the 'time slicing method', experts noted that it requires additional computational power and that it treats the effect of gases, once emitted, independent of later emissions by others (i.e. emissions by others are assumed to be zero).

57. At the meeting, the experts discussed extensively the different methods and made progress in understanding the methods and their characteristics. However, several issues remained unsolved and experts could not agree on a particular method. There is a need to study the issue further.

58. Figure 6 shows an example of the effect of different attribution methods. Because only four large groups were considered, the differences appear to be small. However, these differences could be of greater importance, if the regional resolution is increased

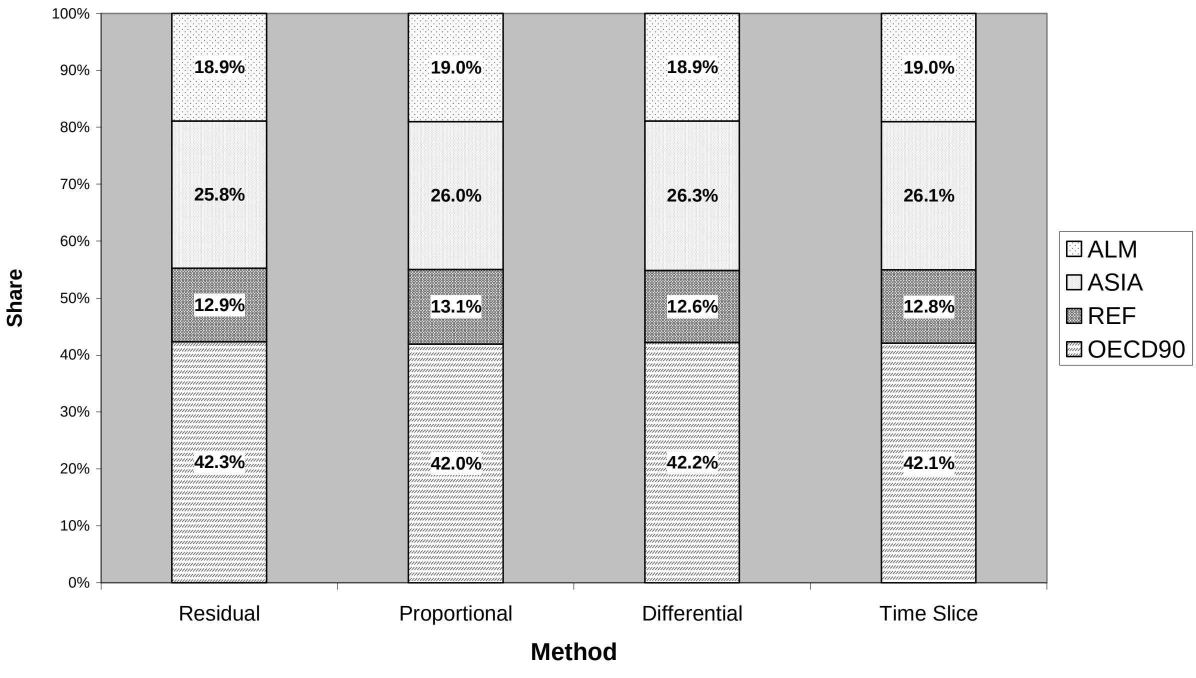

Figure 6. Illustrative results from CSIRO of the attribution calculation for temperature change in 1990 using different attribution methods. Includes emissions of CO_2, CH_4 and N_2O between 1890 and 1990 as provided in EDGAR-HYDE 1.3; earlier emissions were linearly extrapolated

7 CSIRO Atmospheric Research technical papers 38 and 41 and contribution to the project; see project web site.

D. Variation of attribution start and end dates

59. All global emissions should be used in a model calculation to validate the model. It is possible, however, to choose a start date for the attribution, such that emissions prior to that date are not attributed to any particular source. Likewise an attribution end date can be chosen, such that the effect of emissions after the end date of the attribution are not attributed to any particular source.

60. The experts noted that, in general, the further one looks into the past, the more uncertain some of the emission data can become. As a consequence, the further the start date is moved into the past, the more uncertain is the attribution calculation. The extent to which the uncertainty increases depends on the indicator used. For example, due to its short lifetime, methane concentrations today are not influenced by the methane emissions, say 100 years ago. The closer the start date is moved towards the end date, the more the attribution is influenced by fluctuations in the emission data.

61. The experts noted that an alternative to a single start date could be an approach whereby all emissions are counted, though early ones with less weight than later ones, as a trade-off between the comprehensiveness of the analysis and its certainty. The experts also noted that emissions lying within an attribution window, spanning from the present for a fixed number of years into the past, could be attributed.

