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EXECUTIVE BODY FOR THE CONVENTION ON LONG-RANGE TRANSBOUNDARY AIR POLLUTION

Steering Body to the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission for Air Pollutants in Europe (EMEP)
(Twenty-seventh session, Geneva, 8-10 September 2003)
Item 4 (h) of the provisional agenda

Hemispheric Air Pollution: Trends and Intercontinental Transport of Photo-Oxidants, Particles and their Precursors across the Northern Hemisphere (Observations, Models, Policy Implications)

Summary report of the workshop

Introduction

1. Approximately 100 atmospheric scientists and environmental policy officials from 20 countries in Asia, Europe and North America met on 7-9 October 2002, in Bad Breisig (Germany), to assess the current state of knowledge about the hemispheric scale transport of air pollutants. The workshop brought together academic and government scientists from the global and regional air quality science communities with members of the international environmental policy community. The workshop was hosted by the University of Wuppertal (Germany),

organized by the German Federal Environment Agency and supported by the United States Environmental Protection Agency. It was organized within the framework of the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP) under the Convention on Long-range Transboundary Air Pollution.

2. More information, including papers and presentations, is available at the following web site: http://www.physchem.uni-wuppertal.de/PC-WWW_Site/Bad_Breisig/breisig_WS1.html

I. BACKGROUND

3. This workshop was the third in a series of international meetings focused on the intercontinental transport of air pollutants. The first two workshops focused on trans-Pacific and trans-Atlantic transport, respectively:

- First International Conference on Trans-Pacific Transport of Atmospheric Contaminants, Seattle, July 2000 (see Wilkening, K.E., L.A. Barrie, and M. Engle. Science, 290:65-67 (2000));
- EMEP Workshop on photo-oxidants, fine particles, and haze across the Arctic and North Atlantic: transport observations and models, Palisades, New York, June 2001 (EB.AIR/GE.1/2001/11, see also http://www.ciesin.columbia.edu/pph).

This third workshop intended to bring together experts from across the Northern hemisphere to explore the hemispheric nature of air pollutant transport and the source-receptor relationships between North America, Europe and Asia.

II. OBJECTIVES

4. The primary objective of the workshop was to address the following key scientific questions:

(a) Do we have the tools and data to quantify the source-receptor relationships of air pollutants (mainly ozone and its precursors, fine particles and their precursors, and mercury) across the North Atlantic, North Pacific and Arctic, and also between Asia, North America and Europe?

(b) What are the key uncertainties in these source-receptor relationships?

(c) What research activities could help reduce these uncertainties?

(d) How important are the links between these hemispheric air pollution problems and climate change for future air pollution policy?

(e) What are the roles of EMEP, the EUREKA Environmental Project on the Transport and Chemical Transformation of Environmentally Relevant Trace Constituents in the Troposphere over Europe (EUROTRAC), the International Global Atmospheric Chemistry Project (IGAC), the North American Research Strategy for Tropospheric Ozone (NARSTO), the Arctic Monitoring and Assessment Programme (AMAP), European Commission research programmes, etc. in pursuing these research activities?

III. SCIENTIFIC PRESENTATIONS

5. The workshop included more than 30 oral presentations. These presentations discussed research results from long-term monitoring programmes, intensive field campaigns, and regional, hemispheric and global modelling studies. A list of the presentations, in chronological order, is provided in table 1.

6. The workshop concluded with a discussion on the implications of the research findings that had been presented and the research needs that remained.

IV. CONCLUSIONS

A. Relevance of intercontinental and hemispheric transport

7. Current emissions create pollution levels that exceed air quality objectives at various locations throughout the Northern hemisphere. While local or regional emissions and environmental conditions are responsible for most of these exceedances, air quality is also influenced by emissions, transport and transformation processes at the intercontinental and hemispheric scales.

8. There is well-documented evidence for the intercontinental and hemispheric transport of ozone, particles, and their precursors, as well as mercury and persistent organic pollutants.

B. Mechanisms of intercontinental and hemispheric transport

9. Emissions from one continent can influence air quality over another both through an increase in the overall hemispheric burden of pollution and through discrete episodic flows of enhanced pollutant levels. The influence of episodic flows on regional air quality varies depending on location, season and the pollutant concerned.

