Chapter A4. Global and Regional Modeling

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In this outline we need to address the following questions:

(1) How do we approach modelling intercontinental transport?
(2) What are our best estimates for ozone and aerosols?
(3) How do we apply these results to key issues of importance for policy?
(4) How are our estimates likely to change with changing emissions and climate?
(5) What do we need to do to improve estimates over the next 5-10 years?

This is broadly follows the 2007 interim report, but with a greater emphasis on policy-relevant issues, on uncertainty and fit-for-purpose of current models, and with an increased regional emphasis.

Outline of Chapter

A4.1 Modelling intercontinental transport
A4.1.1 Modelling approaches (Tracey, Arlene, Greg/Amir)
A4.1.2 Methods for calculating source-receptor relationships (Dick)
A4.1.3 Coherency of approaches (Oliver, Arlene)

A4.2 Quantifying intercontinental transport of ozone and aerosols
A4.2.1 Global tropospheric ozone budget and surface ozone (Arlene)
A4.2.2 Source-receptor relationships for ozone (Arlene, Ruth, Joshua?)
A4.2.3 Transport of aerosols and their precursors (Michael, Denise, Mian)
A4.2.4 Source-receptor relationships for aerosols (Michael, Denise, Joshua, Mian)

A4.3 Quantifying policy-relevant metrics (Thomas, Denise)
A4.3.1 Exceedance or air quality standards (Tracey, Arlene, Thomas)
A4.3.2 Influences on deposition (Jan Eiof, Frank?)
A4.3.3 Effects on sensitive environments (Jan Eiof)
A4.3.4 Attribution to specific sources (Bill, Kengo, ...)

A4.4 Improving model estimates of intercontinental transport
A4.4.1 Principal sources of model uncertainty (Arlene, Michael, Joshua)
A4.4.2 Uncertainty in model transport processes (Martin?)
A4.4.3 Representation of transport episodes (Mat, Dick, Thomas)
A4.4.4 The influence of model resolution (Meiyun, Tracey)
A4.4.5 Insights from regional models (Greg, Joshua, Tracey, Gufran?)
A4.4.6 Strategies for reducing uncertainties (Don, Greg)

A4.5 Future changes in S-R relationships (Bill, David, Joshua)
A4.5.1 Changes with future emissions (Oliver, Sunling)
A4.5.2 Changes with future climate (Ruth, Gitte, ...)

A4.6 Summary and recommendations

A4.1 Modelling intercontinental transport

Set scene by describing model approaches, metrics and techniques

A4.1.1 Modelling approaches

What model approaches can we use? (trajectory models, CTMs with inert tracers, CTMs/GCMs with full chemistry/aerosol, inverse modelling, adjoint and tangent-linear approaches, tagging/colouring tracers, etc.). Base on intro to HTAP2007 5.1 but update with recent approaches.

A4.1.2 Methods for calculating source-receptor relationships *(or "Metrics for ICT"??)*

Source attribution, S/R relationships, nonlinearity (sensitivity vs. attribution) and other metrics for intercontinental transport. Distinguish attribution and S/R relationships for ozone. Include summary of timescale issues – particularly effects of O3-precursors on CH4, but note existance of other long-lived mode excitations. Base on preliminary draft of Chapter 1, together with bits from HTAP2007 5.1.1.

A4.1.3 Coherency of approaches

Value of standardised intercomparisons (ACCENT, HTAP), difficulty of evaluation vs. observations, metrics for evaluating performance, caveat on limitations/uncertainties of different approaches. Reduce HTAP2007 5.1.2 and add new material; short section, perhaps append to section above.

A4.2 Quantifying intercontinental transport of ozone and aerosols

Summarize current model budgets, evaluate against measurements to demonstrate fit-for-purpose, and then quantify S-R relationships from published (and HTAP) studies. Focus on ozone and then on aerosol.

A4.2.1 Global tropospheric ozone budget and surface ozone

Provide a brief summary of the tropospheric ozone budget (ACCENT study, HTAP update?) and overview of surface ozone (HTAP analysis), including comparison with observations. Summary of previous regional attribution studies here. Include a summary of modelled ozone trends (RETRO and other studies) to provide context of background ozone that ICT builds on. Include regional import/export budgets? Update HTAP2007 5.2.1 with new HTAP results.

Figures: surface O3, observation comparison, trends(?)

Table: O3 source attribution from previous studies (if available?)

A4.2.2 Source-receptor relationships for ozone

Summarize literature studies with a new, shorter table. Focus on final results from HTAP study (SR6 runs, 5.2.3); highlight consistency/differences with earlier studies. Add a new focus on seasonality, and an expanded regional focus based on Fiore et al. 2009 analysis. Include estimates of CH4 effects. May want to differentiate instantaneous and equilibrium O3 responses. Impacts of interannual variability. Surface and column impacts.

Figures: matrix of S-R relationships showing seasonality, include Arctic; figure of spatial variability?

Table: Simplified version of Table 5.2, with HTAP results added. Table: HTAP emission perturbations?

Table: S-R matrix for surface O3 for SR6 runs – annual mean, month of maximum effect(?)

A4.2.3 Transport of aerosols and their precursors

Provide summary of aerosol budgets, lifetimes/timescales and important issues for particular types of aerosol. Describe how well we can model these, with brief evaluation. Mirrors ozone subsection A4.2.1 Base on HTAP2007 5.3.1 and 5.3.2 with new material.

Figures: aerosol fields, evaluation vs observations, trends(?)