62. It was mentioned that countries might not have existed throughout the attribution period. Special consideration would be necessary for such cases. Also, the significance of the start dates may vary with the sector considered, depending on when activities in that sector started.

63. Figure 7 shows a preliminary example provided by one expert of the effect of changing the attribution start date from 1890 to 1950. The left two columns show the relative contribution to increased temperatures in 2000 of the four regions. The right two columns show the contributions to increased temperature of the four groups in the year 2100, assuming future emissions of the IPCC SRES A2 scenario. Here the change in the start date (third to fourth column) has less influence on the results.

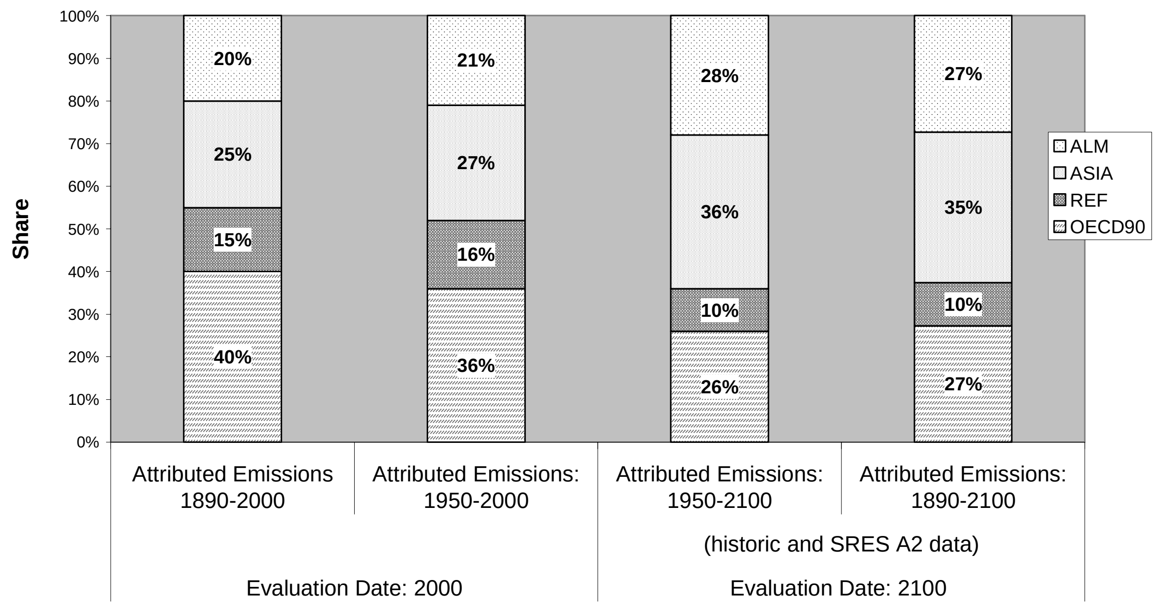

Figure 7. Example by CICERO of temperature change for different attribution start and end dates. Attributes CO_2, CH_4 and N_2O emissions from EDGAR database, assuming the IPCC SRES A2 scenario for future emissions.

E. Evaluation date

64. Usually the attribution is determined at the end of the emission period. To consider also the long-term effects of emissions, the indicator can be evaluated at a future point in time after the attributed emissions have stopped. These considerations are only relevant to those indicators related to unrealized effects, i.e. in the cause-effect chain from concentrations onwards. The composition of the atmosphere after the attributed emissions have stopped has an effect on decay processes and therefore may influence the outcome of the attribution.

65. If the evaluation date is moved further into the future, the absolute values of indicators change (e.g. sea level continues to rise after attributed emissions have stopped) and the relative contribution of different sources might change as well. Evaluating an indicator further in the future also gives less weight to short-lived gases and fast climate system processes, since those will have decayed or be inactive while long-lived gases and slow climate system processes will still be present or active in the atmosphere.

66. Figure 8 shows the effect on the relative attribution of moving the evaluation date from 2000 to 2050, 2100 and 2500. The relative contribution to increased temperatures from emissions between 1890 and 2000 of the four regions is shown, including CO_2, CH_4 and N_2O and assuming no emissions after the year 2000. Note that the changes in the attribution between 2000 and 2050 compared to later periods are a consequence of the distribution of methane emissions within the groups.

