Overview TF HTAP draft final report PART A: Ozone-Aerosol

- Per chapter
- Status
- Research needs
- What are the main messages that need to be brought out?
- What do we know and why should we care?
- What work needs to be completed to convey these main messages?

Chapter structure

- Chapter A1: Conceptual Overview of Hemispheric or Intercontinental Transport of Ozone and Particulate Matter
- Chapter A2: Observational Evidence
- Chapter A3: Emissions & Projections
- Chapter A4: Global and Regional Modeling
- Chapter A5: Impacts on Health, Ecosystems, and Climate
- Chapter A6: Synthesis

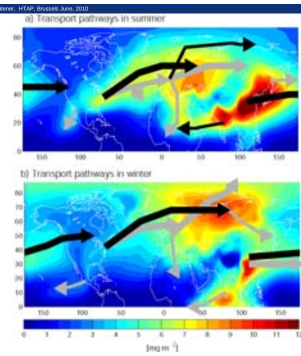
A1: Conceptual Overview of Hemispheric or Intercontinental Transport of Ozone and Particulate Matter. Dick Derwent/Owen Cooper

- Introducing policy context; source, transport patterns, emissions, lifetimes

Baseline concentrations refer to observations made at a site when it is not influenced by recent, locally emitted or produced man-made pollution.
Global or hemispheric background concentration is a model construct that estimates the atmospheric concentration of a pollutant due to natural sources only.

- Source Receptor versus Source Attribution
- What are the driving mechanisms of long-range transport/meteorology, and how influence by climate change.
- Introduction of Chapter 2-6 (small update if needed)
- 27 pages

A1: Pathways of hemispheric pollution transport



CO passive tracer

Lower troposphere

Mid-upper troposphere

Flexpart, A. Stohl et al, 2004

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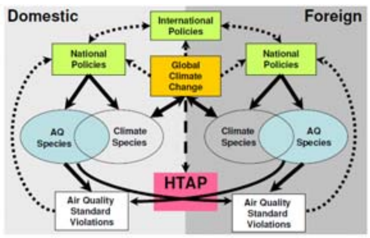
A1: policy context



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A2 Observational Evidence and Capabilities Related to Intercontinental Transport of Ozone and Aerosols. Kathy Law, David Parrish

- •Direct observational evidence for long-range transport of ozone and aerosols from satellite, aircraft, and ground-based data.
- •Long-term changes (trends) in the amount of ozone or aerosols
- •Using meteorological/tracer measurements for source attribution
- •Field experiments
- •Recommendations

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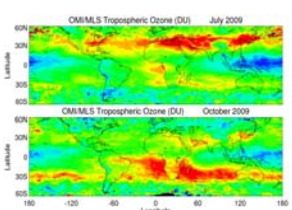
A2.2 ozone



Present satellite retrievals are limited to tropospheric columns with little vertical profile information. Satellites are particularly valuable for tracking emission changes of NO2 over source regions. Also other components (CO, SO2, CH2O)

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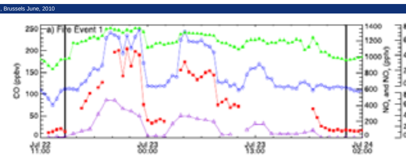
A2: example of event



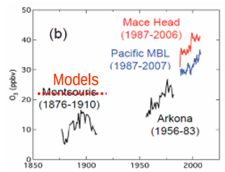
PICO-NARE Observatory (Azores, Portugal) transport of boreal wildfire emissions.
CO is plotted with open blue circles, NOy is plotted with red squares,
BC is plotted with open purple triangles and O3 is plotted with green triangles.

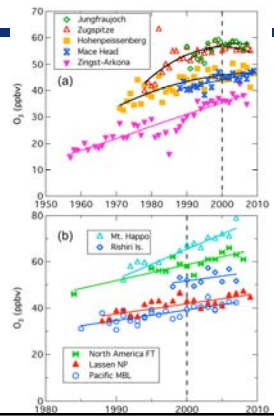
NAS Report

Several other examples: Do they convey the message of event and broad contineous transport and their relevance?

A2: Ozone trends

Dentener, HTAP, Brussels June, 2010 9





Pre-industrial levels not well understood
What about recent trends?