10. Intercontinental transport episodes may involve: (a) advection in the boundary layer; or (b) lifting into the free troposphere via deep convection, orographic effects and, in particular, synoptic scale weather systems (for example, warm conveyor belts).

11. The most important pathways by which one continent influences another may differ. From Asia to North America and from North America to Europe, transport in the free troposphere

appears to be more important than transport in the boundary layer. Between Europe and Asia, boundary-layer transport and orographic lifting may be the most important.

12. For ozone, average ground-level concentrations are influenced by the hemispheric transport of ozone and its precursors through an overall increase in the hemispheric burden within the troposphere. This average increase in hemispheric burden appears to have a greater effect than discrete intercontinental transport events.

13. For aerosols and their precursors, episodic flows appear to be most important for intercontinental transport. The spatial distribution of aerosols is more heterogeneous than that of ozone due primarily to the episodic nature of strong emission events, as well as removal by wet deposition. Given this heterogeneity, aerosol transport may create more of a regional burden of pollution than a hemispheric burden.

14. For mercury, export into the free troposphere contributes to a hemispheric or global pool of elemental mercury. Mercury deposition patterns are more related to patterns of emissions and precipitation than to transport events. The contribution of intercontinental transport to annual mercury deposition varies from continent to continent. Modelling studies suggest that the relative contribution of emissions sources on other continents to annual mercury deposition is the largest for North America, less for Europe, and the lowest for Asia, which is primarily due to the spatial pattern of emissions.

C. Modelling of intercontinental and hemispheric transport

15. To account for the non-linearity and complexities of the atmospheric system, it is necessary to simulate control strategies using predictive models. Ideally, this simulation should be performed with an integrated system of models capable of linking the local, regional and hemispheric scales.

16. Our current models of hemispheric transport produce credible representations of the gross observed features of ozone and aerosol distributions. However, simulation of specific intercontinental transport episodes challenges the capabilities of current models, and we do not have the observational resources needed to test the hemispheric anthropogenic influences during specific episodes simulated by the models.

17. Modelling of these transport pathways has resulted in a variety of estimates for the relative contribution of intercontinental transport to ground-level ozone and aerosol concentrations and mercury deposition. Estimates from recent studies for ozone, aerosols and mercury are shown in tables 2 (a), (b) and (c) respectively. These estimates are highly uncertain due to the non-linearity and coupling of the large variety of physical and chemical processes involved, the uncertainty associated with model input assumptions, such as the magnitude of emissions, and the lack of adequate observations to fully evaluate the performance of the models.

18. The estimates of intercontinental influence indicate the need to address these flows through control policies but alone they are not sufficient to assess the impact of alternative control strategies.

D. Implications for the future

19. The emissions of ozone precursors from Asia, North America and Europe have more than doubled since pre-industrial times. As a result the hemispheric burden of ozone has increased by 50% to 100% over pre-industrial levels. Observations suggest that local air pollution problems persist in North America, Europe and Asia, and the hemispheric burden is continuing to increase. Any further increase in Northern hemispheric emissions will aggravate the exceedance of air quality objectives. Emissions increases in the tropics may have greater impacts than emissions increases at mid-latitudes because climatic conditions in the tropics may allow even more ozone to be formed per unit of emissions. The continuing build-up of methane will also contribute to rising ozone levels.

20. For aerosols, the main drivers for peak intercontinental influences are large forest fires and dust storms. The frequencies of these events are likely to change in the future in response to changes in climate, land use and human intervention. Desertification, erosion of agricultural land and biomass accumulation in boreal forests are of particular concern. While aerosols associated with other anthropogenic activities are not the main drivers of peak events, their intercontinental transport has been observed.