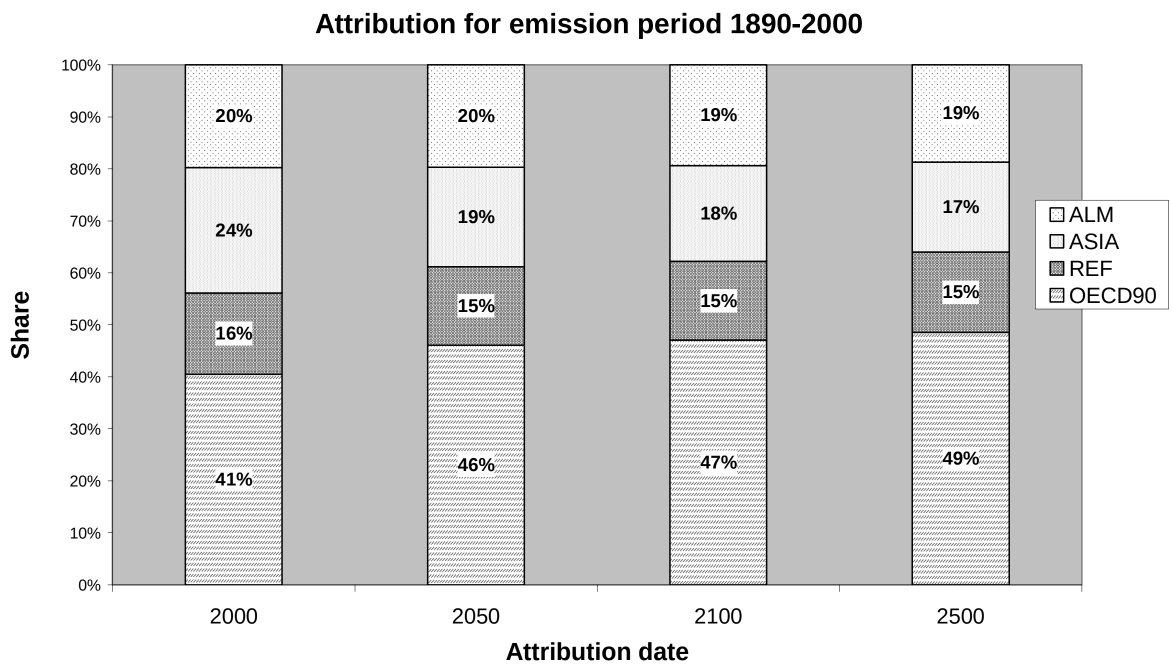

Figure 8. Example by LBNL of how the attribution changes after attributed emissions have "stopped" in 2000. Attributes CO_2, CH_4 and N_2O emissions, assumes no emissions after the year 2000

F. Other forcings: aerosols and ozone precursors

67. Aerosols (such as sulphates and carbonaceous material) and ozone precursors (CO, NO_x, non-methane volatile organic compounds (NMVOCs)) have certain characteristics that are different from those of the greenhouse gases included in the Kyoto Protocol:

(a) Aerosols and ozone precursors react in the atmosphere on the regional scale and have effects on regional and global climate;

(b) Some aerosols can have a cooling effect (such as sulphate), others (such as black carbon) and ozone precursors contribute to a warming effect.[8] Ozone precursors also have an effect on the lifetime of the greenhouse gas methane;

(c) Emissions of aerosols and ozone precursors are much more uncertain than those of the greenhouse gases included in the Kyoto Protocol. Hence their attributable effects on the atmosphere are more uncertain.

68. Presently, Annex I Parties to the Convention should provide information on the following indirect greenhouse gases: CO, NO_x and NMVOCs. Annex I Parties are also encouraged to provide information on SO_x.

69. Aerosols are not covered under the Convention or the Kyoto Protocol. However, aerosols should be included in simple climate models to verify the historical record. They may also influence an attribution calculation. In some test cases, when the cooling effects are considered, the results changed significantly. Cooling effects introduce methodological problems in comparing positive and negative contributions to radiative forcing and temperature change. See preliminary results from NIWA and UIUC on the web site.

G. Different scenarios

70. Different emission scenarios can be used to test the robustness of methodological choices, for example, both increasing and decreasing scenarios.

71. Future emission scenarios can influence different atmosphere decay processes. The use of different future emission scenarios may therefore change the attribution results, if the indicator is evaluated at a point in time in the future. The magnitude of the change depends on the attribution method. For the 'time-slicing method' the result does not depend on the emission scenario chosen, while for other methods the scenario choice might influence the attribution for future attribution dates.

H. Display of results

72. Experts noted that the results of different models and those of a single model can be presented in different ways. Additional consideration needs to be given to the manner in which results are displayed to ensure clarity and balance. The outputs could be put in the context of other socio-economic indicators.