A2: Airquality implications

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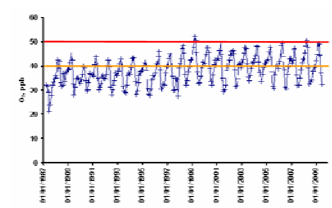
Mace Head



LRT Air quality issues in outflow of Asia and in Arctic

A2 transport of Aerosol;satellite based

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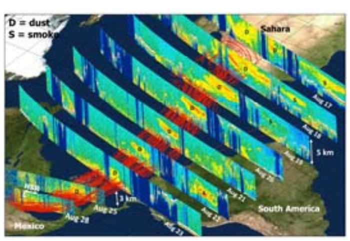

Increasing role of lidar, satellite, and satellite lidar

Ground-based lidar networks and mountain top measurement sites in Europe, North America and Asia provide large continuous data sets to characterize events

A2: long term surface observations

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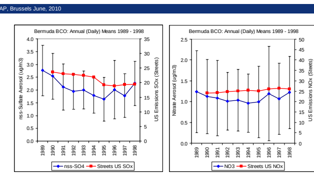

Decades in-situ measurements have established the importance of intercontinental transport of aerosol from dust, forest fires, and anthropogenic sources.

Need for expansion of observational networks

Optimum observation strategy for in situ and ground-based measurements to characterize intercontinental transport of aerosols. A particular focus should be on additional measurements to quantify the sources and properties of the organic and black carbon components of transported aerosols

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A2: Models-Measurement: Flexpart, adjoint, inverse

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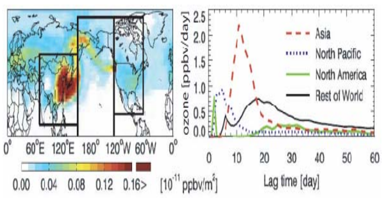

Particle dispersion models for source attribution; adjoint, complementary to Eulerian models
Picture also in Chapter 4

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A2: Use of tracer (ratios) to demonstrate LRT

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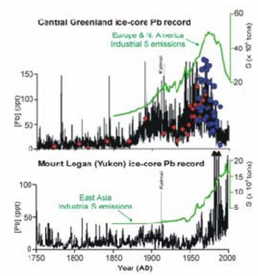
- Utilize proxy records of aerosol deposition (e.g. from ice cores) as targets to test simulations of chemical transport models over multi-decade intervals.



Analysis of long-term aerosol and trace element records provides information about inter-annual variability in source attribution as a particular downwind measurement site as well as insights into how emissions may have changed in the past.

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A2 Tracer ratios, O3-CO-VOC, fingerprinting

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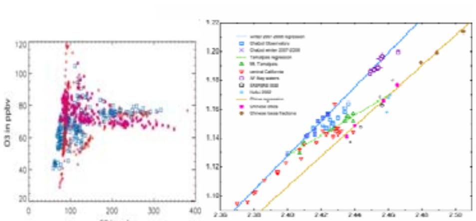
- Measured trace elements and isotopic ratios can provide useful constraints on different source types and emission regions influencing aerosol data.
- Further development of isotope and geochemical fingerprinting techniques for the identification of different source types and, in the case of stable isotopes information about chemical processes occurring during transport.`



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A2: Lagrangian experiments

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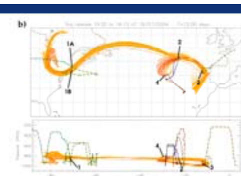


- Provide information on plume processing during transport
- Evaluates performance of global models, and the impact of resolution, regarding plume transport and speed of dilution
- Can be used to develop plume-in-grid descriptions for global models
- Better understanding of mass entrainment FT to BL.

A2: Research needs

- Surface sites; mountains sites; role of WMO-GAW
- Vertical profiles
- Aircraft- commercial airlines and unmanned aircraft
- Satellite: current use, w/ surface observations models; geostationary, future missions (gap)
- Using existing datasets for testing of models: beyond climatological testing/events

A2: Remaining Issues

Rather long 67 pages=>shorten.

Some duplications (e.g. modelling section,w/chapter 3,4).

Some sections need more focus on message

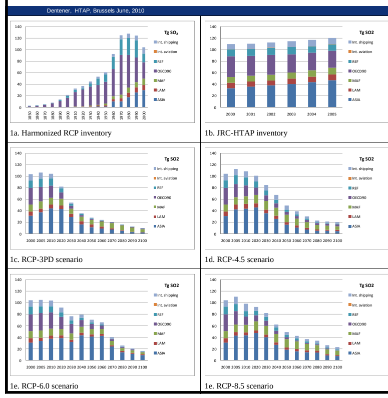
Many key messages- would be good to reduce/combine/organize them to make them stronger

… but overall a lot of good material is there!