V. RECOMMENDATIONS FOR FUTURE RESEARCH

21. Participants in the 2001 workshop in Palisades recommended that a systematic approach to model evaluation, long-term monitoring, intensive observational studies and emissions inventory development was needed to improve the understanding of the intercontinental transport of air pollutants in the Northern hemisphere. Furthermore, they found that the linkages between regional and global air quality and climate change as well as the associated variability needed to be better understood, and the communications between the various scientific communities addressing these issues could be improved. Building on these recommendations, the participants at the 2002 workshop in Bad Breisig emphasized the following research priorities:

(a) The development and exploitation of global observing networks, using multiple measurement technologies and platforms, including:

(i) Comprehensive surface “supersites”;

(ii) Rapidly evolving satellite and ground-based remote sensors;

(iii) Instrumented commercial passenger and research aircraft;

(b) The improvement of emissions inventories, especially for biogenic sources and the simulation of historical trends;

(c) The development of linked or nested models capable of simulating transport and transformations across the range of spatial scales from local through regional to global;

(d) The development of techniques to manage, analyse and synthesize diverse types of information from multiple sources and disciplines (e.g. source activity; emissions; meteorology; surface, aircraft and satellite observations; model predictions);

(e) The fostering of interdisciplinary communication and collaboration across the various research communities addressing ozone, aerosols, mercury and climate change to capitalize on shared research approaches and to leverage limited resources.

Table 1. Scientific presentations

Title of presentation	Presenter and affiliation
Hemispheric emission scenarios	Markus Amann IIASA, Laxenburg, Austria
Testing global models of intercontinental pollution transport using aircraft and satellite observations	Daniel Jacob Harvard University, United States
Intercontinental transport of pollution: inflow to the west coast and outflow from the east coast of North America	David Parrish NOAA, Boulder, United States
Long-range transport of pollutants across the Northern Pacific: what we are learning from recent field experiments	Greg Carmichael University of Iowa, United States
Trends of tropospheric ozone in East Asia and Europe: Implication of regional emission and intercontinental transport	Hajime Akimoto IGCR, Yokohama, Japan
Calculating the hemispheric component of the trends in European surface ozone levels over the last two decades	Jan Eiof Jonson Norwegian Meteorological Institute, Blindern, Norway
Results of major activities of Acid Deposition Monitoring Network in East Asia (EANET)	Tsumugu Totsuka Acid Deposition and Oxidant Research Center, Niigata, Japan
The surface ozone concentration at Okinawa Island under the strong influence of oceanic high pressure	Kentaro Murano NIES, Okinawa, Japan
Episodes and climatology of ozone and transport patterns based on EMEP monitoring data and trajectory statistics	Michael Kahnert EMEP, Chemical Coordinating Centre
A chemical characterization of North American pollutant plumes over Europe and a 15-year climatology of global warm conveyor belt transport	Caroline Forster Technical University of Munich, Germany
A transport and ozone climatology for the North American West coast: impact of Asian and stratospheric source regions	Owen Cooper University of Virginia, United States
Regional ozone and aerosol pollution in China	Yuanhang Zhang Peking University, China
Transport of pollutants between North America and Europe	Thomas Trickl IMK-IFU Garmisch-Partenkirchen, Germany
Role of EMEP and other international programmes in the investigation of the hemispheric transport of toxic substances	Sergey Dutchak EMEP, Meteorological Synthesizing Centre East
Global Northern hemispheric modelling of tropospheric ozone	Jos Lelieveld MPI Mainz, Germany
Intercontinental transport and the contribution from global emission controls to ozone levels within Europe	Richard Derwent Met. Office, United Kingdom
A global modelling view on long-range transport of atmospheric pollutants	Martin Schultz MPI for Meteorology, Hamburg, Germany
Factors regulating the seasonal cycle of intercontinental air pollution transport between Asia, the United States and Europe	Denise Mauzerall Princeton University, United States
Characterisation of soil dust aerosol in China and its transport/distribution during 2001 ACE-Asia – Model simulation and validation	Sunling Gong Meteorological Service, Toronto, Canada