A4.2.4 Source-receptor relationships for aerosols

Summarize published literature studies, and update from recent HTAP analysis for different aerosol types. Issues associated with size distributions (links with Chapter 5). Interannual variability. Surface and column impacts. Effects of nitrate and anthropogenic SOA (need input from literature). Build on HTAP2007 5.3.3 with input from HTAP paper (Schulz et al., in prep).
Figures: matrix of S-R relationships, showing seasonality and/or aerosol type differences.
Table: S-R matrix (for each aerosol type?) mirroring ozone table.

A4.3 Quantifying policy-relevant metrics

Focus on specific aspects of intercontinental transport that are of key policy relevance, and attempt to quantify them.

A4.3.1 Exceedance of air quality standards

How much does ICT contribute to exceedance of AQ standards? Can we extend analysis of previous studies (see Fiore et al., and National Academy report)? Include region-scale analysis (fig 5.8), but supplement with more location-specific analysis (further analysis required). Complete analysis of variability (O3: 1-hr, aerosol: daily) to show temporal frequency distribution of ICT effects (Joshua). Include aerosol as well as ozone exceedances here. Transport episodes (followed up in A4.4.3).
Figures: examples of frequency distribution of ICT effects (region; also location?)

A4.3.2 Influences on deposition

Key focus on reactive nitrogen deposition; base on HTAP2007 5.4, but replace/supplement ACCENT analysis with the HTAP work from Sanderson et al., 2009. Also focus on deposition of black carbon (particularly to the Arctic). Would be good to cover O3 deposition (e.g., crop damage), but this may need further analysis. Leave discussion of critical loads for the impacts chapter (chapter 5).
Figures: Nitrogen deposition distribution, BC deposition,....

A4.3.3 Effects on sensitive environments

New section to bring together analysis of impacts on Arctic for ozone, CO and aerosols - base on Shindell et al., 2008 (draw on AeroCom results and HTAP2007 5.3.2). Include analysis of impacts on urban areas (O3), higher altitudes (aerosol) and key biomes (N or S deposition) if analysis available.
Figures: Arctic O3 figures from Drew's paper, ...

A4.3.4 Attribution to specific sources

New section: HTAP analysis focused mostly on regional attribution from anthropogenic emissions, but it would be good to say something about source-type attribution (e.g., forest fires vs. industry) from published literature, HTAP aerosol runs and from ES studies. Tagging/colouring tracers. Also needs to say something about the role of CH4 and its control for influencing O3. What is the role of natural sources (lightning, stratosphere) in altering S-R relationships for O3? (and aerosol where nonlinear?) Need to coordinate with section A4.2.1/A4.2.3 where regional attribution of "background" required.

A4.4 Improving model estimates of intercontinental transport

How confident are we of our ability to predict source-receptor relationships? What is our best estimate of the uncertainty? What are the effects of spatial resolution? What improvements are necessary?

A4.4.1 Principal sources of model uncertainty

Brief overview of key sources of model uncertainty in chemistry, aerosol processing, scavenging, etc., and their likely impact on conclusions. Highlight previous studies from literature estimating magnitude of these effects; base on HTAP2007 5.7.
Figure: can we quantify uncertainty well enough to illustrate with an IPCC-like bar chart?

A4.4.2 Uncertainty in model transport processes

Focus on transport processes based on analysis of TP1/TP1x studies using idealised tracers, and comparison of these with SR1/SR6 studies. Base on HTAP2007 5.5 but need to quantify variability and determine contribution to variability in SR1-6 runs.

Figure: TP1x example of model variability in PBL mixing (or newer analysis).

A4.4.3 Representation of transport episodes

New section focusing on how well/poorly we represent individual transport events in models based on comparison with observations. Examples from literature (e.g., Kiley et al., 2003 from TRACE-P) and with initial analysis of HTAP ES studies vs. ICARTT observations. Can we extract information on model biases in episodic vs background transport? Analysis of VOC ratios as photochemical clocks.

Figure: something from ES studies vs. ICARTT? VOC ratios from David Parrish?

A4.4.4 The influence of model resolution

New section addressing the effects of model resolution on estimates above. Compare high and low resolution results where available; consider the value of nested approaches (source or receptor nesting?). Draw together ES and SR studies. Summary of cross-scale issues and downscaling.

A4.4.5 Insights from regional models

Explore how we can use regional models to improve process understanding. Compare regional model results for SR1-6 (where available) with global results. Summary of lessons learned from MICS-Asia and other regional intercomparisons. Examples from regions of interest?

A4.4.6 Strategies for reducing uncertainties

Address known CTM/GCM weaknesses (base on HTAP2007 5.7), highlight importance of improved process representation (HTAP input to upcoming AC&C studies), and more critical comparison vs. observations. How do we improve confidence in estimates of S-R relationships? Need something on new strategies: regional foci, nesting, assimilation, adjoint techniques, tangent-linear approaches; build on recommendations from National Academy report.

A4.5 Future changes in S-R relationships

How will source-receptor relationships change due to emissions and climate over the next 20-50 years?

A4.5.1 Changes with future emissions

Summarize expected changes in O3/aerosols from literature. Describe initial analysis from FE studies and relate to linearized estimates. Include regional focus and attribution of changes; expected contribution to trends (and the changing global background).

Figures: S-R relationships under future emissions.

A4.5.2 Changes with future climate

Summarize previous studies with changing climate based on Doherty et al., Hess et al. Overhaul of HTAP2007 5.8.2 including new results on changing S-R relationships from FC studies, and contribution to underlying trends (changing global background). Regional insights?

Figures: S-R relationships and how they change with climate

A4.6 Summary and recommendations

Key findings and recommendations, outline of future priorities, input towards an “integrated approach”