A3: Emissions and Projections, J. van Aardenne, D. Streets

- Available datasets for studies of hemispheric transport of AP: current and future (RCPs)
- Description of data in EDGAR-HTAP (hierarchy of datasets)
- Emission trends 1850-2100
- Natural emissions
- Case study for Asia
- Examples of trends in the USA
- Integration of emissions, modelling, measurements
- Constraints from satellites

A3: Current+future datasets



1a. Harmonized RCP inventory

1b. JRC-HTAP inventory

1c. RCP-3PD scenario

1d. RCP-4.5 scenario

1e. RCP-6.0 scenario

1e. RCP-8.5 scenario

Long-term emission trend datasets (century-scale) are becoming available and present a new opportunity to characterize intercontinental pollution flows in the past and future.

Uncertainties are higher the further away we get from present-day conditions

Gridded emission distributions for the past and future are rudimentary.

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A3: key messages

•A long-term dataset of major anthropogenic emissions from 1850-2100 at 0.1º × 0.1º available for use in chemical transport models to assess changes in intercontinental transport over time. Future emissions use the IPCC AR5 Representative Concentration Pathway (RCP) scenarios

•Comparison of the EDGAR-HTAP dataset (regional emission inventories substitute global data) (2000-2005)

•Present-day emissions are relatively well understood by sector and world region but some species are still unreliable in some parts of the world (e.g., black carbon and NMVOC emissions from developing countries, NH3)

•New spatially distributed proxy datasets are needed to more accurately distribute past and future emissions

•This adds uncertainty to our ability to reliably model intercontinental transport; some source/receptor relationships are inherently better known than others

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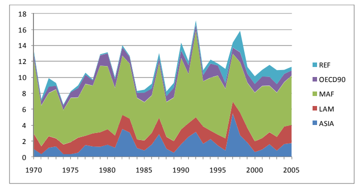
A3: Natural emissions; biomass burning



natural sources soil emissions, windblown dust, volcanoes, and remote biomass burning rarely fall within the purview of national governments and may need greater attention from the TF HTAP.

Natural emissions are changing in time: new approaches needed to quantify them

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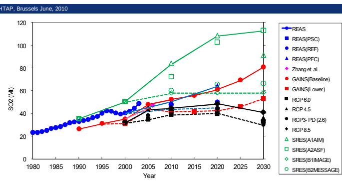
A3: Case study Asia

SO2



Emissions are not always the same among inventories compiled by different research groups, and sometimes the differences are large.

- harmonisation good, but finding underlying reasons better
- lessons to be learned from country/regional inventories (e.g. RAPIDC)

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A3: Inverse modelling of emissions

- The integrated study of emissions, forward and inverse modeling, and satellite and ground observations can usefully bound source magnitudes and lead to improved emission inventories.
- Previous studies demonstrate a clear need for the development of an integrated framework of emissions, models, and observations that can be readily applied to different intercontinental transport situationsand can quickly adapt to new technical capabilities as they arise (new satellite retrievals, new network data releases, etc.)
- Careful study of the large-scale relationships between primary precursor emissions (e.g., emission ratios, speciation profiles) and observed secondary species (from satellites, campaigns, networks) can advance our understanding of the formation mechanisms and our ability to select effective mitigation options for the primary species.

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A3: Issues

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- 55 pages- lots of figures, it can be shortened. Overall structure seems to work.
- Some duplications (e.g. modelling section,w/chapter 2; satellite stuff).
- Some sections need to be completed, material to be integrated
- Good section on integration
- Missing explicit description of emissions used in Chapter 5, mitigation costs

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A4: Global and Regional Modeling G. Carmichael, O. Wild

Dentener, HTAP, Brussels June, 2010 26

- Description of modelling approaches; intercomparison, model source attribution
- Quantification of intercontinental transport
- O3 trends
- HTAP modelling study; CH4, yearly month, MDA8 (policy relevant) O3
- LRT influence of O3 on various time and spatial scales, scalability of O3 SR (linearity)
- Aerosol: SR surface concentrations, deposition, column load, linearity of aerosol SR policy relevant SR
- AEROCOM-HTAP specific experiments on dust and biomass burning, hindcast
- Source attribution
- Uncertainty: parameterizations, resolution, chemistry
- Changes due to future emissions and climate change

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A4: current model skills for O3

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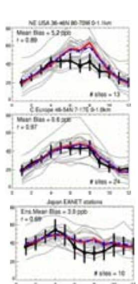
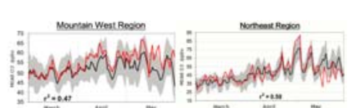


The observed regional and seasonal variability in surface ozone is reproduced relatively well in current models lending confidence in our ability to represent the key large-scale processes controlling the formation, transport and removal of ozone and its precursors. However, significant discrepancies exist on shorter spatial and temporal scales indicating weaknesses in our representation of local- and urban-scale processes in current models.