Title of presentation	Presenter and affiliation
A numerical simulation of long range transport of yellow sand (Asian dust) observed in April 1998 in Korea	Soon-Ung Park University Seoul, Republic of Korea
Global atmospheric and oceanic profiles for weather and climate prediction	Adrian F. Tuck NOAA, Boulder, Colorado, United States
Linking the Eulerian EMEP model to hemispheric air pollution: Initial analysis of non-linearities in source – receptor relationships	Leonor Tarrasón EMEP, Meteorological Synthesizing Centre West
Intercontinental transport and climatic effects of air pollutants (ICAP): A modelling initiative at USEPA	Carey Jang U.S. EPA, Research Triangle Park, United States
Indirect effects of air pollution on a global scale: Methane and surface ozone	Michael Prather UC Irvine, California, United States
Linking ozone pollution and climate change: The case for controlling methane	Arlene Fiore Harvard University, United States
Atmospheric transport of mercury in the Northern hemisphere	Gerhard Petersen GKSS Geesthacht, Germany
Intercontinental transport of mercury in the Northern hemisphere	Oleg Travnikov EMEP, Meteorological Synthesizing Centre East
Measurements of ozone, water vapor, carbon monoxide and nitrogen oxides by Airbus in-service aircraft (MOZAIC)	Andreas Volz-Thomas Research Center Jülich, Germany
Observations of large scale air pollution and its long-range transport using the European passenger aircraft system (CARIBIC)	Franz Slemr MPI Mainz, Germany
Inter-hemispheric transport in South Asia: Lessons from INDOEX	Russell Dickerson University of Maryland, United States
Importance of vertical transport concerning continental outflow of pollutants	André S.H. Prévot Paul Scherrer Institute, Switzerland
Global measurements of tropospheric ozone using the TOMS instrument	Alexander Frolov University of Maryland, United States
Observation-based tools for global/local aerosol characterization	Rudolf Husar Washington University, St. Louis, United States
Monitoring requirements for the study of intercontinental transport of atmospheric pollution	Oystein Hov EMEP, Chemical Coordinating Centre

Table 2 (a). Estimates of surface ozone increases[1] at northern mid-latitudes from intercontinental transport of pollution

Source region	Receptor region	O_3 increase (ppbv)[2]	Method of estimate	Reference
Asia	North-western United States, spring	4 (mean), 7.5 (max)	Sensitivity simulation with no anthropogenic emissions from source region	Berntsen et al. (1999)
Asia	Western United States, spring	3-10 (range during Asian pollution events)	Sensitivity simulation with no surface emissions from source region	Yienger et al. (2000)
Asia	Europe, United States	1.0 (United States), 0.8 (Europe)	Annual mean increases from sensitivity simulations with 10% increases in emissions from source region; results were multiplied by 10 to estimate total effect of current anthropogenic emissions from the source continent	Wild and Akimoto (2001)
Europe	Asia, United States	1.1 (Asia), 0.9 (United States)		
United States	Europe, Asia	2.0 (Europe), 0.8 (Asia)		
Asia and Europe	United States, summer	4-7 (typical afternoon range), 14 (max)	Sensitivity simulation with no anthropogenic NO_x and NMVOC emissions from source region	Fiore et al. (2002a)
Europe	East Asia, spring	3 (daytime mean)	*Ibid.*	Liu et al. (2002)
North America	Europe, summer	2-4 (daytime mean), 5-10 (events)	*Ibid.*	Li et al. (2002)
North America	Mace Head, Ireland	0.4 (winter), 0.2 (spring), -0.3 (summer), -0.9 (fall)	Mean observed difference in O_3 concentrations in 1990-1994 for air masses originating from the United States and Canada vs. from Iceland and Greenland	Derwent et al. (1998)
North America	Europe, yearly mean	18 (Atlantic fringes),10-15 (central Europe)	Ozone produced in tropospheric column over source region	Derwent et al. (2002)
Asia	Europe, yearly mean	9 (Atlantic fringes), 5-7 (central Europe)		
Background (anthro-pogenic methane)	United States, summer	6 (afternoon mean)	Sensitivity simulation with anthropogenic CH_4 emissions reduced globally by 50%; O_3 increases from that simulation were doubled to estimate total increase from anthropogenic CH_4	Fiore et al. (2002b)
Background (1980-1998)	United States	3-5 (spring, fall)	Observed trend in the O_3 frequency distribution at rural sites	Lin et al. (2000)
Background (1984-2002)	United States west coast	10	Observed trend at surface sites and from aircraft missions (1984-2002)	Parrish (2002)
Asia (future)	United States	2-6 (western United States), 1-3 (eastern United States), highest in April-June	Sensitivity simulation with tripled Asian NO_x and NMVOC emissions	Jacob et al. (1999)
Asia (future)	Western United States, spring	30-40 (max during Asian pollution events)	Sensitivity simulation with quadrupled Asian emissions	Yienger et al. (2000)

[1] All estimates are from global 3-D models except Derwent et al. (1998), Lin et al. (2002), and Parrish (2002).
[2] Parts per 10^9 by volume.