I. General observations

73. The experts noted that changes in attribution parameters might have different effects on the attribution result for a region as a whole than for individual countries within that group, because emission patterns of individual countries may vary within a group.

VI. SCIENTIFIC AND ANALYTICAL CAPACITY-BUILDING – BROADENING PARTICIPATION

74. As noted elsewhere 16 institutions presented a preliminary analysis at the expert meeting, all but one from developed countries. The developing country experts who were present contributed actively to the discussion, but any future effort would require building further understanding of the scientific and methodological aspects among a larger number of countries. To gain insights into possible ways of moving forward, participants were asked several questions, as noted below.

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[8] IPCC TAR, Working Group I, chapters 5 and 6.

1. Questions for developed country experts: Are your models publicly available and would your institution be willing to host a scientist from a developing country?

75. Ten participants indicated that their models were either available on the Internet or could be made available easily. These included: CICERO, Danish Energy Agency, ECOFYS, Hadley Centre, IAE, RIVM, RITE, Université Catholique de Louvain and University of Illinois (two groups).[9] The same participants, plus those from Brazil, CSIRO and IIASA, indicated an interest "in principle" in hosting scientists from developing countries.

76. Since all the participants were attending in their personal capacity, the responses were subject to the need to confirm such possibilities with the senior management of the institutions and the availability of funds for travel. Such one-to-one agreements between experts could prove to be an expeditious means of transferring models and building understanding about how they can be applied. However, this approach may require institutions in developed countries to seek additional support from their sponsors or permission to reallocate funds.

2. Questions for developing country experts: Are you personally interested in participating in future analysis? Do you think your institution would be interested in participating in future analysis?

77. Among the developing country experts present, two indicated that they would be personally interested in undertaking analysis. Others indicated that they were confident that they could find experts in their institutions who would be interested. In both cases the answers assume that they would have access to one or more of the available tools and some training. The expert from China indicated that such arrangements might be made via existing bilateral agreements, for example, those between China and the United Kingdom and the United States.

3. Questions for all participants: Do you have any suggestions regarding how to broaden participation of experts from developing countries? What links should be established with other international processes or groups?

78. Regarding the first question, the following are examples of some of the suggestions made by the experts. The expert from Kenya noted that the World Meteorological Organization regional centres in Africa have a nucleus of experts who should be contacted to determine their interest. Several experts also indicated that the START centres might be a source of additional expertise given their existing scientific infrastructure. The experts from Latin America noted that the International Global Atmospheric Chemistry (IGAC) project is undergoing a reassessment of its mission and may be a source of financial support and scientific capability. Several of the experts from developing countries noted that their countries could, in some instances, assist in developing or testing historical emission data sets, such as the one presented at the meeting by the University of Rio de Janeiro. Finally, several participants suggested that training workshops could be held to assist more experts from developing countries and expose them to the scientific issues.

79. The discussion of the second question largely focused on how the SBSTA could enhance the scientific credibility of any analysis undertaken in the future by engaging other groups to peer review the proposed approach to future work or the results. In this regard, the following options could be considered:

(a) The IPCC could be invited to nominate experts to review the scientific approach and results of any future analytical process;

(b) The IGBP and WCRP could be solicited to oversee or contribute to any future analytical process and/or be requested to undertake a scientific review of the approach and results;

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[9] See project web site.

(c) The Chair of the SBSTA could plan and guide future work, drawing on other groups for advice and assistance and possibly a scientific steering committee.

80. In considering these suggestions, the SBSTA may wish to consider the time frame for any future analysis and the specific role that such institutions could play, since it is likely that the management of these groups would need to seek the approval of their memberships.

VII. POSSIBLE NEXT PHASE

A. Building a more robust attribution tool

81. The first two expert meetings defined the problem of attributing climate change/damage to national/regional emissions and began a discussion of the methodology and scientific issues**.** The most recent expert meeting (25–27 September 2002) brought together scientific experts on the climate system, integrated assessment modelling and policy making. 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. However, it became clear during the discussions that developing the simplified tools from this exercise into robust tools for attribution at a fine resolution would be a major scientific undertaking that integrates the scientific findings of the TAR with new work that will reach beyond that of the TAR**.** The pathway for accomplishing this, through a phase III process, was a major focus of discussion.

82. The objective of a phase III would be to build a set of model components and data sets to enable the design of a robust attribution methodology, together with an uncertainty analysis, that will withstand scrutiny by the wider scientific community. To this end it is suggested that an effort be directed towards scientific validation of the data sets and tools, by comparing model predictions with observed indicators of change.