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A4: Scale Issues

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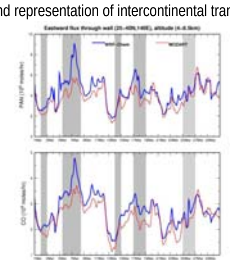
Apply newly-available modelling tools (e.g., multiple-nested models from global to urban scales, assimilation and bias-correction approaches) along with remote-sensing data to improve assessment and representation of intercontinental transport processes.

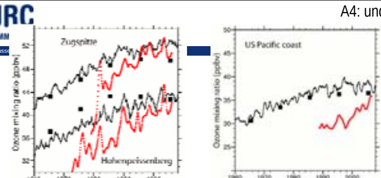


Regional model studies suggest that sub-grid-scale processes (convection, frontal lifting, heterogeneous PBL mixing, etc.) have a major effect on pollution export. Differences in chemical mechanism lead to large differences in regional model results.

Support the application of high-resolution global and regional models to investigate the effect of smaller-scale processes on continental import and export budgets.

Current global CTMs are unable to resolve the strong chemical contrasts associated with urban regions, and so are not generally appropriate for evaluating the impact of long-range transport on attainment of air quality standards in these environments

A4: understanding O3 trends

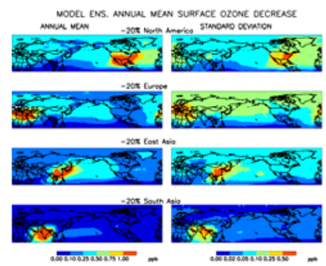


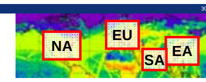
Given that models may be underestimating the anthropogenic contribution to surface ozone, we have high confidence that current surface ozone is significantly higher than preindustrial levels (NAS, 2009).

The observed increase in surface ozone over the past 40 years is reproduced qualitatively by current models, but there are significant differences in the magnitude and regional variation in this trend compared with observations. These discrepancies indicate that precursor emissions and/or atmospheric processes are not represented well in current models.

Need to examine observed trends in surface ozone through multi-year model simulations using most reliable assessments of changing emissions and meteorology in order to
(1) explain/attribute changes, (2) put observed trends in a global context, and
(3) critically test model ability to reproduce long-term composition changes.

A4: O3 Source Receptor relationships

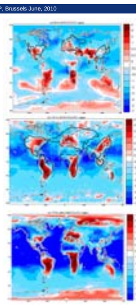




Estimates of S-R relationships indicate that 20% changes in present-day anthropogenic precursor emissions affect regional monthly mean surface ozone by 0.2-0.9 ppbv (over continental regions downwind. This is about 10-20% of the impact over the emission region itself on an annual basis. However, this masks large temporal and geographic variability which needs to be characterised much better.

Controlling CH4 is/will be of major importance in limiting increases in baseline surface ozone

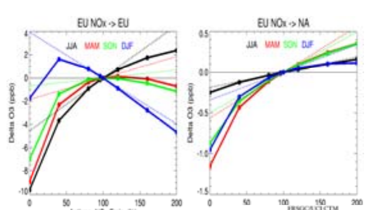
A4: O3 and climate change

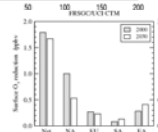


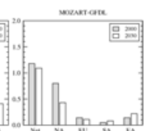
Future changes in climate are expected to increase the effect of precursor emissions over the source region and reduce the effect over downwind receptor regions. However, the magnitude of these effects is relatively small, and is driven by changes in the lifetime of NOy and not by changes in transport patterns. The effect of natural emission changes and wider climate-related feedbacks have not been evaluated fully yet

Figure A4.6.2.1: Difference in annual-average surface ozone concentrations between the 2090s and 2000s decade for a) GISS-PUCCINI-ModelE, b) STOC-HadAM3 and c) UM-CAM.
The differences are due to climate and climate-sensitive natural emissions changes alone (lightning for both models; isoprene for STOC-HadAM3). Units are ppb. The 500ppt contour of NOx concentrations for the 2000s decades is shown in black.