Table 2 (b). Estimates of surface aerosol increases[1] at northern mid-latitudes from intercontinental transport of pollution

Source region	Receptor region	Aerosol type	Aerosol increase (μg m^{-3} unless stated otherwise)	Method of estimate	Reference
Asia (mean)	United States yearly means	Organic carbon	0.013 (western U.S.) 0.007 (eastern U.S)	Sensitivity simulation with no anthropogenic emissions from source region	Park et al. (2002)
		Elemental carbon	0.005 (western U.S.) 0.003 (eastern U.S.)		
Asia (events)	North-western United States, spring 1997	All	~200 particles cm^{-3}	Observed increases at Cheeka Peak Observatory in air masses of Asian origin	Jaffe et al. (1999)
Asia (dust event)	Western United States, April 1998	All	40-63 (PM_{10}[2]), 4-11 ($PM_{2.5}$[2])	Observed increases at a number of monitoring stations	Husar et al. (2001); Vaughan et al. (2001)
Asia (dust event)	Lower Fraser Valley, British Columbia, Canada, April 1998	All	18-26 (PM_{10}[2])	Attribution based upon elemental composition at a number of monitoring stations	McKendry et al. (2001)
Asia (dust event)	North-western United States, April 1993	All	4-9 (PM_{10}[2])	Observed increases at three monitoring stations	Jaffe et al. (2002)
		Organic carbon	0.4-0.7		
		Elemental carbon	0.03-0.1		
Sahara (mean)	Florida, United States	Mineral dust	0.8-16.3 (monthly mean, max. in July) 10-100 (daily max during episodic events in summer)	Long-term observations in Miami	Prospero et al. (1999)
Sahara (mean)	Eastern United States (east of 106ºW)	Mineral dust	1 (annual mean) 4-8 (July)	Attribution based upon Al/Si ratios at monitoring stations	Husar (2002)
Sahara (dust events)	Israel, March 1998	All	1000-1900 (PM_{10}[2])	Observations in Tel Aviv	Alpert and Ganor (2001)

[1] All estimates are from observations except for Park et al. (2002).

[2] PM, particulate matter with diameter less than 2.5μ ($PM_{2.5}$) or less than 10μ (PM_{10}).

Table 2 (c). Estimated contribution of the intercontinental transport to mercury deposition within the Northern hemisphere

Receptor region	Source region	Mercury deposition, tons/year	Method of estimate	Reference
Europe	North America	5.4 (4%)	Hemispheric modelling (3D Eulerian model). Per cent shows fraction in the total annual deposition to the receptor region from global anthropogenic sources.	Travnikov and Ryaboshapko (2002)
	Asian Russia	3.8 (3%)		
	Western, Central and Southern Asia	6.2 (5%)		
	Eastern and South-Eastern Asia	9.3 (7%)		
North America	Europe	25.7 (18%)		
	Asian Russia	6.6 (5%)		
	Western, Central and Southern Asia	9.1 (6%)		
	Eastern and South-Eastern Asia	26.9 (19%)		
Asian Russia	Europe	20.4 (31%)		
	North America	5.1 (8%)		
	Western, Central and Southern Asia	7.9 (12%)		
	Eastern and South-Eastern Asia	15.9 (24%)		
Western, Central and Southern Asia	Europe	15.6 (13%)		
	North America	3.8 (3%)		
	Asian Russia	4.2 (4%)		
	Eastern and South-Eastern Asia	7.6 (6%)		
Eastern and South-eastern Asia	Europe	11.7 (5%)		
	North America	3.8 (1%)		
	Asian Russia	3.2 (1%)		
	Western, Central and Southern Asia	14.1 (5%)		
New York State (United States)	Asia	30%	Global modelling. Per cent shows fraction in the total annual deposition to the receptor region from global anthropogenic sources.	Seigneur et al. (2002)
	Europe	14%		
	South America	4%		
	Africa	2%		

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