83. It was felt that the tools should be composed of model components that are based on the best scientific knowledge and that "model tuning" to fit historical observations should be avoided. This approach is necessary in order to make transparent the scientific uncertainties in the underlying climate science. Moreover, such model tuning does not avoid errors in the attribution calculation since non-linearities and biases can produce errors that do not simply scale out. The validation of the tool through comparison of key components with the historical record forms an independent test of the accuracy of the historical forcing (including the attributable emissions) and the model response.

B. Choice of validation data

84. The minimal set of historical climate parameters that form the basis of this validation comprises:

(a) Historical global surface mean temperature change;

(b) Global mean sea-level rise from the tide gauge record and, from the early 1990s, altimeter data;

(c) Long-lived greenhouse gas concentrations (CO_2, CH_4, N_2O, chlorofluorocarbons (CFCs)).

85. In addition, ocean heat content and tropospheric O_3 changes may be useful as validation data sets, and the difference between the northern and southern hemisphere temperature anomalies can provide an additional constraint. However, not all types of simple models may be able to predict all of these additional quantities.

C. Model components

86. Following this philosophy of rigorous validation, the group of experts discussed the model components that need to be included in the attribution tool (see tables 2 and 3). The tool should include an emissions component, biogeochemical system components and climate system components. In addition, where appropriate, feedbacks between components will also be included. The model components are listed in the first column of tables 2 and 3. For practical application an attribution component will also be needed. Possible choices of attribution method, their advantages and disadvantages, are discussed in section V of this report.

87. The suggested approach is to avoid tuning and this requires that the components in the attribution tool should be based on the best available scientific representations (e.g. bottom-up emission inventories). These are summarized in the second column of the tables. The third column summarizes the meeting's recommendations for the reference case attribution tool and parameter choices. These represent the simplest type of model that the experts felt captured the behaviour of the best available representations. The fourth column lists needed sensitivity testing with the completed tool and/or data that must be developed in order to complete the validation exercise. Finally, action items for the development of this tool are shown in the last column.

88. The results presented at the expert meeting were produced with models of varying degrees of complexity. Some of the more sophisticated models already match some of the requirements for a reference case attribution tool (column 3 of the tables). In most cases, additional sensitivity studies or model validation tests are needed. Hence it is anticipated that any phase III work would build upon, and aim to improve, the models used to produce the preliminary results in this paper.

D. Executing phase III

89. The aim of the phase III exercise would include a number of steps over a two-year period. The steps would include:

(a) Data completion and intercomparison;

(b) Peer review of the phase III design;

(c) Testing and validation of modules, sensitivity analysis and quantification of uncertainties.

Data completion and intercomparison

90. The experts noted that phase III would require the cooperation of the scientific community. In particular, the required modules, emissions data, uncertainty data, and climate forcing data should be made available to the community that will build more robust attribution tools. This will require some effort, since not all data that are part of the literature are currently fully available. The endorsement by the SBSTA could be a critical feature in ensuring such cooperation.

Peer review of the phase III design

91. The design of phase III should be reviewed by the scientific community. This process can be completed in parallel with the completion of the emissions data sets. It could be initiated by seeking comments from the community on this document, particularly the following tables. Based on feedback from such an exercise, a revision of the specifications, schedule and other information could be produced.

Testing and validation of modules, sensitivity analysis and quantification of uncertainties

92. The modules and data associated with the design should then be developed in a transparent manner and made widely available to the scientific community to encourage widespread participation. Then sensitivity studies should be carried out which simulate the range of uncertainties noted in the tables. These studies should test the sensitivity of the attribution tool to the specification of the climate system modules, the biogeochemical modules, the emissions modules, and the forcing. Two kinds of sensitivity to parameters or data are of prime interest: the sensitivity of the global mean indicators and the sensitivity of the fractional attribution results. For the former, historical observations provide a data set against which we can compare, whereas for the fractional attribution there is currently no consensus as to a correct or incorrect result. These studies will form the basis of the validation of the attribution tools and will inform the scientific community as well as policy makers about the most important of the uncertain parameters within the attribution model. Moreover, the results from these studies need to be combined in order to provide an overall measure of uncertainty in the attribution calculations.

93. The phase III validation will quantify any biases in the reference model with respect to the historical record, and the scientific community can use sensitivity studies to gauge the importance of any biases (i.e. to determine whether the biases are larger than might be explained by uncertainties in the data). If the biases are large, a special, focussed effort should be convened to determine (i) how best to resolve differences between the historical data and the reference model and (ii) the consequences of this resolution for the attribution. The result of such a workshop should then be the design of a new reference case (or cases) as well as an improved quantification of uncertainties.