A2: linearity/scalability of SRs; scenarios







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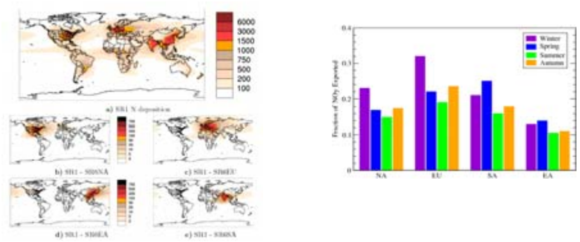
A4: Ndep



Export fractions for NOy from each HTAP source region feach season

In many regions deposition of oxidised sulphur and nitrogen is large, and exceedance of critical loads occurs widely over many ecosystems. The intercontinental contribution to these exceedances is small. However, particular attention should be paid to long range transport to polar regions where ecosystems are likely to be more vulnerable.

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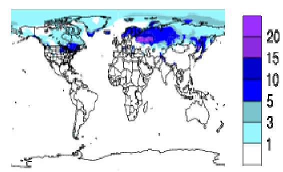
A4: LR transport to the Arctic



Multi-model experiments shown that over the 4 polluted regions, the surface concentrations of sulfate and BC are mostly (70-90%) from "domestic" pollution sources. However, "foreign" contributions are increasingly large at higher altitudes. Over the Arctic surface, European pollution is the most significant source of sulfate while biomass burning from Eurasia is the major contributor to BC and POM. More than 80% of surface dust is from Asia and Africa

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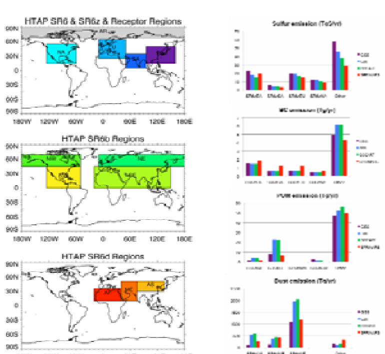
A4: Aerosol modelling HTAP/AEROCOM



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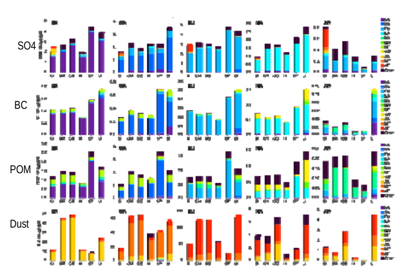
A4: Source attribution of Aerosol



Near linearity

Over the 4 polluted regions, the surface concentrations of sulfate and BC are mostly (70-90%) from "domestic" pollution sources.

"foreign" contributions are increasingly large at higher altitudes.

Over the Arctic surface, European pollution is the most significant source of sulfate while biomass burning from Eurasia is the major contributor to BC and POM.

More than 80% of surface dust is from Asia and Africa

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A4: Remaining Issues

Rather long 70 pages=>needs to be shortened
Organisation can be improved
Lack material on TP1x and Field experiments
Provide key messages needed for Synthesis
A4 needs most work!

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A5: Impacts on Human health, Ecosystem, and climate

- Introduction: AQ standard
- Human health: effects of PM; O3; short term and long term LRT effects
- Ecosystems-Agriculture: experimental evidence, metrics, interaction with LRT, climate change
- Climate: ozone+PM Radiative Forcing; mechanisms of RF
  - short-lived/long-lived components
  - regional forcings; regional+global response; Arctic;
  - relationship of emissions-RF; future RF.

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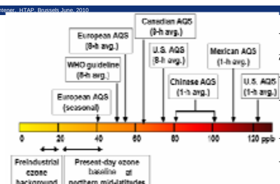
A5: Worldwide ozone standards: short-term



	zone Standards, µg/m³	
		8 hr
		100 µg/m³ (51 ppbv)
		120 µg/m³ (60 ppbv)
		147 µg/m³ (75 ppbv)
India	180 µg/m³	100 µg/m³
China (Grade II)	200 µg/m³	-
South Korea	196 µg/m³ (100 ppbv)	118 µg/m³ (60 ppbv)
Japan	118 µg/m³ (60 ppbv)	-
Indonesia	235 µg/m³	-

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A5: Impacts/Health

- There is broad consensus that exposure to ambient PM and ozone causes adverse health effects that range from minor sensory irritation to death.
- Short-term exposure to PM is associated with increased daily mortality and morbidity in hundreds of studies worldwide. Long term exposure to PM2.5 has been associated with increased mortality from chronic cardiovascular and respiratory disease.
- PM is the most important air pollutant for health.
- Short-term exposure to ozone is associated with increased daily mortality and morbidity in hundreds of studies worldwide. Unlike PM, the evidence linking ozone with long-term mortality is limited.

A5: premature deaths

TABLE 2. Annual Avoided Cardiopulmonary Mortalities (Hundreds) Following 20% NO_x, NMVOC, and CO Emission Reductions in Each Region, Assuming No Concentration Threshold (bold) and Assuming a Concentration Threshold of 35 ppb (normal font)[a]

	receptor region				
source region	NA	EA	SA	EU	NH
NA	**9 (4 – 13)**	**7 (3 – 10)**	**6 (3 – 9)**	**11 (5 – 17)**	**36 (18 – 55)**
	9 (4 – 14)	4 (2 – 6)	5 (3 – 8)	6 (3 – 9)	27 (13 – 41)
EA	**2 (1 – 3)**	**43 (21 – 66)**	**6 (3 – 9)**	**5 (3 – 8)**	**59 (29 – 91)**
	1 (1 – 2)	40 (19 – 61)	5 (2 – 8)	3 (1 – 4)	49 (24 – 76)
SA	**1 (0 – 1)**	**4 (2 – 6)**	**76 (37 – 117)**	**2 (1 – 3)**	**85 (41 – 130)**
	0 (0 – 1)	3 (1 – 4)	66 (32 – 101)	1 (0 – 2)	71 (34 – 108)
EU	**2 (1 – 3)**	**8 (4 – 12)**	**6 (3 – 10)**	**17 (8 – 26)**	**38 (18 – 58)**
	1 (0 – 1)	6 (3 – 8)	6 (3 – 9)	25 (12 – 38)	40 (19 – 61)

[a] Confidence intervals (95%) reflect uncertainty in the CRF only (1).

3 studies have estimated that reductions in ozone precursor emissions may avoid more premature mortalities outside of some source regions than within, mainly because of larger populations outside of those source regions; especially North America and Europe

A5: Impacts-Health; findings

- Contributions to PM from emissions within a region are expected to be much more important for human health than emissions from foreign continents.
- Influence potential, impact per unit of emissions, 1-3 orders of magnitude smaller for LRT.
- Intercontinental transport of PM is estimated to cause more human mortalities than intercontinental transport of ozone, due to the stronger relationships between PM and mortality.
- In one study, most of the mortalities due to intercontinental PM are attributed to dust; those attributed to anthropogenic PM are estimated to be ~25% of the total.

A5: Health Recommendations

Estimates of health impacts of air pollutants and long-range transport need research on:

- concentration-response relationships in less industrialized nations - over a range of concentrations, including short-term and long-term effects - low- or high-concentration thresholds,
- improving the resolution of global atmospheric models and improving nested models that encompass the global, regional, and urban scales, to better represent concentration gradients in and near urban areas,
- the possible differential toxicity of different PM components and particle sizes,
- possible changes in PM and pollutant mixtures as they are transported and age, and the effects of such changes on toxicity,
- possible interactive effects of PM, ozone, and other pollutants on human health.

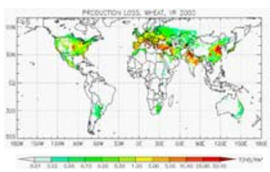
A5: Impacts on vegetation

- Ozone impacts on agricultural crops- forests-grasslands: key-experiments only from Europe, North America and lesser extent Asia.
- PM radiation impacts, and deposition (eutrophication/acidification)
- Different metrics in Europe (AOT40) and North America (SUM06, Mx)
- *AOT30 was as statistically robust in terms of defining crop damage but was considered have implications for control strategies outside of Europe and hence AOT40 was retained*
- Flux metric better suited to deal with rising background O3