94. Other methodological issues needing consideration for a possible phase III include:

(a) For further assessment it is suggested that different future scenarios (IPCC SRES) be used to see also the effect of emission *reductions* on the sensitivity of the methods used. For the analysis of effects beyond 2100, stabilization scenarios may be used as background atmosphere;

(b) If socio-economic indicators are used to display the results, those listed in the IPCC SRES should be included;

(c) A Monte Carlo analysis could provide additional insight into the sensitivities.

E. Role and contribution of other international scientific groups

95. Further consideration could be given to possible roles and contributions of other scientific groups, such as the IPCC, the IGBP and the WCRP (see also paragraph 77).

Table 2. Discussing the atmospheric abundance, biogeochemical cycles, climate change and feedbacks

ISSUE	STATE-OF-THE-ART MODELS AND DATA SETS	WHAT IS RECOMMENDED IN SIMPLE MODELS FOR REFERENCE CASE	SENSITIVITY STUDIES FOR VALIDATION AND ATTRIBUTION	ACTION ITEMS
CFCs	Well-known for historical, future	Use TAR formulation	No sensitivity needed	
Carbon-cycle (CO_2) - in ocean - in land	TAR intercomparison showed that models were similar over the short term – long term is more uncertain Large uncertainty especially on fertilization and temperature feedbacks	Bern and ISAM-type models are needed Non-linear models needed for future	Test ocean circulation feedbacks; (e.g. biology + stability) Conduct sensitivity to land feedbacks	
CH_4-O_3-OH chemistry	Moderately well-known, but interannual variability is unexplained; O_3 trends are poorly known	Use response functions from TAR	Test uncertainty to NO_X and CO emissions, to lifetime of CH_4, and to stratospheric O_3 depletion	
Biogeochemical cycle of N_2O; NO	There are no global models The fraction of fertilization nitrogen emitted as NO, NH_3, and N_2O is very uncertain	N_2O is included in SRES scenarios but not NO, NH_3	Need to include in simple models and look at sensitivity of emissions of NO, N_2O, NH_3	Need to develop emission model for the fraction of fertilizer nitrogen emitted as NO, NH_3, and N_2O
Biogeochemical cycle of CH_4	There are geographic specific models with feedbacks to changes in temperature (ΔT), and water cycle (ΔH_2O) - There are no permafrost models - Feedbacks to anthropogenic emissions are not as important as the natural CH_4 cycle	Need to include in simple models	Explore sensitivity to uncertainties in natural CH_4	Need to develop a representation of natural CH_4 cycle and changes associated with changes in temperature and the water cycle
Aerosol burden for SO_4, organic carbon (OC), black carbon (BC), dust and natural aerosols	At least a factor of 2 uncertainty in burden Natural emissions uncertainty is a factor 2 Biomass/fossil fuel breakdown is important for determining climate forcing	Use TAR formula for SO_4, OC, BC; Climate feedback to lifetime is not included in simple models and is uncertain Need to include all aerosols (because natural aerosols are needed to get indirect effects) Need future and historical emissions including breakdown of fossil and biomass burning emissions	Explore sensitivity to lifetime consistent with range in TAR Use different historical and future scenarios for emissions Explore different breakdowns for fossil and biomass emissions of OC/BC in future scenarios. Explore effects of natural emissions representation for indirect effects	Include all aerosols, both natural and anthropogenic (Develop formula based on TAR results) Develop breakdown of fossil and biomass burning emissions of OC and BC