A5: Vegetation; yield losses

Currently, global yield losses are predicted to range between
- 3%-5% for maize,
- 7% -12% for wheat,
- 6% -16% for soybean,
- 3% - 4% for rice,

which represents an economic loss of $14-$26 billion (10^9) per year



A5: vegetation recommendations

- Experimental studies using O3 profiles that simulate enhanced background O3 concentrations, perhaps with a focus on crops, forests and grasslands that have growth periods extending into those seasonal periods when the relative LRT contribution to pollution is greatest.
- A pan-Asian OTC/FACE field campaign to establish dose-response relationships specific for Asian species (crops, forests and grasslands) growing under Asian climatic and management conditions.
- Assessment of the suitability of the flux based O3 index to identify LRT effects on ecosystems.
- Development of flux networks that monitor O3 fluxes in addition to other biogeochemical species (such as N, C and water vapour).
- An improved understanding of the processes by which seasonality in O3 exposure influence damage to ecosystems.
- Global modelling experiments that use flux-based indices to estimate the influence of LRT on ecosystem damage.
- Improved critical loads for tropical and Asian ecosystems.
- Improved understanding of how LRT may influence recovery or time-development of damage of ecosystems to acidification and eutrophication.

A5: Impacts - Climate

Mainly looks at RF; lot of introductory material

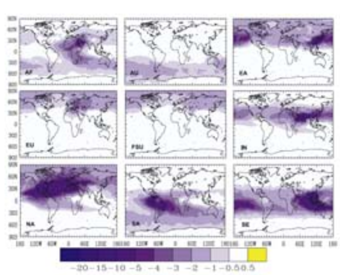


Figure 7. Annual total-sky instantaneous radiative forcing at the tropopause due to short-lived O_3 perturbations resulting from a 10% reduction in surface anthropogenic NO_x emissions from each of the nine regions.

RF due to aerosols and ozone are highly uncertain, among the most important uncertainties in climate change. Observations of aerosol absorption and vertical distributions are particularly needed to reduce these uncertainties.

Forcings resulting from changes in emissions of aerosols, their precursors, and ozone precursors (except methane) depend strongly on location, timing, and the background composition, and these dependencies merit further research.

Reductions in PM would improve air quality, but for cooling aerosols, including sulfate, nitrate and organic carbon, this would generally exacerbate global warming. Reductions in BC would typically are likely to benefit both air quality and climate.

A5: Import sensitivity of RF

Import sensitivity (mean ± std. dev) for annual-averaged **top-of-atmosphere all-sky aerosol direct radiative forcing**				
Receptor	NA	EU	EA	SA
BC	38%±38%	22%±20%	13%± 6%	20%± 8%
POM	23%±24%	17%±18%	20%± 7%	10%± 7%
Sulfate	17%±15%	12%±10%	19%±12%	37%±20%
BC+POM+Sulfate	16%±15%	12%±11%	20%±13%	33%±20%

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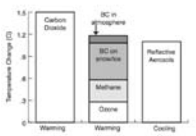
A5: Climate Change in the Arctic



The Arctic is experiencing rapid climate change. Arctic climate is affected by ozone and aerosols that are the result of long-range transport from other regions, as well as by ozone and aerosols outside of the Arctic. Deposition of black carbon in snow is understood to be an important contributor to warming in the Arctic.

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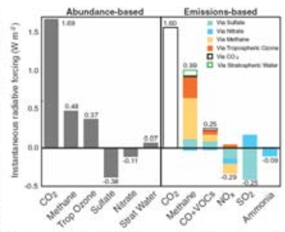
A5: emissions based RF

Fig. 1. Radiative forcing from 1750 to 2000. Numerical values within the figure give the net forcing (instantaneous at the tropopause). Uncertainties in the abundance-based values are 0.16 for CO_2, 0.05 for methane, +0.15 to −0.10 for ozone, 0.20 for sulfate, 0.10 for nitrate, and 0.05 for stratospheric water (5). For emissions-based values, we estimate uncertainties by adding the forcing uncertainties for each component in quadrature, yielding 0.14 for methane, 0.04 for CO+VOCs, 0.09 for NO_x, 0.23 for sulfate, and 0.10 for ammonia. AIE are not included. All forcing values are from this work except those from CO_2 and stratospheric water, which are based on the IPCC AR4 (5).



Big difference for CH4

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A5: Impacts;Remaining Issues

Rather long 79 pages=>needs to be shortened overall

Health-section; parts needs to be finished

Vegetation- some overlap with A4; and with A5-climate; need key finding

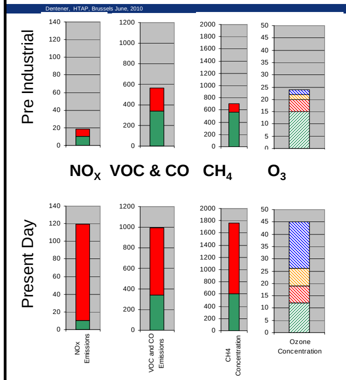
Health-Climate: key findings are very general

A lot of good material!