Table 2 ***(continued)***

ISSUE	STATE-OF-THE-ART MODELS AND DATA SETS	WHAT IS RECOMMENDED IN SIMPLE MODELS FOR REFERENCE CASE	SENSITIVITY STUDIES FOR VALIDATION AND ATTRIBUTION	ACTION ITEMS
Solar forcing Volcanic forcing	Solar: Data for after 1978 are good Several reconstructions for the time period before 1978 are available but are uncertain [current GCM models start in 1850 and results are used to tune simple models' sensitivity; need more GCM runs with solar changes] Volcanic: Data for optical depth are available from several reconstructions, but all data sets are not available as forcing	Solar and volcanic forcing needs to be included; select one of the reconstructions The use of independent measures of these forcings and independent measures of climate sensitivity implies there is no guarantee that models will fit the historical ΔT	Explore sensitivity to available reconstructions for volcanoes and solar variations, including possible future projections	Forcing changes with time (ΔF (time)) need to be developed for the different historical reconstructions of solar and volcanic forcing and distributed to modellers Define/document the reference case, develop the alternatives Need more GCM runs with solar changes
Radiative forcing for the long-lived greenhouse gases: CO_2, CH_4, N_2O, CFCs	Well-known spectroscopy	Use TAR formula	No sensitivity needed	
Radiative forcing due to tropospheric O_3	Spatial distribution causes +/-30% uncertainty in forcing	Use TAR formula	Consider uncertainty range of +/-30%	
Aerosol direct forcing: SO_4, OC, BC	Can get uncertainty in forcing from TAR, Ch. 6 tables (needs to be done)	Use TAR formula to convert emissions to radiation forcing (RF)	Consider uncertainties based on range of results in TAR	Develop uncertainty in forcing from TAR, Ch. 6 tables
Forcing from anthropogenic changes in dust	Several models produce different forcings (both positive and negative)	Need to develop formula for burden and forcing based on TAR results	Consider range in TAR	Develop formula for burden and forcing based on TAR results
Aerosol indirect forcing: SO_4, OC, BC	No central recommendation based on complex models	Fixed at –1.8 Wm^{-2} in 2000 with a formula for historical emissions of SO_2 and natural aerosols effects based on SO_2 emissions	Consider a range of central estimates from 0 to about –2.5 Wm^{-2}; Consider use of OC/BC emissions in formula	Develop formulation that accounts for the role of OC/BC emissions in indirect forcing
Changes in global average surface temperature from radiative forcing	Equilibrium warming range is 1.5°C-4.5°C for CO_2 increasing from 280 to 560 ppm.	Included	Test this range of climate sensitivity	

Table 2 *(continued)*

ISSUE	STATE-OF-THE-ART MODELS AND DATA SETS	WHAT IS RECOMMENDED IN SIMPLE MODELS FOR REFERENCE CASE	SENSITIVITY STUDIES FOR VALIDATION AND ATTRIBUTION	ACTION ITEMS
Changes in ocean temperature and sea level rise from thermal expansion	Need to reconcile differences between Levitus and GCMs and recommend uncertainty range for ocean heat uptake/transient response (use GCM impulse / response)	Tune to central estimate of GCMs or the Levitus observations	Vary to replicate the extremes in different GCMs and the observations.	Reconcile differences between GCMs and between GCMs and observations. Recommend uncertainty range for ocean heat uptake/transient response
Sea level rise from the change in land ice	Most climate predictions made using mass balance parameterizations. Some large sheet models are available.	Use TAR recommendation for ice melt relationships and parameters	Explore uncertainty range to both glaciers and large sheets	Develop further estimates of uncertainty range from coupled ice sheet models
Global damage indicators	Δ T, (Δ T/Δ t) over 10 years, sea level	Regional effects unpredictable especially precipitation and sea level rise so recommend only the global indicators be used		
Feedbacks due to change in lightning and effects on chemistry, change in H_2O, T, circulation	H_2O is important	None included at present	Need to test uncertainty to H_2O changes	Need to design a method to include feedbacks to chemistry from changes in H_2O and its uncertainty

Table 3. Discussing emissions and land-use changes

ISSUE	STATE-OF-THE-ART MODELS AND DATA SETS	WHAT IS RECOMMENDED IN SIMPLE MODELS FOR REFERENCE CASE	SENSITIVITY STUDIES FOR VALIDATION AND ATTRIBUTION	ACTION ITEMS
CO_2 – fossil	(a) CDIAC/Marland version#? (b) EDGAR based on Marland? (c) BP, by country, 1960-	Use (a)	Use (b) and (c) also	***, ###
CO_2 – land use	(a) Hougton, 1x1,1700-1990 (LULUCF) (b) EDGAR (is it different?) (c) IGBP & IBIS (Foley)		Very important. Disagreement on historical data. Use range of available data sets (with tuning) and test.	***, ###
CO_2 – natural	None	No change	None	
CH_4 – anthrop	(a) EDGAR, by country, with uncertainty (b) Stern & Kaufman - ?1x1 (c) others?	Use (a)	Use (b) and others?	***
CH_4 – natural	(a) RIVM, 5x5 (b) Matthews	tbd	tbd	***
N_2O – anthrop.	(a) EDGAR,with uncertainty	Use	Use given uncertainty	***
N_2O – natural	(a) fixed (use TAR top-down)	Use TAR top-down	tbd	***
HFCs, PFCs, SF_6	(a) UNFCCC, country reporting (b) EDGAR, SRES, region (c) Other sources ??	Use EDGAR for valid studies, will need to use FCCC for attrib.	None	***
CFCs & strat. O3	(a) WMO/UNEP O3 assessment 1998 (b) UNEP database for country data?	Use O3 assessment for valid., but need country for attrib.	None	***
NO_X – anthrop.	(a) EDGAR (b) National Greenhouse Gas Inventories Programme (NGGIP)	Use (a)	Aviation could be done separately (SRAGA) but not in simple models	***, check consistency for non-GHG with NGGIP
NO_X – natural/bio	(a) TAR review	Use TAR	but may need BGC feedbacks for climate change	^^^
CO – anthrop.	As for NO_X			***, ^^^
VOC – anthrop.	As for NO_X			***
SOx** (anthrop.)	(a) EDGAR (b) Smith, 1x1 (c) LeFohn, country?	Use (a)	tbd	***, &&&