Overview of Chapter A6: Summary

- Observational Evidence: Events and Trends
- Use of Modeling Analyses
- Source Attribution
- Source/Receptor Relationships
- Impacts on AQ Standards, Health, Ecosystem, Climate
- Effect of Expected Changes in Emissions and Climate
- Implications for International Policy
- Further Research and Analysis Needs

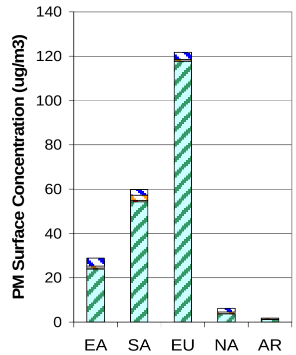
A6: O_3 Source Attribution
(illustrative only, not quantitative)



- Anthropogenic
- Natural
- NOx/VOC/CO in Region
- NOx/VOC/CO out of Region
- Methane
- Natural

What should we compare?
- **past, present, future**
- **global, region**
- **average, peak**

A6: PM Source Attribution
(Illustrative, Based on Table 4.8)



- Anthro PM & precursors in Region
- Anthro PM & precursors out of Region
- Vegetation Burning?
- Dust & Sea Salt

What should we compare?

A6: Ozone Impacts

- Air Quality Objectives and Standards
  - *In-source region* emissions contribute the most to the highest peak concentrations, and therefore, exceedances of standards based on short term average concentrations.
  - Intercontinental transport is already sufficient to exceed the thresholds of some air quality objectives, particularly those based on long-term averages or accumulated exposure over a threshold concentration (AOT40, …)
- Source-Receptor Sensitivity
  - Ozone concentrations are most sensitive to changes in in-source region emissions, but changes in intercontinental transport can produce 30-70% of the response (impact sensitivity) of the in-source region controls.
- Health Impacts
  - Intercontinental transport of ozone may contribute 20% to >50% of avoided mortalities in a given receptor region. Emissions reductions, particularly in EU and NA, may produce more health benefits outside the source region than within.
- Ecosystem Impacts
  - Intercontinental transport of ozone may contribute up to 40% of crop yield loss, depending on location, crop and response functions used. At current baseline levels, crop yield loss exceeds $15B globally; any further increase will exacerbate this exposure.
- Climate Impacts
  - Ozone and its precursors, particularly methane contribute significantly to changes in global and regional climate, depending on location, timing, and background composition.

A6: PM Impacts

- Air Quality Objectives and Standards
  - Intercontinental transport events (particularly associated with dust and fires) are sufficient to exceed the thresholds of standards based on short-term average concentrations.
  - Except for dust (and vegetation burning?), intercontinental transport of PM is generally small, but may contribute a large fraction of concentrations in clean areas.
- Source-Receptor Sensitivity
  - PM concentrations are most sensitive to changes in in-source region emissions, but changes in intercontinental transport can produce 4-18% of the response (impact sensitivity) of the in-source region controls.
- Health Impacts
  - Intercontinental transport of PM may cause 380,000 premature mortalities, globally, 75% of which are attributed to dust.
- Ecosystem Impacts
  - Intercontinental transport of S and N contributes to acidification and eutrophication and changes in surface radiation.
- Climate Impacts
  - PM contribute significantly to changes in global and regional climate, both positively and negatively, depending on chemical composition, location, timing, and background composition. Black carbon deposition on snow and ice is understood to be a particularly important positive forcing, especially for the Arctic and the Himalyan regions.

A6: Policy Implications

- Control of foreign sources of ozone and PM is not a substitute for domestic control of ozone and PM sources.
- Together, foreign sources contribute to significant adverse public health, natural and agricultural ecosystem damage, and near-term climate forcing on regional and global scales.
- As domestic sources are reduced and AQ standards are tightened, the absolute and relative importance foreign sources will increase without the implementation of controls. Increasing emissions in other source regions will require greater controls in a given region to meet fixed standards.
- Controlling emissions generates benefits outside of a given source region, potentially larger than the benefits within the source region itself.
- Collective action is needed to decrease emission sources and their various impacts at the local, regional, hemispheric, and global scales.

Length of Part A

A1: 25 (27)
A2: 45 (67)
A3: 35 (45)
A4: 45 (70; still parts missing)
A5: 45 (79)
A6: 10 ()
Total 205 pages