Table 3 ***(continued)***

ISSUE	STATE-OF-THE-ART MODELS AND DATA SETS	WHAT IS RECOMMENDED IN SIMPLE MODELS FOR REFERENCE CASE	SENSITIVITY STUDIES FOR VALIDATION AND ATTRIBUTION	ACTION ITEMS
SOx (natural)	(a) fixed	Fixed	None, but may need BGC feedbacks for climate change	
BC/OC (fossil)	Novakov, only some countries Liousse, country, 1970- Penner, country, 1950- EDGAR – need fuel use and emission factors Bond, ?ready	tbd		***
BC/OC (bio-fuel)	EDGAR (need to develop) Logan and Yevich Streets (Asia only, as check)	tbd		***
BC/OC (bio-burn)	(a) EDGAR			^^^
BC/OC (natural)	(a) 1980s temperate region	Fixed	None? Natural important to indirect effect of anthrop.	***
Secondary OC	(anthrop.) = work in progress (natural) = use TAR estimates			***
Dust - anthrop	No clear record	Fixed	tbd	
LUC Albedo	Bonan, Foley developed LUC data set by country? Check LULUCF	Scale to TAR 2000 amount	tbd	***

Notes:
*** Need to define and/or document the reference case, develop the alternatives. Must have country breakdown for attribution. Need to establish fair algorithm of determining "country" emissions when break-up/new nations occur?

Need to do more detailed evaluation of uncertainty for time history of emissions by country, i.e., is the early-vs-late uncertainty different from the cumulative?

^^^ Biomass burning is a major uncertainty for time trend and for country attribution. Paleodata on soot may provide some information on how different the burns would be without human intervention.

&&& Need to compare fuel use that went into the emission scenario (compare to CDIAC), emission factors by fuel type.

Annex

AGENDA OF THE EXPERT MEETING ON ASSESSMENT OF CONTRIBUTIONS TO CLIMATE CHANGE

Welcome
Peter EWINS, Chief Executive, Meteorological Office , United Kingdom
Luiz Gylvan MEIRA FILHO, Brazil

Review of past activities on the proposal and objectives of this meeting
Dennis TIRPAK, UNFCCC secretariat

Session Ia: Presentation of new results
Summary and comparison of the results of the modelling exercise
Fabian WAGNER

CICERO, Norway
Bård ROMSTAD / Jan FUGLESTVEDT

CSIRO Atmospheric Research, Australia
Ian ENTING / Cathy TRUDINGER

DEA-CCAT, Denmark
Jesper GUNDERMANN

LBNL, United States of America
Fabian WAGNER

Université Catholique de Louvain
Ben MATTHEWS

The Institute of Applied Energy (IAE), Japan
(Also presents the results of RITE, Japan)
Atsushi KUROSAWA

University of Illinois, Climate Research Group, United States of America
Natasha ANDRONOVA / Michael SCHLESINGER

ISAM, University of Illinois, United States of America
Atul JAIN

RIVM, the Netherlands
Michiel SCHAEFFER

National Institute of Water and Atmospheric Research, New Zealand
Greg BODECKER

Hadley Centre, United Kingdom
Jason LOWE

ECOFYS, Germany
Niklas HÖHNE

Session Ib: Model and data validation
Historical record of methane emissions - model and data validation
Michael PRATHER

Historical aerosol forcing and black carbon treatment in simple climate models
Joyce PENNER

Historical contributions to global warming by country for CO_2, CH_4 *and* N_2O
Silvia MUYLAERT

Session II: Discussion and conclusions
Discussion and formulation of conclusions on the different topics
- *Representation of the climate system*
- *Model validation / data*
- *Methodological issues in calculating contributions to climate change*

Session III: Broadening participation
Discussion: How to build bridges between developing and developed country scientists on climate change modelling?

Closure of the meeting

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